The Role of Uncertainty, Sentiment and Cross-Country Interactions in G7 Output Dynamics*

by

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

Abstract

Output fluctuations in the G7 are characterised using a VAR model of countries' actual and expected outputs and uncertainty over these. New measures are developed to quantify the relative importance of economic prospects-versus-uncertainty, global-versus-national effects and fundamentals-versus-sentiment for countries' persistent output movements. National and global contributions are found to be equally important across the G7 although considerable differences exist between countries. Uncertainty, and especially cross-country uncertainty, is important in propagating the effects of shocks and generates around 20% of countries' persistent output movements on average. Fundamentals dominate output movements although, with an 80:20 split, sentiment plays a non-negligible role.

Keywords: Uncertainty, Sentiment, Fundamentals, Survey Expectations, Global Shocks, National Shocks

JEL Classification: C32, D84, F44

*†University of Warwick, UK; ††University of Nottingham, UK; †††University of Melbourne, Australia. Version dated November 2016. Corresponding author: Anthony Garratt, Warwick Business School, University of Warwick, Coventry, CV4 7AL, UK. Email: Anthony.Garratt@wbs.ac.uk.

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. The potential influence of cross-country interactions in output dynamics is obvious given the effects 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 confidence is less clear; sometimes commentators appear to use the phrase to convey agents' hopes and anxieties on the future prospects of the underlying fundamentals at home and abroad; sometimes the phrase relates to agents' reaction to risk/ambiguity/uncertainty over the fundamentals; and sometimes the phrase suggests a more autonomous role in which agents' beliefs have an effect on economic activity separately to the fundamentals. In what follows, we shall describe this latter role as the effect of 'sentiment'.

This paper introduces new measures to quantify the extent to which countries' output movements are influenced by the globalised nature of trade and financial linkages, by news on future prospects versus uncertainty about these prospects and by autonomous movements in sentiment versus fundamentals. The measures are based on a reduced-form VAR model of countries' actual output series, their expected output series as reported in surveys and the uncertainty surrounding the expected series. The multi-country VAR framework is able to capture the complex interactions between countries' outputs in a parsimonious and transparent way and allows us to quantify the importance of the interactions arising through countries' actual trade and investment activities and through cross-border reactions to countries' planned outputs. The use of survey measures of expected outputs also makes possible an analysis of the effects of agents' beliefs about output movements including the role of optimism/pessimism over future economic prospects (reflected in the average responses to the survey) and the role of the uncertainty surrounding these (reflected by the extent of disagreement across survey respondents). This analysis is not possible using actual output only and allows us to conduct a VAR-based test of the rationality of expectations - taking into account the potential for information rigidities -

and hence to distinguish and quantify the effect of beliefs about fundamentals from the autonomous role played by sentiment in countries' output dynamics.

The new measures are used in the paper in an analysis of output movements in the G7 economies over the last twenty years. The underlying VAR model is constructed using the 'Global VAR' [GVAR] framework elaborated in, inter alia, Pesaran *et al.* (2004), Garratt *et al.* (2006) and Chudik and Pesaran (2016). For the global-versus-national analysis, we can compare our results with those in the literature investigating similar questions using different methods; for example, papers by Kose *et al.* (2003, 2008) and Crucini *et al.* (2011), among others, who employed dynamic common factor models to evaluate the relative importance of a global factor in driving countries' output growths.[1] Crucini *et al.* (2011)'s results are typical, finding that a global factor 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). As we shall see, our results on the global-versus-national split are broadly similar, providing some reassurance that our methods, which rely on output data only, deliver reasonable measures.

Our use of survey data allows an analysis of the role of time-varying uncertainty on business cycle fluctuations as well as that played by optimism/pessimism over future economic prospects. Future prospects are captured by the average of the survey responses at each time while uncertainty can be measured by the disagreement across survey respondents. The interaction of uncertainty with adjustment costs in investment and hiring, the reaction of financial markets to risk, and decision-makers' aversion to ambiguity provide many potential routes by which uncertainty might influence output dynamics,[2] sometimes focusing on uncertainty as a cause of recession and sometimes seeing uncertainty as a vehicle for prolonging the effects of other recessionary shocks. Recent empirical evidence suggests uncertainty plays a major role in output dynamics[3]. But these results rely

[1]The common factor approach typically uses data on countries' outputs and components of aggregate demand to measure the effects of global shocks, national shocks and component-specific shocks.

[2]See the discussions in Bloom et al. (2012), Fernández-Villaverde,et al. (2011), or Ilut and Schneider (2012), for example.

[3]For example, Ilut and Schneider (2014) assign around 40% of US business cycle movements to con-

on potentially contentious identifying assumptions some of which are mitigated in our analysis by our focus on output data and our explicit modelling of output expectations alongside uncertainty. Further, much of the commentary on the global recession following the Financial Crisis of 2008 suggests an important international dimension in the role of uncertainty in business cycle fluctuations,[4] and our analysis of cross-country interactions can provide important insights on this.

The paper's measure of the relative importance of fundamentals-versus-sentiment is, as far as we know, the first of its type in the literature. We assume that output movements and variations in uncertainty that are driven by fundamentals will be consistent with rationality in expectations formation, with the rest labeled as being driven by 'sentiment'. Output movements and variations in uncertainty due to fundamentals can include those associated with 'information rigidities' where agents form rational expectations (RE) but are either slow to make use of publicly available information ('sticky information RE') or observe fundamentals only with error ('noisy information RE'), as described in Mankiw and Reis (2002) and Sims (2003), for example. We assume that output fluctuations or changes in uncertainty driven by fear, concern for fairness or other psychological factors are inconsistent with RE and operate independently of underlying economic fundamentals.[5] The renewed interest in the role of agents' beliefs in output dynamics has generated an empirical literature which examines the nature of information rigidities through the

fidence shocks; an uncertainty measure accounts for around one third of the forecast error variance of US production at a three-year horizonin in Bachmann et al. (2011); Bloom et al. (2012) argue that a reasonably calibrated uncertainty shock would result in a short-lived but substantial fall in output, by around 3%, in their DSGE model of the US; and Baker at al. (2016) estimate peak reductions of around 1% in industrial production across a number of countries in response to shocks to uncertainty of the size typically observed in recent years.

[4]See, for example, Kannan *et al.* (2009) on the role of coordination failures across borders in inhibiting export and credit growth and in postponing investment decisions, or Kose and Terrones' (2015) discussion of global recessions.

[5]These influences are discussed in Akerlof and Shiller's influential (2009) text, for example, and are often described as 'animal spirits'.

use of forecasters' survey responses[6] or which uses stock price data, direct measures of confidence and other forward-looking series to distinguish the effects on output of news on fundamentals from those of sentiment.[7] Our use of survey data in this paper is in the same spirit as this recent empirical work but adds to the literature by testing the rationality of expectations formation in the presence of information rigidities in a VAR context and by quantifying in a novel variance decomposition the separate contribution of fundamentals and sentiment to persistent movements in output in the G7 countries.[8]

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 and uncertainty are developed and brought together in the GVAR framework. We also explain how assumptions on information rigidities can be tested and accommodated in our model and describe the decompositions that we can use to distinguish global from national effects, the role of uncertainty, and the effect of fundamentals versus sentiment in output dynamics. Section 3 describes the VAR model obtained for the G7 economies over the period 1994q1-2014q2 and presents the results of the decomposition analysis. As we shall see, the results show cross-country influences to be as important in understanding G7 output movements as national ones, although there are considerable differences across countries, echoing the findings in the common factor literature. We find that an important element of the cross-country interactions comes through uncertainty about other countries' prospects although the role of uncertainty appears to prolong the effects of shocks rather than to provide a major source of shocks. Perhaps most controversially, we also find that the restrictions implied by assumptions of RE in the presence of information rigidities are rejected and that, although fundamentals do dominate in explaining persistent movements in output, the effects of sentiment are non-negligible, contributing around 20% of the permanent effects of shocks to a country's output on average. Section 4 provides some

[6]See, for example, Andrade and Le Bihan (2013), Coibion and Gorodnichenko (2011, 2012) and Dovern et al (2012, 2015).

[7]See, for example, Beaudry and Portier (2006), Barsky and Sims (2011, 2012) and Bachmann and Sims (2012).

[8]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.

concluding comments.

2 Modelling Output in a Global Economy

2.1 The Modelling Framework

An analysis that focuses on the role of agents' beliefs in output fluctuations has to pay careful attention to the information that is available to agents in real time. This means, for example, that the measures of actual output should account for 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.[9] 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 $s=1$, 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'). In practice, the expectation measure of ${}_t y_t^e$, say, is the mean of the nowcasts of y_t calculated across a number of forecasters surveyed at t, and so a measure of the uncertainty over the state of the economy is also provided by the disagreement between respondents over the nowcast at that time.[10] We denote this uncertainty by ${}_t y_t^u$ and measure it in practice by the inter-quartile range of the survey respondents' nowcasts.

Considering just one country in isolation for the time being, and focusing on the case where only contemporaneous and one-period-ahead expectations are used, output

[9]The first-release data is also often revised. As we explain below, in what follows, we do not model the revisions process, effectively assuming that revisions simply constitute noise.

[10]Of course, more variability in individuals' subjective density forecasts also consitutes greater uncertainty and should be taken into account where available. However, as discussed in Bachmann et al (2011) and Dovern et al. (2012, 2015), inter alia, the disagreement measure serves as a useful proxy for uncertainty in many circumstances and is often the best measure avaliable.

dynamics can be characterised by the model

$$\begin{bmatrix} {}_ty_{t-1} - {}_{t-1}y_{t-2} \\ {}_ty_t^e - {}_ty_{t-1} \\ {}_ty_{t+1}^e - {}_ty_t^e \\ {}_ty_t^u \end{bmatrix} = \Gamma_0 + \sum_{k=1}^{p} \Gamma_k \begin{bmatrix} {}_{t-k}y_{t-1-k} - {}_{t-1-k}y_{t-2-k} \\ {}_{t-k}y_{t-k}^e - {}_{t-k}y_{t-1-k} \\ {}_{t-k}y_{t+1-k}^e - {}_{t-k}y_{t-k}^e \\ {}_{t-k}y_{t-k}^u \end{bmatrix} + \begin{bmatrix} \xi_{1t} \\ \xi_{2t} \\ \xi_{3t} \\ \xi_{4t} \end{bmatrix} \tag{1}$$

for $t = 1, ..., T$ where the $\Gamma_k = [\gamma_k(l, m)]$, $l, m = 1, 2, 3, 4$ are (4×4) matrices of parameters, and the ξ's are mean zero innovations in output growths and uncertainty. 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); the expected one-period ahead growth in output (also published in the survey dated at time t); and the level of uncertainty surrounding the contemporaneous output level.[11]

The model in (1) can 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 $\mathbf{y}_t = (\ {}_ty_{t-1}, {}_ty_t^e,\ {}_ty_{t+1}^e,\ {}_ty_t^u)'$, $\boldsymbol{\varepsilon}_t = (\varepsilon_{1t},\ \varepsilon_{2t},\ \varepsilon_{3t},\ \varepsilon_{4t})' = (\xi_{1t},\ \xi_{1t}+\xi_{2t},\ \xi_{1t}+\xi_{2t}+\xi_{3t},\ \xi_{4t})'$ and the $\mathbf{A}$'s are functions of the original Γ's. Assuming actual and expected output growths are stationary in (1), the $\mathbf{A}$'s will incorporate restrictions that ensure the shocks $\boldsymbol{\varepsilon}_t$ have a permanent effect on the three output level measures and that they move together one-for-one in the long run.[12] 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 on uncertainty at t. These shocks capture 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

[11] The use of direct measures of expectations means we can assume the information sets of economic agents and the econometrician are the same, circumventing the problems of non-fundamentalness often discussed in VAR analysis based on structural models involving expectations; see Leeper et al. (2013).

[12] Indeed the model can also be written in terms of $\Delta_t y_{t-1}$, $\Delta_t y_t^e$, $\Delta_t y_{t+1}^e$and ${}_ty_t^u$ where the model explicitly contains the (two) cointegrating vectors $(1, -1, 0, 0)$ and $(1, 0, -1, 0)$.

that the $\boldsymbol{\varepsilon}_t$ reflect autonomous shifts in beliefs which might also cause permanent changes in actual and expected outputs.

Note that the model of (1) and (2) treats news on uncertainty in the same way as news on output levels. Policy announcements that generate uncertainty on domestic regulatory or macroeconomic policy or events creating ambiguity on the world economic outlook are reflected in ε_{4t} and these will have permanent effects on actual and expected levels of output. Our model therefore explicitly captures the 'first moment' effects of good or bad news on economic prospects and the 'second moment' effects of uncertainty shocks. This is an advantage over models that use more generic sentiment or confidence indices since those indices typically reflect an amalgam of the first and second moment effects. Having said this, the uncertainty shocks ε_{4t} will be correlated with news on output levels ε_{1t}, ε_{2t} and ε_{3t} and identifying restrictions need to be imposed if we want to separate out any distinct effects from uncertainty shocks. For example, Bachmann et al. (2011) and Baker et al. (2012) impose a Choleski ordering in which uncertainty is determined first so that news on uncertainty at t influences time-t measures of output but not vice versa. Of course, any conclusions drawn on the relative importance of uncertainty shocks will only be as robust as the identifying assumptions underlying them but the results will provide a useful upper bound on the influence of uncertainty if the above Choleski ordering is assumed.

The model in (1) and (2) makes no assumptions on the expectation formation process or agents' use of information other than that expectational errors are stationary. This is consistent with a full-information RE (FIRE) model or a RE model incorporating information rigidities and, indeed, all these RE models are nested within the general form at (1). For example, the assumption of FIRE means that

$$ {}_t y_{t-1} = {}_{t-1}y^e_{t-1} + \xi_{1t} \qquad \text{and} \qquad {}_t y^e_t = {}_{t-1}y^e_t + \xi_{2t} \quad , \tag{3} $$

so that expectational errors and revisions are orthogonal to past information. These assumptions can be incorporated into (1) by the restrictions that $\gamma_1(1,2) = 1$, $\gamma_1(2,3) = 1$ and all the other elements of the first two rows of the Γ_i are zero. Equally, as described by Coibion and Gorodnichenko (2012), the sticky information RE (SIRE) assumption is typically taken to mean that agents update their information each period with probability $(1-\lambda)$, so that the reported average forecast of output at $t+f,\ \ f\geq 0$, consists of a weighted average of the RE forecasts of y_{t+f} over the past; i.e. ${}_ty^e_{t+f}=(1-\lambda)\sum_{h=0}^{\infty}\lambda^h$ ${}_{t-h}y^{RE}_{t+f}$ where ${}_{t-h}y^{RE}_{t+f}$ is the RE of y_{t+f} at $t-h$. This motivates a set of very specific relationships between expectational errors and revisions, including that[13]

$$ {}_ty_{t-1}-\ {}_{t-1}y^e_{t-1}=\frac{\lambda}{1-\lambda}(\ {}_{t-1}y^e_{t-1}-\ {}_{t-2}y^e_{t-1})+\xi_{1t}\ . \quad (4)$$

This relationship can be accommodated within the model at (1), setting $\gamma_1(1,1)=1-\gamma_1(1,2)$, $\gamma_1(1,1)=-\gamma_2(1,2)$ and all the other elements of the first row of the Γ_k to be zero. Alternatively, again as elaborated by Coibion and Gorodnichenko (2012), the less restrictive assumption of noisy information RE (NIRE) can be captured by imposing the restrictions that expectational errors are a higher order function of lagged expectational errors and revisions:

$$ {}_ty_{t-1}-\ {}_{t-1}y^e_{t-1}=\sum_{k=1}^{p}\left[\lambda_{1k}(\ {}_{t-k}y_{t-k-1}-\ {}_{t-k-1}y^e_{t-k-1})+\lambda_{2k}({}_{t-k}y^e_{t-k}-\ {}_{t-k-1}y^e_{t-k})\right]+\xi_{1t} \quad (5)$$

which again translates to restrictions on the first two rows of the Γ_k.

Similar RE-consistent restrictions also apply to the uncertainty equation. For example, Coibion and Gorodnichenko (2012) note that disagreement between forecasters should be independent of news on outputs in the NIRE case. This is because agents here continuously update their forecasts so that the only source of disagreement relates to idiosyncratic differences in information sets and there is no reason to believe these change over the business cycle. The same is true for FIRE so both FIRE and NIRE imply zero restrictions on the output terms in the fourth row of (1). In contrast, since only a subset of agents update their information at any time under SIRE, disagreement between survey respondents will vary systematically over the business cycle and no restrictions are implied for the fourth row by SIRE.

[13]Other relationships include

$$ {}_ty^e_{t+f}-\ {}_{t-1}y^e_{t+f}=\frac{\lambda}{1-\lambda}(\ {}_{t-1}y^e_{t+f}-\ {}_{t-2}y^e_{t+f})+\xi_{ft}$$

for $f\geq 0$. However, these rely on there being direct measure of expectations more than one period ahead which we have not included in (1).

It is worth noting that the absence of restrictions on the third row of the model even in the most restrictive FIRE case still leaves scope for complex interactions between actual and expected outputs in the underlying behavioural model of output. But the various models incorporating the restrictions associated with NIRE, SIRE and FIRE provide useful benchmarks to explain output dynamics in terms of fundamentals and information rigidities. As described below, comparison of these benchmark models (and particularly the least restrictive NIRE model) against the unrestricted model provides a means of measuring the role of sentiment in output fluctuations.

2.2 Global interactions

The single-country model considered above is 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, weighted averages of 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, and using an i subscript to denote country $i = 1, .., n$, note first that the single-country model in (1) can be extended to include global actual growth, ${}_t y^*_{i,t-1} -_{t-1} y^*_{i,t-2}$ and the corresponding global expected growths and global uncertainties. Here, ${}_t y^*_{i,t-1} = \sum_{j=1}^{n} w_{ij}$ ${}_t y_{j,t-1}$ is a measure of the 'foreign' output level for country i obtained as a weighted average of other countries' outputs using fixed weights w_{ij} chosen to capture the influence of country j on country i (using trade volumes or some other metric, for example). The vector $\mathbf{y}_{it}$ contains foreign actual, nowcast and expected future outputs and uncertainty defined in the same way (i.e. as weighted average of the other countries' measures). The national model in (2) can then be extended to include foreign growth and uncertainty and be written as

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

This model provides a straightforward means of accommodating global influences on a country's output, now explicitly incorporating the effect of other countries' actual and expected levels of activity and uncertainty about these in addition to the effect of foreign activity already captured in (2) through the country's own expectations measures.

The second stage in the construction of a GVAR explaining actual and expected outputs and uncertainty across the n countries is achieved by stacking the country-specific series into a single $4n \times 1$ vector $\mathbf{z}_t = (\mathbf{y}'_{1t},..,\mathbf{y}'_{nt})'$ and writing $\mathbf{y}^*_{it} = \mathbf{w}_i \mathbf{z}_t$ where $\mathbf{w}_i$ is the $1 \times 4n$ 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 the individual vectors of weights $\mathbf{w}_i$ into $\mathbf{W}$, the n country-specific models in (6) can be written

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

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 be cross-country correlations in these innovations, Σ will be close to block diagonal and these shocks can be thought of as nation-specific ones (with off-diagonals capturing within-country correlations between innovations on the actual and expected outputs and uncertainty). We can now write

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

or equivalently

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

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

Of course, the assumption of rationality in expectations formation implies additional restrictions, imposed on the global terms, when working with the GVAR. Specifically, FIRE requires the terms to enter only as contemporaneous revisions so that, for example, the expressions for ${}_t y_{i,t-1}$ and ${}_t y^e_{i,t}$ in (3) become

$$\begin{aligned} {}_t y_{i,t-1} &= {}_{t-1}y^e_{i,t-1} + \beta_{i0}(\ {}_t y^{*e}_{i,t} - \ {}_{t-1}y^{*e}_{i,t}) + \beta_{i1}(\ {}_t y^{*e}_{i,t-1} - \ {}_{t-1}y^{*e}_{i,t-1}) + \xi_{1it} \ ; \\ \text{and } {}_t y^e_{i,t} &= {}_{t-1}y^e_{i,t} + \beta_{i2}(\ {}_t y^{*e}_{i,t} - \ {}_{t-1}y^{*e}_{i,t}) + \beta_{i3}(\ {}_t y^{*e}_{i,t-1} - \ {}_{t-1}y^{*e}_{i,t-1}) + \xi_{2it} \end{aligned}$$

These restrictions ensure that, when the countries are stacked and arranged in the GVAR, revisions in each countries' output expectations are orthogonal to the information available for all countries at time $t-1$ as required by FIRE. As in the national case discussed earlier, the assumption of SIRE weakens the restrictions, allowing time-$(t-1)$ revisions of global outputs to enter too, and NIRE allows still more flexibility in which all available revisions on the national and global variables help explain time-t revisions of ${}_t y_{i,t-1}$ and ${}_t y^e_{i,t}$.

2.3 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). For these, 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 $\mathbf{C}(L) = \mathbf{I} + \mathbf{C}_1 L + \mathbf{C}_2 L^2 + \mathbf{C}_3 L^3 + ...$ Clearly, shocks to the output growth and uncertainty 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.[14] Lee and Pesaran (1993) propose the use of PP's to measure the long-run response of the levels 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 $4n \times 4n$ matrix $\mathbf{P}(K)$ whose (i, j)-th

[14] Uncertainty is assumed staionary in levels so innovations to the $\Delta\ {}_t y^u_{i,t}$ are self-cancelling and shocks have no effect on the level of uncertainty at the infinite horizon.

element is given by

$$\rho_{ij}(K) = \frac{\mathbf{e}_i'\mathbf{H}(K)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\text{- }\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\text{- }\mathbf{C}(0)'\mathbf{e}_j)}}, \qquad i,j = 1,...,4n, \tag{11}$$

where $\mathbf{e}_i$ is the $4n \times 1$ selection vector with unity in its i-th element and zeros elsewhere and where $\mathbf{H}(K) = \left(\sum_{k=0}^{K} \mathbf{C}_k\right)\text{- }\left(\sum_{k=0}^{K} \mathbf{C}_k\right)'$ for $K = 0, 1, ...$ Here, the $\mathbf{H}(K)$ capture the size of the permanent effects of the shocks on output and uncertainty 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

$$\rho_{ij} = \frac{\mathbf{e}_i'\mathbf{C}(1)\text{- }\mathbf{C}(1)'\mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\text{- }\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\text{- }\mathbf{C}(0)'\mathbf{e}_j)}}, \qquad i,j = 1,...,4n. \tag{12}$$

This matrix provides a variance-based measure of the infinite-horizon effect of shocks to the system. For output effects, it is most easily interpreted by considering the measures $P_i = \sqrt{\rho_{ii}}$ based on its diagonal elements, where $i = 1, 5, 9, ..., 4n - 3$ refer to the first of the four 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 and the underlying dynamics of the actual and expected output and uncertainty series.

2.3.1 Persistence decompositions: national versus global shocks and the role of uncertainty

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 role of uncertainty shocks on output dynamics. 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 $\Phi_k^N = \mathbf{B}_k$, $k = 0,..,p+1$ 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 - $= (\mathbf{I} + \mathbf{M}^*)\Sigma(\mathbf{I} + \mathbf{M}^*)'$ so that the variance in $\mathbf{v}_t$ can be decomposed to write - = - ^{N}+- ^{G} where - $^N = \Sigma$, - $^G = \mathbf{M}^*\Sigma(\mathbf{I} + \mathbf{M}^*)' + \Sigma\mathbf{M}^{*\prime}$, and - ^{N} and - ^{G} capture the relative sizes of the national and global shocks respectively.

The persistent effects of shocks can now be 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

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

where $\rho_{ij}^N = \frac{\mathbf{e}_i' \mathbf{C}^N(1)\Sigma^N \mathbf{C}^N(1)' \mathbf{e}_j}{\sqrt{(\mathbf{e}_i'\mathbf{C}(0)\Sigma\mathbf{C}(0)'\mathbf{e}_i)(\mathbf{e}_j'\mathbf{C}(0)\Sigma\mathbf{C}(0)'\mathbf{e}_j)}}$ 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.

The persistence measures of (11) and (12) can also be decomposed in a way to examine the persistent effect of uncertainty shocks. Generally, the shocks to the uncertainty equations in (7), ξ_{i4t}, have the same sort of persistent effects on output levels as news on the outputs themselves - i.e. the ξ_{i1t}, ξ_{i2t} and ξ_{i3t} - although no structural interpretation can be given to these given the correlations that exist between the series. If, however, we assume a time-ordering of the shocks, so that survey respondents' views on outputs are formed with the uncertainty of the decision-making environment already given, then we can identify the effects of the uncertainty shocks. In this case, we can separate out the uncertainty shocks - denoted by $\boldsymbol{\delta}_t = (v_{4t}, v_{8t}, ..., v_{28t})'$ - from the shocks to the GVAR in (7) by regressing $\mathbf{v}_t$ on $\boldsymbol{\delta}_t$ and writing $\mathbf{v}_t = \overline{\mathbf{D}}\boldsymbol{\delta}_t + \widetilde{\mathbf{v}}_t$. In this case, (10) can be written in terms of uncertainty shocks and 'other', unidentified shocks $\widetilde{\mathbf{v}}_t$ to give

$$\begin{aligned}\Delta\mathbf{z}_t &= \mathbf{C}(L)\ \left[\overline{\mathbf{D}}\boldsymbol{\delta}_t + \widetilde{\mathbf{v}}_t\right] \\ &= \mathbf{D}(L)\boldsymbol{\delta}_t + \mathbf{C}(L)\widetilde{\mathbf{v}}_t\end{aligned}$$

and the numerator of the persistence measures in (11) can be decomposed as

$$\begin{aligned}\mathbf{e}_i'\mathbf{C}(1)\Sigma\mathbf{C}(1)'\mathbf{e}_j &= \mathbf{e}_i'\mathbf{C}(1)\ \left[\widetilde{\Sigma} + \overline{\mathbf{D}}\Psi\overline{\mathbf{D}}'\right]\mathbf{C}(1)'\mathbf{e}_j \\ &= \mathbf{e}_i'\mathbf{C}(1)\widetilde{\Sigma}\mathbf{C}(1)'\mathbf{e}_j + \mathbf{e}_i'\mathbf{D}(1)\Psi\mathbf{D}(1)'\mathbf{e}_j \qquad (16)\end{aligned}$$

where $\widetilde{\Sigma}$ and Ψ are the variance-covariance matrices of $\widetilde{\mathbf{v}}_t$ and $\boldsymbol{\delta}_t$ respectively. Dividing throughout by the denominator of (11), we decompose the effects of a shock that causes output to rise by 1% on impact into that part due to uncertainty shocks (ρ_{ij}^{U}) and 'the remainder' due to economic prospects (ρ_{ij}^{P}). This decomposition assigns the maximum possible effect to the uncertainty shocks so that the persistence measures obtained with this time-ordering assumption provide a useful upper bound on the measure of the effect of uncertainty.

2.3.2 Persistence allocation: the role of fundamentals versus sentiment

The persistence measures of (11) and (12) can also be used to measure the relative importance of fundamentals versus sentiment in output fluctuations if we assume that output movements and variations in uncertainty due to fundamentals are consistent with RE. In the FIRE case, for example, the restrictions of (10) and the assumption that uncertainty does not vary systematically over the business cycle means that the $\mathbf{B}_{ik}$ and $\mathbf{B}_{ik}^{*}$ in (6) would take the form

$$\mathbf{B}_{i1}^{F} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ * & * & * & * \\ 0 & 0 & 0 & * \end{bmatrix}, \quad \mathbf{B}_{ik}^{F}(1:3,.) = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ * & * & * & * \\ 0 & 0 & 0 & * \end{bmatrix} \text{ for } k = 2,..,p+1$$

$$\mathbf{B}_{i0}^{F*} = \begin{bmatrix} \beta_{i1} & \beta_{i0} & 0 & 0 \\ \beta_{i3} & \beta_{i2} & 0 & 0 \\ * & * & * & * \\ 0 & 0 & 0 & 0 \end{bmatrix}, \quad \mathbf{B}_{i1}^{F*} = \begin{bmatrix} 0 & -\beta_{i1} & -\beta_{i0} & 0 \\ 0 & -\beta_{i3} & -\beta_{i2} & 0 \\ * & * & * & * \\ 0 & 0 & 0 & * \end{bmatrix}, \quad \mathbf{B}_{ik}^{F*} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ * & * & * & * \\ 0 & 0 & 0 & * \end{bmatrix} \text{ for } k = 1,$$

where the F superscript denotes that the FIRE restrictions have been imposed. These restrictions ensures that expectational errors in each country are orthogonal to past information at home and abroad, with uncertainty independent of the business cycle and evolving according to past uncertainty only. We can separate out the contribution to output fluctuations of the RE-fundamental effects from the remainder by writing $\mathbf{B}_{k} = \mathbf{B}_{k}^{F} + \mathbf{B}_{k}^{S}$ $k = 0,..,p+1$. We then note that (9) can be re-written as

$$\mathbf{z}_t = \left(\Phi^{F} + \Phi^{S}\right) + \sum_{k=1}^{p+1} (\Phi_k^{F} + \Phi_k^{S})\mathbf{z}_{t-k} + \mathbf{v}_t, \qquad t = 1, ..., T, \tag{18}$$

where $\Phi^F = (\mathbf{I} - \mathbf{B}_0^{*F}\mathbf{W})^{-1}\mathbf{B}$, and $\Phi_k^F = (\mathbf{I} + \mathbf{B}_0^{*F}\mathbf{W})^{-1}(\mathbf{B}_k^F + \mathbf{B}_k^{*F}\mathbf{W})$ and $\Phi_k^S = \Phi_k - \Phi_k^F$ for $k = 1, ..., p+1$. The permanent effects of shocks to output associated with RE-fundamentals can then be distinguished from those associated with sentiment following a similar method to that outlined in (14) and (15) treating the fundamental element in (18) in the same way the national effects were treated in (13). The difference here is that, rather than decomposing the variance using the estimated parameters as in (14), in (18) we are 'allocating' the variance to fundamentals and sentiment according to a set of imposed restrictions. Since we are simply imposing coefficients, the variation associated with the separate elements could, in principle, take arbitrarily large values with the off-setting covariance ensuring the overall persistence in the unrestricted model is unchanged. In these circumstances, the variance allocation conveys the *relative* importance of fundamentals versus sentiment and this is captured by the ratio of the persistence measures (with the covariance unallocated to either).[15]

3 Modelling Output Fluctuations in the G7, 1994q1-2014q2

The empirical work of the paper uses actual and expected output data for the G7 economies (Canada, France, Germany, Italy, Japan, United Kingdom, and United States) observed over the period 1994q1-2014q2.[16] 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 produced by various public and private institutions (including investment banks, research institutes and so on).[17] Our quarterly measures of expected output are based on the mean forecasts delivered by the survey respondents mid-way through the quarter in March, June, September and December, while our uncertainty measure refers

[15]In the national-global decomposition, the covariance was implicitly allocated to the global measures as the covariance would be zero in the absence of global effects.

[16]The sample period is dictated by the availability of expectations data in a consistent form for all the G7 economies.

[17]It could be argued that professional forecasters' expectations do not reflect those of a typical economic agent. But even if professional forecasters are 'unsentimental' themselves, for example, they may have an incentive to report expectations that match their clients' sentiments.

to the inter-quartile range of the individuals' responses. In quarter t, *Consensus Forecasts* 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 $\sim$ 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 uncertainty measure ${}_ty^u_{it}$ is based on the disagreement across respondents on contemporaneous growth ${}_t\widetilde{y}^e_{it} - {}_t\widetilde{y}_{i,t-4}$.[18]

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 2014q2*. This provides a final vintage measure of output and its use 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.[19] 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 ${}_ty^e_{it} = {}_t\widetilde{y}^e_{it} - {}_t\widetilde{y}_{i,t-4} + {}_Ty_{i,t-4}$. Implicitly, our measure of the first release of the actual output series ${}_ty_{i,t-1}$ is taken to be the same as the final vintage ${}_Ty_{i,t-1}$ assuming that there are no revisions between t and the end of the sample period. We effectively assume that the 'true' actual output series is released with a one quarter delay, 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 weights w_{ij} used in the construction of country i's global variables are given by the total trade between countries i and j in 2005 expressed as a fraction of all of i's trade across the G7, as reported in the IMF's *Direction of Trade Statistics*.

The actual output, expected current output and expected future output series are plotted for each country in Figure 1a and the mean and standard deviation of the growths of the series reported in Table 1. 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

[18]See Dovern et al. (2012) for more detailed description of how we construct our uncertainty measure based on *Consensus Economics* data.

[19]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.

margin. The onset of the financial crisis in late 2007/early 2008 provides a good example in most countries where the plots show that the full extent of the downturn is only slowly incorporated into the survey nowcasts of current growth.[20] Across the sample period, the (annualised value of the) mean actual quarterly growth rate varies from 0.83% in Italy to 2.62% in Canada but it is clear that there is considerable volatility in growths across all countries, with one standard deviation of the actual quarterly rate ranging from 2.19% in France up to 4.28% 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.[21]

The uncertainty measures are plotted in Figure 1b. These also show considerable variability over time and demonstrate that there are no straightforward patterns in the series over the business cycle: the correlations between each country's uncertainty measure and its contemporaneous growth are not significantly different to zero in any country and they average at just -0.02 across the seven countries. Table 1b provides some summary statistics to describe the cross-country interactions between output growth and uncertainty based on pairwise correlations between a country's uncertainty and growth experiences and those of the other countries of the G7. Column (2), headed 'Growth-Uncertainty', reinforces the individual country observation that there almost no significant correlations between output growth in a country and uncertainty elsewhere in the G7. But column (3), headed 'Uncertainty-Uncertainty', shows there is good evidence of common cross-country movements in the uncertainty measures, with most of the underlying pairwise correlations between uncertainty measures taking values in the range 0.25-0.35 (and only correlations

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

[21]With rational expectations, for example, the variance in actual growth is equal to the sum of the variances of expected and unexpected growths, and the variance in actual growth always exceeds the variance of expected growth therefore.

involving uncertainty in Italy and the UK lacking significance). These correlations are of a similar order of magnitude to the underlying correlations between countries' growths reported in column (1). The fact that both uncertainty and growth in most country are contemporaneously related to uncertainty and growth experiences elsewhere, while the relationships between output growths and uncertainty at home and abroad are less straightforward, suggests that the global dimension of our GVAR model will play an important part in our characterisation of output dynamics.

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) while our uncertainty measures are stationary without transformation. It also showed that the expectational errors ${}_ty_{it-1} - {}_{t-1}y^e_{it-1}$ and revisions in expectations ${}_ty^e_{it} - {}_{t-1}y^e_{it}$ are stationary. This ensures that the modelling framework set out in (1) is appropriate.[22]

The empirical analysis is based around the four equation VARs,

$$\begin{bmatrix} {}_ty_{i,t-1} - {}_{t-1}y_{i,t-2} \\ {}_ty^e_{i,t} - {}_ty_{i,t-1} \\ {}_ty^e_{i,t+1} - {}_ty^e_{i,t} \\ {}_ty^u_{i,t} \end{bmatrix} = \Gamma_{i0} + \sum_{k=1}^{2} \Gamma_{ik} \begin{bmatrix} {}_{t-k}y_{i,t-1-k} - {}_{t-1-k}y_{i,t-2-k} \\ {}_{t-k}y^e_{i,t-k} - {}_{t-k}y_{i,t-1-k} \\ {}_{t-k}y^e_{i,t+1-k} - {}_{t-k}y^e_{i,t-k} \\ {}_{t-k}y^u_{i,t-k} \end{bmatrix}$$

$$+ \sum_{k=0}^{2} \Gamma^*_{ik} \begin{bmatrix} {}_{t-k}y^*_{i,t-1-k} - {}_{t-1-k}y^*_{i,t-2-k} \\ {}_{t-k}y^{*e}_{i,t-k} - {}_{t-k}y^*_{i,t-1-k} \\ {}_{t-k}y^{*e}_{i,t+1-k} - {}_{t-k}y^{*e}_{i,t-k} \\ {}_{t-k}y^{*u}_{i,t-k} \end{bmatrix} + \boldsymbol{\delta}_i \; d08q1 + \begin{bmatrix} \xi_{i1t} \\ \xi_{i2t} \\ \xi_{i3t} \\ \xi_{i4t} \end{bmatrix} \quad (19)$$

for $i = 1, .., 7$, $t = 1994q1, ..2014q2$ including an intercept, two lags of each of the three national growth and uncertainty series plus the contemporaneous value and two lags of the corresponding global growth series. Given the impact of the financial crisis on growth,

[22] We conducted standard ADF tests and, following Pesaran (2007), cross-sectionally augmented DF tests where the underlying regressions are augmented by lags in the cross-section average to account for cross-sectional interdependencies. Details are available on request.

we also included a simple time dummy to accommodate outlying observations in 2008q1. The estimated equations perform well in explaining the series with R^2 averaging across the seven countries at 0.55, 0.52 and 0.61 in the three output equations and 0.50 in the uncertainty equations. In the output equations, the results demonstrate that the model is able to capture very complex dynamics with important feedbacks from national and global variables and from actual and expected output and uncertainty variables across all the equations.[23] The equations explaining uncertainty are simpler in that they contain fewer significant explanatory variables, with important dynamics and cross-country interactions across uncertainty measures but relatively weak feedback from the growth series. The consequences of this complexity are illustrated in the persistence measures and profiles below.

Before turning to the persistence measures though, Table 2 provides some test results investigating the rationality of expectations formation. The first three columns show, respectively: the test of the restriction implied by FIRE and imposed on the actual output growth equation embedded within the SIRE model (implying agents update their information every period); the test of the restriction implied by SIRE and imposed on the NIRE model (implying only one lagged revision is required to capture information rigidities); and the test of the restrictions implied by NIRE and imposed on the unrestricted quasi-difference model of (19). The results show that, if one were to start with a simple NIRE model, the restrictions implied by SIRE and FIRE would not be rejected in most countries. But the restrictions imposed to achieve NIRE from (19) are strongly rejected across all countries, showing that there is significant explanatory power for actual output in the lagged actual and expected growth and uncertainty series over and above that captured by output revisions alone. The column headed 'Uncertainty' reports the corresponding tests for rationality in the uncertainty equations. Both FIRE and NIRE assert that uncertainty will not vary systematically over the business cycle and the results reported here show that there are indeed no significant feedbacks from output growth to

[23]As noted following (7), the shocks to the model can be considered nation-specific if the variance-covariance matrix Σ is block-diagonal. A Box M test confirmed this to be the case here with the χ^2 statistic having a p-value of 0.83.

uncertainty in any country. On the other hand, given that we relate fundamentals to the models incorporating rationality (with or without information restrictions), the results from the output growth equations show that there is certainly scope for 'sentiment' to explain output fluctuations. The *quantitative* importance of sentiment on persistent output movements is measured by the persistence statistics below.

3.2 The persistent effects of shocks to G7 output

Table 3 describes the persistence measures defined in equations (12), (15) and (16) based on our GVAR model.[24] The average of the countries' total persistence measures ρ_{ii} is 2.47 meaning that, on average, a shock that causes output in a country to rise by 1% on impact results in output being 2.47% 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 1.04 in Japan - so that the shock has almost the same effect in the long-run as it does on impact - to 3.29 in Canada.

The plots of Figure 2 give a sense of the output dynamics that underlie these results. Figure 2a shows the persistence profile of the shocks to actual, nowcast and expected future outputs taking the countries of the G7 as a whole and gives a useful summary of the system dynamics and interplay between the output series.[25] As we see, news that raises actual output ${}_ty_{t-1}$ by 1% on impact has a corresponding one-for-one effect on the nowcast ${}_ty_t^e$ and an expectation of a further rise in the subsequent quarters (${}_ty_{t+1}^e$ rising by just under 2% on impact for example). After some short-run volatility, the profiles then broadly track each other with a one period delay[26] although they show that the effects of the shock take some considerable time to work through, with the total persistence measure

[24]With 21 parameters estimated in each of the 28 estimated equations, the unrestricted GVAR model described above is highly parameterised. The results below therefore relate to a simplified version of the GVAR model obtained through a specification search in which coefficients are set to zero where the (absolute value of the) t-ratio is less 1.64.

[25]The G7 persistence measures are calculated replacing the selection vectors $\mathbf{e}_i$ and $\mathbf{e}_j$ in (12), (15) and (16) with a 1×7 vector of ones.

[26]Note that these series track each other closely but are not exact horizontal displacements of each other as they would be under FIRE. The (relatively minor) extent to which they differ from this though gives an indication of the (relatively minor) quantitative importance of the deviations from rationality.

levelling out to their infinite horizon value only after four or five years. Figure 2b plots the underlying profiles for the individual countries' actual outputs, showing the variability in persistence across countries but reinforcing the idea of a protracted period of adjustment. Of course, the fact that the prolonged period of adjustment is similar across countries shows that cross-country interactions play a substantial role in output dynamics.

The global-versus-national and prospects-versus-uncertainty decompositions Table 3 also quantifies the importance of these cross-country influences by reporting the decomposition of the persistence measures into national and global effects as described at (15). On average, around 50% of the persistent effects of shocks is associated with national innovations and their propagation over time and 50% of the persistent effect involves global shocks and cross-country propagation mechanisms. Again though, 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 and Japan and close to 50% in the U.S., reflecting these countries' relative autonomy, while Canada, France, Italy and U.K. are found to be more sensitive to outside events. It is interesting to note that these figures are broadly in line with those of Crucini et al (2011) mentioned earlier (finding that global factors account for around 46% of output variation but ranging from 15% in the US to 80% in France) even though the modelling approach and the associated measures of national-versus-global contributions are very different.

The table also provides insights on the sources of persistent shocks applying the Choleski ordering discussed earlier in which uncertainty shocks are assumed to occur first in order to distinguish their effects from those of 'other' unidentified shocks. This further decomposition shows that, on average across the seven countries, uncertainty accounts for 22% of the total, infinite-horizon persistence measures. This is a non-negligible source of shocks although the figure is lower than in some of the recent empirical work aimed at quantifying the effects of uncertainty. Most strikingly, it is the global uncertainty rather than the own-country uncertainty that is found to drive the uncertainty effects that exist, explaining 17% of the 22% on average and with uncertainty effects showing most clearly in those countries we found to be most sensitive to outside events generally.

Figure 3 provides a further insight on the role of uncertainty plotting the persistence profile of actual output across the G7 from our model (as in Figure 2a earlier) but plotting also the equivalent profile obtained from a model which drops the uncertainty variables from the GVAR altogether. This shows that the overall, infinite-horizon persistent effect of shocks on actual output are very similar in the two models.(with ρ_{ii} averaging 2.80 in the model without uncertainty compared to the earlier 2.47). But the dynamics of the two are very different with 95% of the adjustment completed in around two years in the absence of uncertainty, compared to five years in the full model. While uncertainty does not play a major role in terms of the source of persistent shocks to output then, it appears that it plays a very significant role in the propagation of their effects, more than doubling the duration of the adjustment period following shocks.

The fundamentals-versus-sentiment allocation Finally, Table 4 presents the results of the analysis 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, so that the total persistence measures are unchanged, but the total is allocated according to the consistency with rationality restrictions. The formal test results of Table 2 show that none of the FIRE, SIRE or NIRE restrictions are consistent with the data and so Table 4 considers the allocation according to NIRE which involves the fewest restrictions compatible with rationality, at least as far as the output equation is concerned. Of course, the NIRE also implies restrictions on the uncertainty equations too and so the measures ρ_{ii}^{F} and ρ_{ii}^{S} in Table 4 show the persistence allocated to the elements relating to fundamentals and sentiment respectively, as described at (18), having imposed the NIRE restrictions, first based on the full model and then based on the model without uncertainty.

The results show that, while fundamentals dominate in most countries, sentiment also plays a non-negligible role in the persistent movements in output in the G7. The NIRE allocation of persistence puts the influence of fundamentals to sentiment at $69 : 31$ on average in the full model and $75 : 25$ in the model without uncertainty. Japan is an outlier in both cases and the ratios are $76 : 24$ and $80 : 20$ if Japan is excluded. This means that, despite the strong rejection of the NIRE restrictions, the persistence allocation measures show fundamentals to exert by far the largest part of the influence on outputs. On the other hand, even a 20% role for sentiment in explaining the persistent movements in output levels in the G7 is striking and indicates that policy-makers could usefully take such effects into account in their decisions.

4 Concluding remarks

This GVAR model described in the paper provides a straightforward time series characterisation of actual and expected output movements and uncertainty across the G7 economies over the last twenty years. Together with the new measures proposed in the paper, the results provide some interesting insights on recent experiences in the G7 countries. For example, the estimated persistence profiles demonstrate that the effects of the first shocks of the financial crisis experienced at the end of 2007 would have still been felt some 5 years later in 2012 and 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), a large part of this 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 50% of the persistent effect of shocks on outputs across the G7 are found to involve globally-sourced shocks or global dynamics and it is clear that international agencies and coordinated actions by national policy makers will play an important role in mitigating the worst effects of global recessions and encouraging stable growth.

Cross-country interactions are also important in our findings on uncertainty which is found to provide a non-negligible source of persistent shocks in many countries. Averaging at around 20% across the countries, the effect on outputs is smaller than that found elsewhere in the literature but is founded primarily in global interactions, highlighting the role of doubts and ambiguities on trade opportunities and cross-border investments in initiating and prolonging recessions. Indeed, uncertainty appears to play a key role in the propagation mechanism for all shocks, explaining up to half of the five year adjustment period noted above.

Finally, our results show that there has also been an autonomous role for agents' beliefs in propagating the effects of the financial crisis over the years over and above the interaction of countries' fundamentals. Cutting across the analysis of the role of national-versus-global shocks and prospects-versus-uncertainty, our measure shows that sentiment explains around 20% of the permanent effects of shocks to output on average. Persistent output movements are clearly dominated by fundamentals then but sentiment is not inconsequential, highlighting the potential importance of psychological factors and the gaps between belief and reality for understanding output dynamics and formulating policy.

Table 1a: Summary Statistics for Actual and Expected Output Growth, 1994q1-2014q2

	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	2.62	2.26	1.68	2.52	2.85	1.40
France	1.58	2.19	1.34	2.26	1.92	1.73
Germany	1.40	3.42	1.08	2.82	1.86	1.83
Italy	0.83	3.36	0.31	2.88	1.77	2.49
Japan	0.96	4.28	0.95	4.28	1.35	3.12
United Kingdom	2.15	2.52	0.91	3.54	2.33	2.04
United States	2.48	2.59	2.96	2.47	2.28	1.98

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 $t = 1994q1 - 2014q2$ expressed as an annualised percentage rate.

Table 1b: Summary Statistics for Cross-Country Growths and Uncertainty, 1994q1-2014q2

	(1) Growth, Growth		(2) Growth, Uncertainty		(3) Uncertainty, Uncertainty	
	Corr.	(Sig.)	Corr	(Sig.)	Corr	(Sig.)
Canada	0.15	(3/6)	−0.16	(2/7)	0.41	(5/6)
France	0.10	(0/6)	0.11	(1/7)	0.35	(4/6)
Germany	0.11	(2/6)	−0.07	(1/7)	0.26	(4/6)
Italy	0.01	(0/6)	0.07	(0/7)	0.10	(1/6)
Japan	0.10	(2/6)	−0.16	(3/7)	0.33	(4/6)
United Kingdom	0.02	(0/6)	−0.06	(0/7)	0.18	(2/6)
United States	0.01	(1/6)	−0.10	(2/7)	0.30	(4/6)

Notes: 'Growth-Growth' shows, for country i, the correlation between expected contemporaneous growths, ${}_ty^e_{i,t} - {}_ty_{i,t-1}$ and ${}_ty^e_{j,t} - {}_ty_{j,t-1}$ averaged across $j \neq i$; 'Growth-Uncertainty' shows, for country i, the correlation between expected contemporaneous growth ${}_ty^e_{i,t} - {}_ty_{i,t-1}$ and uncertainty ${}_ty^u_{j,t}$ averaged across all j; and Uncertainty-Uncertainty' shows, for country i, the correlation between expected uncertainties, ${}_ty^u_{i,t}$ and ${}_ty^u_{j,t}$ averaged across $j \neq i$. Figures under 'Sig.' show the number of countries for which the correlation is significant at 5% level (i.e. >0.22).

Table 2: Tests of RE Parameter Restrictions in the VAR Model

	Actual Output Growth			Uncertainty
	$\text{FIRE}_{[1]}$	$\text{SIRE}_{[1]}$	$\text{NIRE}_{[15]}$	$\text{FIRE/NIRE}_{[15]}$
Canada	1.18 (0.28)	0.56 (0.48)	$14.10^{\dagger\dagger\dagger}$ (0.00)	1.37 (0.19)
France	0.43 (0.51)	0.61 (0.44)	$17.99^{\dagger\dagger\dagger}$ (0.00)	1.02 (0.45)
Germany	1.94 (0.17)	0.01 (0.92)	$7.1^{\dagger\dagger\dagger}$ (0.00)	1.43 (0.17)
Italy	$4.99^{\dagger\dagger}$ (0.03)	0.12 (0.73)	$10.77^{\dagger\dagger\dagger}$ (0.00)	1.38 (0.19)
Japan	0.88 (0.35)	0.14 (071)	$6.90^{\dagger\dagger\dagger}$ (0.00)	1.49 (0.14)
UK	0.35 (0.55)	1.37 (0.25)	$40.66^{\dagger\dagger\dagger}$ (0.00)	0.76 (0.71)
US	0.12 (0.73)	1.36 (0.24)	$11.13^{\dagger\dagger\dagger}$ (0.00)	0.92 (0.55)

Notes: The table reports F-test statistics of restrictions on the actual output growth and uncertainty equations of the VAR at (19) as described at (10) and in the text. For the growth equations, '$NIRE$' tests the restrictions imposed on the unrestricted quasi-difference equations to achieve NIRE; '$SIRE$' tests the additional restrictions to achieve SIRE; and '$FIRE$' tests the additional restrictions to achieve FIRE. For the uncertainty equations, '$FIRE/NIRE$' tests the restrictions imposed on the unrestricted quasi-difference equations to achieve FIRE and NIRE. The number of restrictions is in [.]. Figures in (.) are p-values and the '†', '††' and '†††' denotes significance at the 10% level, 5% level and 1% level.

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

	National		Global		Total	
	Prospects	Uncertainty	Prospects	Uncertainty	Prospects	Uncertainty
	ρ_{ii}^{N}		ρ_{ii}^{G}		ρ_{ii}	
	ρ_{ii}^{NP}	ρ_{ii}^{NU}	ρ_{ii}^{GP}	ρ_{ii}^{GU}	ρ_{ii}^{P}	ρ_{ii}^{U}
Canada	1.19 (0.34) 36%		2.10 (1.79) 64%		3.29 (1.61)	
	1.14 35%	0.04 1%	1.87 57%	0.24 7%	3.01 92%	0.28 8%
France	0.84 (0.12) 26%		2.37 (0.47) 74%		3.21 (0.39)	
	0.74 23%	0.07 3%	1.35 42%	1.05 32%	2.09 65%	1.11 35%
Germany	1.21 (0.13) 65%		0.66 (0.40) 35%		1.86 (0.31)	
	1.07 57%	0.17 8%	0.53 28%	0.10 7%	1.59 85%	0.27 15%
Italy	0.89 (0.11) 40%		1.35 (0.53) 60%		2.24 (0.46)	
	0.82 37%	0.06 3%	0.50 22%	0.86 38%	1.32 59%	0.92 41%
Japan	1.00 (0.07) 96%		0.04 (0.12) 4%		1.04 (0.06)	
	0.89 85%	0.11 11%	0.08 8%	−0.04 −4%	0.97 93%	0.07 7%
United Kingdom	0.81 (0.12) 34%		1.50 (0.39) 66%		2.39 (0.29)	
	0.79 33%	0.02 1%	0.79 33%	0.79 33%	1.57 66%	0.81 34%
United States	1.72 (0.15) 53%		1.56 (0.90) 47%		3.28 (0.80)	
	1.55 47%	0.23 7%	1.43 44%	0.08 2%	2.98 91%	0.30 9%

Notes: The ρ_{ii} show the infinite horizon persistent effect on output in country i of a shock to actual and expected outputs and uncertainty in all countries 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; the ρ_{ii}^{P} and ρ_{ii}^{U} show the decomposition into that part due to prospects and that part due to uncertainty as defined in the text. The % figures express the elements as a proportion of total persistence. The figures in (.) show estimated standard errors.

Table 4: Persistence Measures at the Infinite Horizon and their Allocation into Fundamentals/Sentiment Components (Full Model and Model excluding uncertainty)

	Fundamentals ρ_{ii}^{S}	Sentiment ρ_{ii}^{S}	Total ρ_{ii}
Canada	85%	15%	3.29 (1.61)
	55%	45%	3.26 (1.62)
France	99%	1%	3.21 (0.39)
	99%	1%	2.24 (0.39)
Germany	43%	57%	1.86 (0.31)
	53%	47%	1.52 (0.31)
Italy	96%	4%	2.24 (0.46)
	99%	1%	2.93 (0.46)
Japan	22%	78%	1.04 (0.06)
	50%	50%	1.19 (0.06)
United Kingdom	55%	45%	2.39 (0.29)
	89%	11%	2.06 (0.29)
United States	83%	17%	3.28 (0.80)
	76%	24%	1.82 (0.61)

Notes: The 'Total' 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 two rows for each country relate to the model with and without uncertainty respectively. 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 (18), and reports the respective figures according to the imposition of the noisy information restrictions ($NIRE$).

Figure 1a: Actual, Nowcast and One-Period-Ahead Expected Outputs

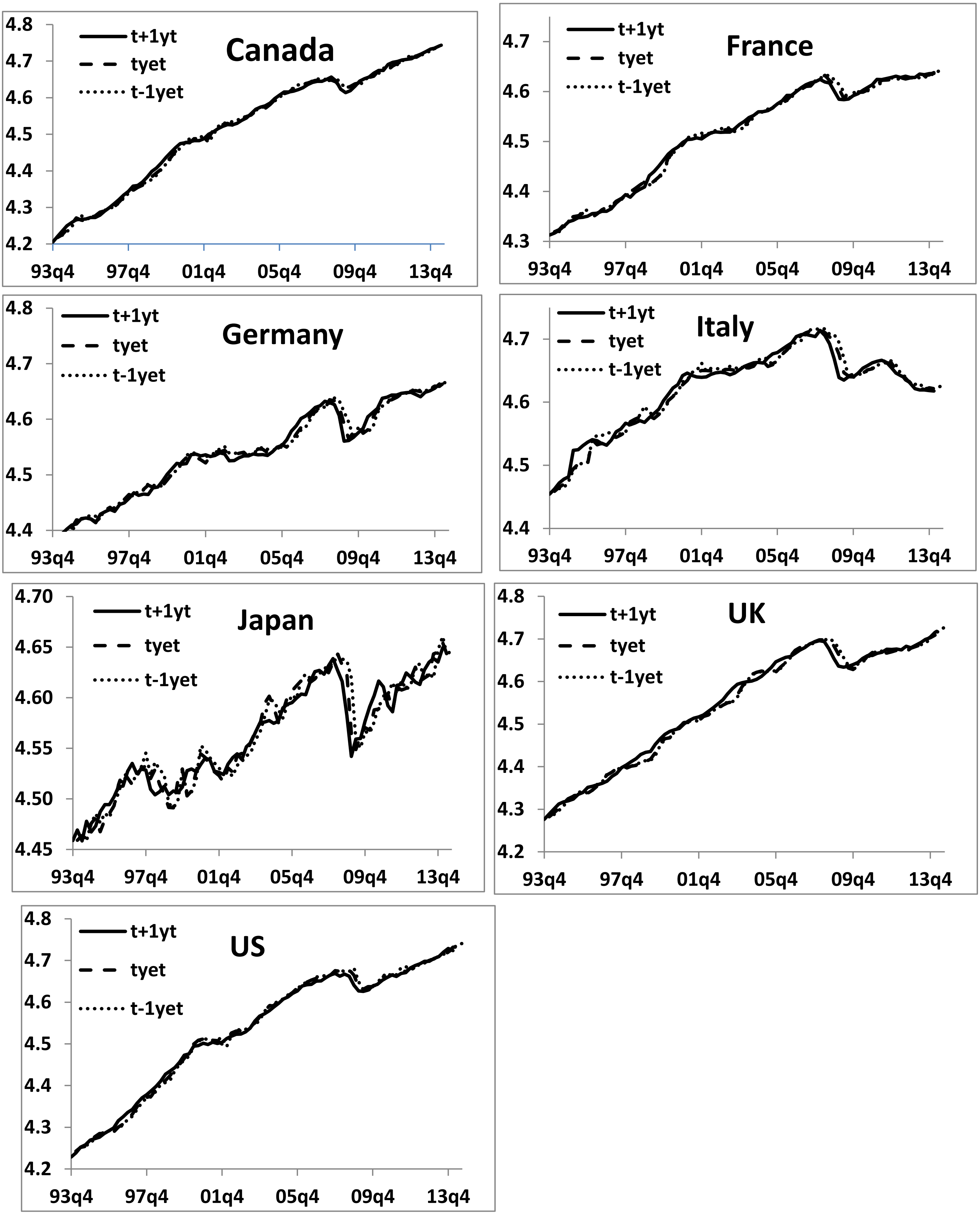


Figure 1b: Interquartile Range (Uncertainty) and Output Growth

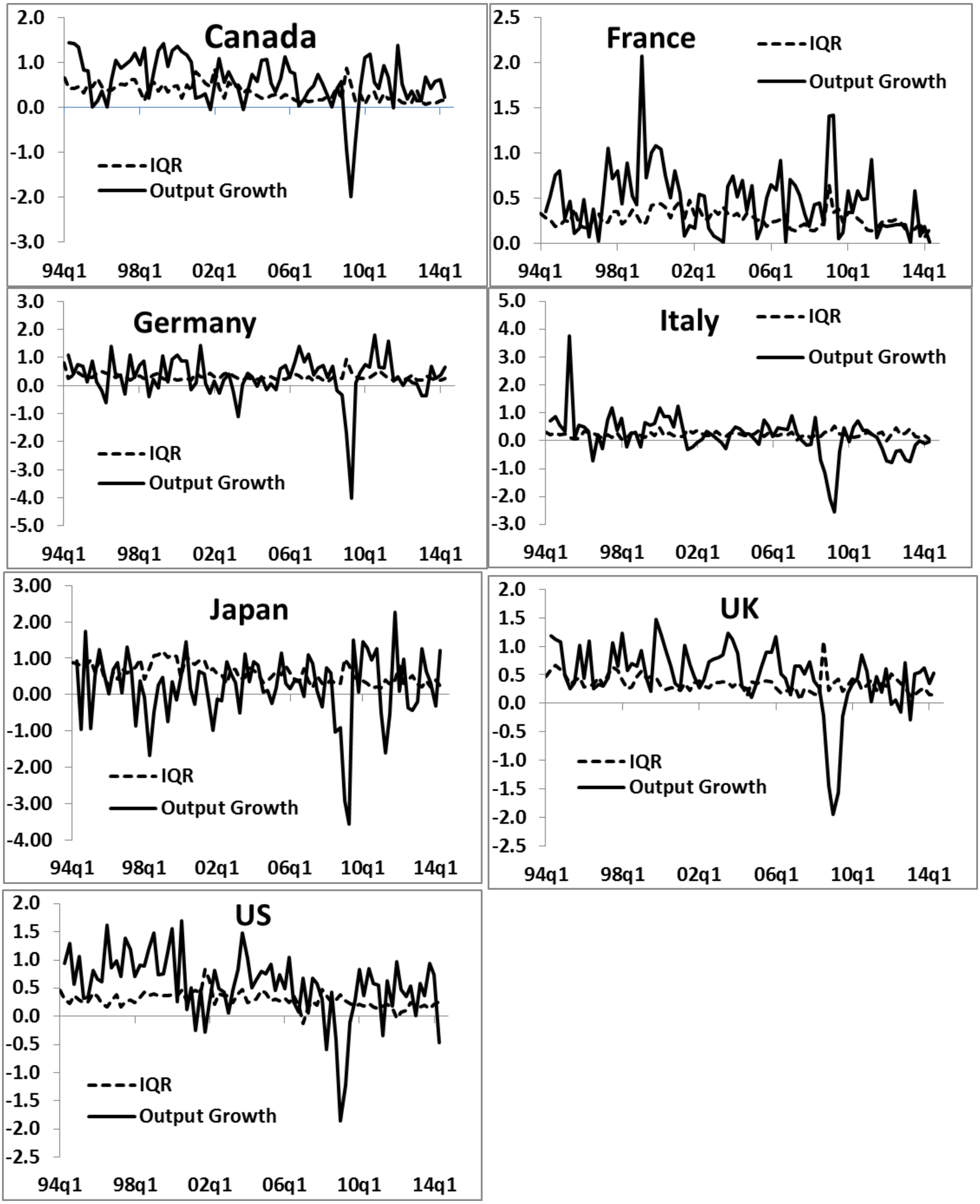


Figure 2a: Persistence Profiles (PP) G7 Actual, Nowcast and One-Period-Ahead Expected Outputs (with uncertainty)

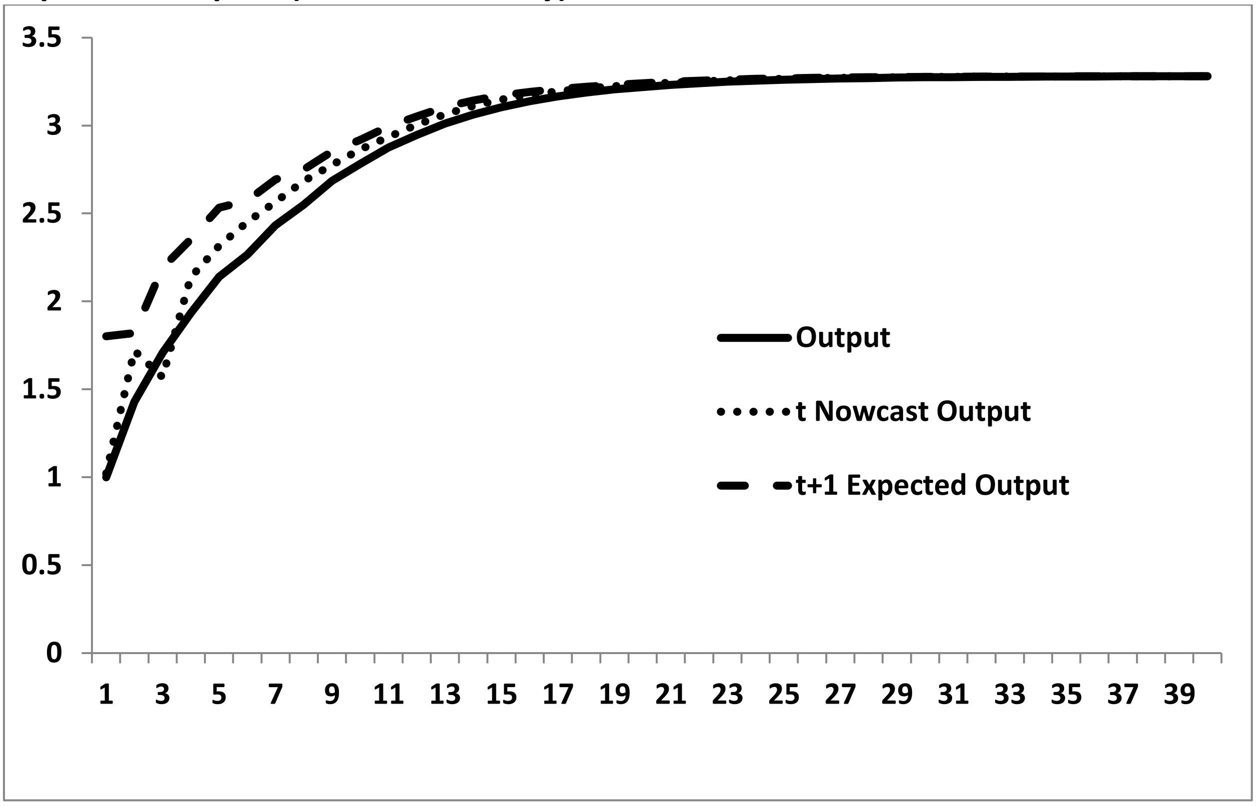


Figure 2b: PP of G7 Individual Countries Output (with uncertainty)

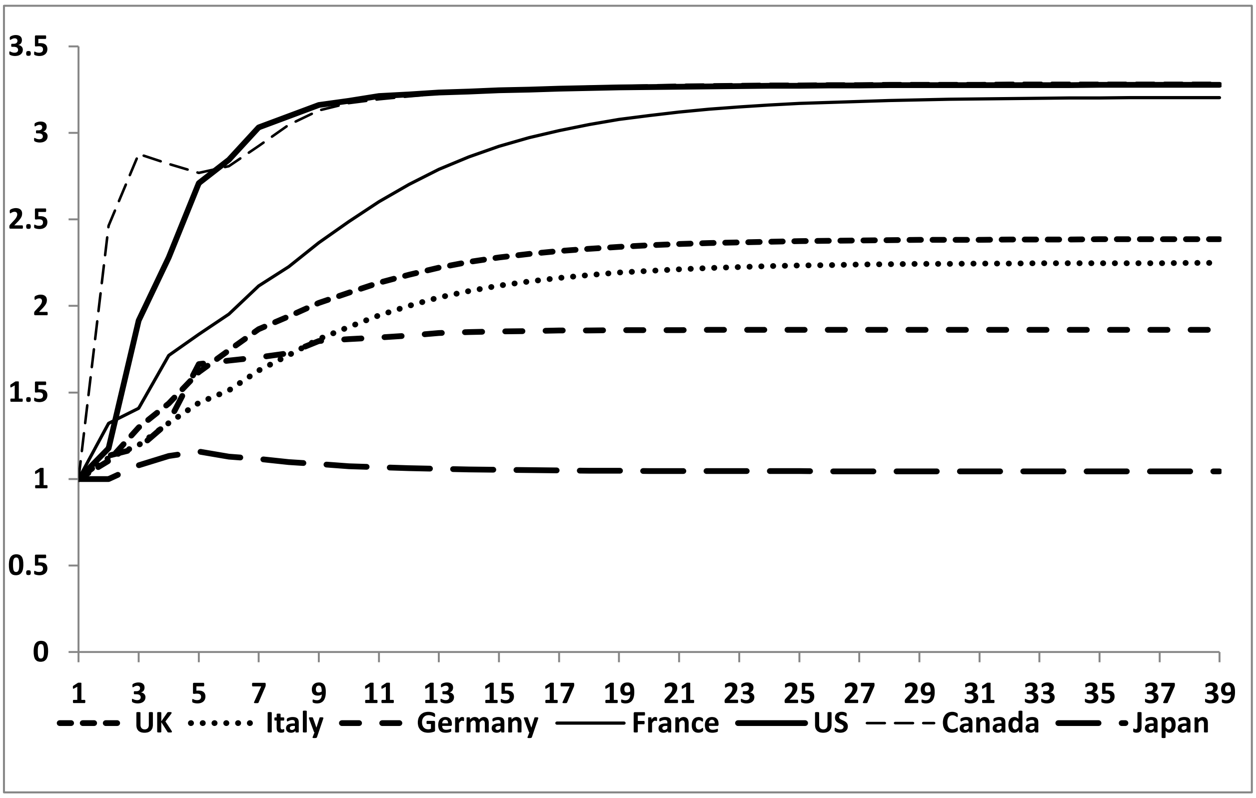
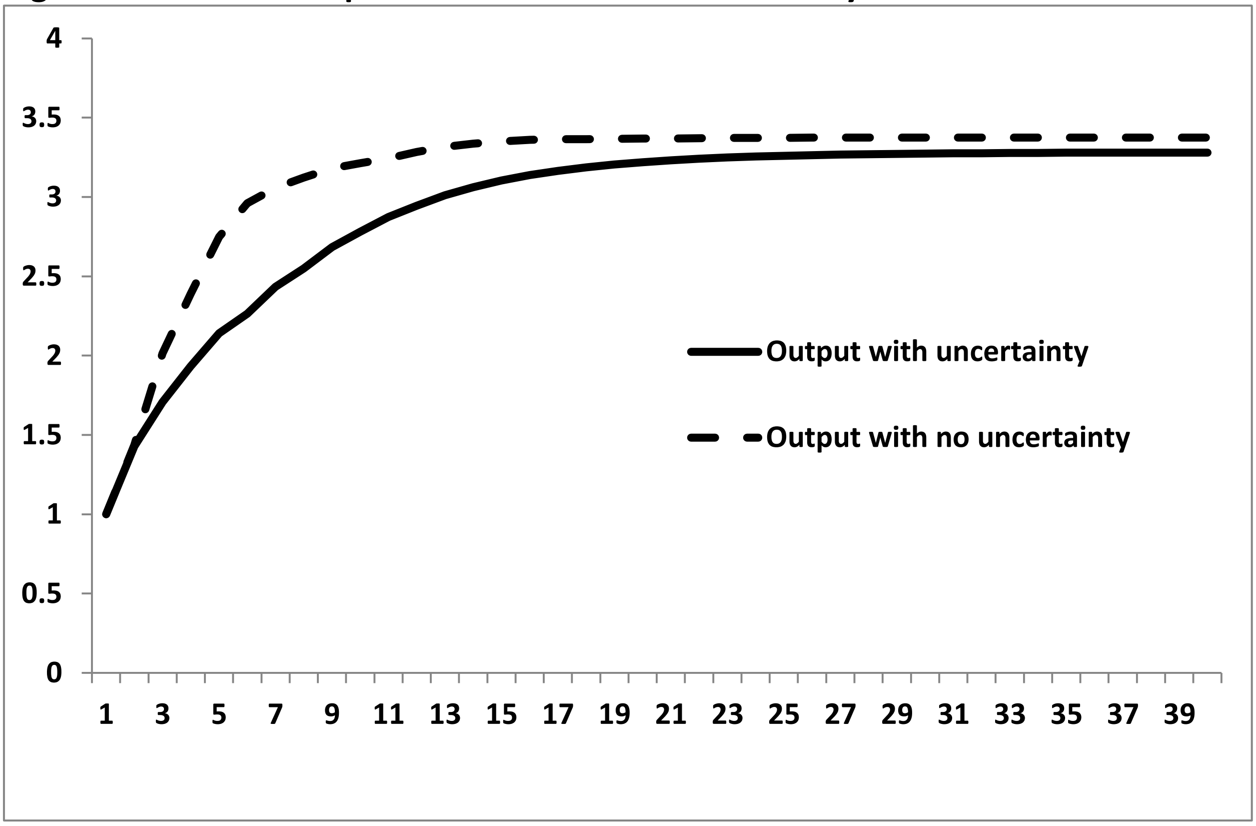


Figure 3: PP of G7 Output with and without uncertainty



References

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.

Andrade, P. and H. LeBihan, (2013), "Inattentive Professional Forecasters," *Journal of Monetary Economics*, 60, 967-982.

Bachmann, R., S.Elstner, and E.R. Sims, (2013), "Uncertainty and Economic Activity: Evidence from Business Survey Data." *American Economic Journal: Macroeconomics* 5 (2): 217–49.

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.

Baker, S.R., N. Bloom and S.J. Davis, (2016), Measuring Economic Policy Uncertainty, (forthcoming) *Quarterly Journal of Economics.*

Bloom, N., M. Floetotto, N. Jaimovich, I.Saporta and S.Terry, (2012), "Really Uncertain Business Cycles", *NBER Working Paper*, No. 18245.

Chudik, A. and M.H. Pesaran, (2016), "Theory and Practice of GVAR Modelling", *Journal of Economic Surveys*, 30, 165-197.

Coibion, O. and Y. Gorodnichenko, (2011). "Monetary Policy, Trend Inflation and the Great Moderation: An Alternative Interpretation," *American Economic Review,* 101, 341-370.

Coibion, O. and Y. Gorodnichenko, (2012). "Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts," *IMF WP* 12/296.

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.

Dovern, J., U. Fritsche, P. Loungani, and N. Tamirisa, (2015), "Information Rigidities: Comparing Average and Individual Forecast for a Large International Panel", *International Journal of Forecasting*, 31, 14-154.

Dovern, J., U. Fritsche and J. Slacalek, (2012), "Disagreement among Forecasters in G7 Countries", *Review of Economics and Statistics*, 94(4), 1081–1096.

Fernández-Villaverde, J., P.Guerrón-Quintana, J.F. Rubio-Ramírez and M. Uribe, (2011), "Risk Matters: The Real Effects of Volatility Shocks." *American Economic Review* 101 (6): 2530–61.

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.

Ilut, C.L. and M. Schneider, (2014), Ambiguous Business Cycles, *American Economic Review* 2014, 104(8): 2368–2399

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, M.A. and M. E. Terrones, (2015), *Collapse and Revival : Understanding Global Recessions and Recoveries*, IMF Publications.

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.

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.

Leeper, E.M., T.B. Walker and S-C Yang, "Fiscal Foresight and Information Flows", *Econometrica*, 81(3), 1115-1145.

Mankiw, N.Gregory, Ricardo Reis, 2002. "Sticky Information Versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve," *Quarterly Journal of Economics* 117(4), 1295-1328.

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.

Sims, C. A., (2003), "Implications of Rational Inattention," *Journal of Monetary Economics* , 50(3), 665-690.