International Economic Journal
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713685453

Are economic growth and the variability of the business cycle related? Evidence from five European countries

Stilianos Fountas [a]; Menelaos Karanasos [b]
[a] Department of Economics, University of Macedonia, Thessaloniki, Greece [b] Economics and Finance, Brunel University, Uxbridge, UK

Online Publication Date: 01 December 2008

To cite this Article Fountas, Stilianos and Karanasos, Menelaos(2008)'Are economic growth and the variability of the business cycle related? Evidence from five European countries',International Economic Journal,22:4,445 — 459

To link to this Article: DOI: 10.1080/10168730802497478

URL: http://dx.doi.org/10.1080/10168730802497478

International Economic Journal
Vol. 22, No. 4, December 2008, 445–459

Routledge
Taylor & Francis Group

Are economic growth and the variability of the business cycle related? Evidence from five European countries

Stilianos Fountas[a*] and Menelaos Karanasos[b]

[a]*Department of Economics, University of Macedonia, Thessaloniki, Greece;* [b]*Economics and Finance, Brunel University, Uxbridge, UK*

We use a long series of annual data that span over 100 years to examine the relationship between output growth and its uncertainty in five European countries. Using the GARCH methodology to proxy uncertainty, we obtain two important results. First, more uncertainty about output leads to a higher rate of growth in three of the five countries. Second, output growth reduces its uncertainty in all countries except one. Our results are robust to alternative specifications and provide strong support to the recent emphasis by macroeconomists on the joint examination of economic growth and the variability of the business cycle.

Keywords: output growth; output growth uncertainty; GARCH

JEL Classification: C22; E32

1. Introduction

Until the early 1980s, macroeconomic theorists treated the analysis of the real business cycle (RBC) as separate from the study of economic growth. In the 1980s, three important contributions in business cycle theory by Kydland and Prescott (1982), Long and Plosser (1983), and King et al. (1988) integrated the theories of the business cycle and economic growth in their models. However, these models did not consider the possibility that the variability of the business cycle might relate to the rate of economic growth. Similarly, for the most part, developments in growth theory have been made without consideration of the variability in the business cycle. The scene has changed recently at both the theoretical and empirical front. At the theoretical level, Blackburn and Pelloni (2005) and a number of studies summarised by these authors examine how cyclical fluctuations might relate to long-run economic growth. At the empirical level,

*Corresponding author. Email: sfountas@uom.gr

ISSN 1016-8737 print/ISSN 1743-517X online

DOI: 10.1080/10168730802497478
http://www.informaworld.com

recent studies by McConnell and Perez-Quiros (2000) and Stock and Watson (2002) highlight the importance of the reduction in US GDP growth volatility in the last two decades and its implications for growth theory. The early dichotomy in macroeconomic theory between economic growth and the variability of economic fluctuations should be reconsidered given several theories outlined below regarding the relationship between output volatility and growth. These theories predict a positive, negative or no association between the two variables. The empirical evidence to date, based on cross-section country studies, panel data studies, or time-series analyses of individual countries is also quite mixed. The theoretical and empirical ambiguity surrounding the RBC variability–economic growth relationship provides us with the motivation to expand on the empirical aspects of this issue.

We attempt to cover a gap in the existing empirical literature by employing a long span of annual output data that starts in the 1800s on five European countries. This approach has two advantages over existing studies. First, we are able to analyze the RBC variability–growth relationship over a period that spans over 100 years, thus including in our analysis periods of significant variation in output growth, such as the two World Wars, the Great Depression and the volatile 1970s. Second, the use of annual data allows us to perform a more appropriate test of the Black (1987) hypothesis that predicts a positive effect of output variability and uncertainty on the growth rate of output. Black's argument is based on the response of investment and output growth to a change in uncertainty regarding the profitability of investment projects, and hence can be better tested in a study that uses low-frequency data (see Caporale and McKiernan 1998).

The rest of the paper is structured as follows. Section 2 presents a survey of the theoretical literature on the relationship between the RBC and economic growth. Section 3 reviews the existing empirical literature. Section 4 outlines our econometric model and section 5 presents our main results and an interpretation. Section 6 describes some robustness tests. Finally, Section 7 summarises our main conclusions.

2. Theoretical background

Given the absence of a theoretical consensus, the anticipated relationship between output variability and economic growth remains an empirical issue. Macroeconomic theory offers three possible scenarios regarding the impact of the former on the latter. First, there is the possibility of independence between output variability and growth. In other words, the determinants of the two variables are different from each other. According to some business cycle models, output fluctuations around the natural rate are due to price misperceptions in response to monetary shocks. On the other hand, changes in the growth rate of output arise from real factors such as technology (Friedman 1968).

The scenario of a negative association between output variability and average growth goes back to Keynes (1936) who argued that entrepreneurs, when estimating the return on their investment, take into consideration the fluctuations in economic activity. The larger the output fluctuations, the higher the perceived riskiness of investment projects and, hence, the lower the demand for investment and output growth. A similar result is obtained by the literature on sunspot equilibria (Woodford 1990). According to Bernanke (1983) and Pindyck (1991), the negative relationship between output volatility and growth arises from investment irreversibilities at the firm level. Ramey and Ramey (1991) show that in the presence of commitment to technology in advance, higher output volatility can lead to suboptimal ex post output levels by firms (due to uncertainty-induced planning errors) and hence, lower mean output and growth.

Finally, the positive impact of output variability on growth can be justified by several economic theories. First, more income variability (uncertainty) would lead to a higher savings rate (Sandmo, 1970) for precautionary reasons, and hence, according to neoclassical growth theory, a higher equilibrium rate of economic growth. This argument has been advanced by Mirman (1971). An alternative explanation is due to Black (1987) and is based on the hypothesis that investments in riskier technologies will be pursued only if the expected return on these investments (average rate of output growth) is large enough to compensate for the extra risk. As real investment takes time to materialize, such an effect would be more likely to occur in empirical studies utilizing low-frequency data. More recently, Blackburn (1999) using a model of endogenous growth generated by learning-by-doing shows that business cycle volatility raises the long-run growth of the economy.

The effect of output volatility on growth is not always unambiguous. A number of studies (Smith 1996; Grinols and Turnovsky 1998; Turnovsky 2000) show that, with preferences represented by a constant elasticity utility function, the growth rate is positively related to volatility provided the coefficient of risk aversion exceeds one. Smith (1996) shows that the sign of the growth-volatility relationship depends on whether the intertemporal elasticity of substitution exceeds or falls short of one. The above papers all refer to a closed economy. Turnovsky and Chattopadhyay (2003), in a stochastic general equilibrium small-open economy model of a developing country, examine the effect of output volatility on growth allowing for three additional types of variability (in the terms of trade, government spending and money supply) to have an impact on output growth. The theoretical model implies that output volatility has an ambiguous effect on growth. This result is confirmed by numerical simulations that show that the effect is small.

The opposite type of causality, running from growth to output uncertainty, may also be examined in the present analysis. From a theoretical point of view, the sign of this causality relationship is negative. An increase in growth leads to more inflation (the short-run Phillips curve effect). Empirical evidence by Briault (1995) supports this effect. Furthermore, a higher inflation rate lowers output growth uncertainty (Ball et al. 1988). In the tradition of New Keynesian Economics, a higher inflation rate leads to more frequent optimal price adjustments and therefore nominal shocks cause smaller real effects as well as a lower output variability.

Recently, a growing theoretical literature has developed that examines the correlation between average output growth and its variability in an endogenous growth set-up (Blackburn and Galinder 2003; Blackburn and Pelloni 2004, 2005). Blackburn and Galinder (2003) focus on the importance of the source of technological change for the sign of correlations between growth and its volatility. In a stochastic real growth model the authors show that positive (negative) correlation will most likely arise in a framework of internal (external) learning where the agents improve their productive efficiency by investing time in learning (benefit from knowledge spillovers taking place among agents).

In a stochastic monetary growth model Blackburn and Pelloni (2004) show that the correlation between growth and its variability is a function of the type of shocks buffeting the economy. The study concludes that the correlation will be positive (negative) depending on whether the real (nominal) shocks dominate. In a richer setting, Blackburn and Pelloni (2005) use a stochastic monetary growth model with three different types of shocks (technology, preference and monetary) that have permanent effects on output due to wage contracts and endogenous technology. The authors show that output growth and output variability are negatively correlated irrespective of the type of shocks causing fluctuations in the economy.

3. Empirical evidence

The empirical evidence to date on the association between output growth and its variability is mixed. Early studies employed cross-section (Kormendi and Meguire 1985) or pooled data (Grier and Tullock 1989) and found evidence for a positive association. Ramey and Ramey (1995) used a panel of 92 countries and a sample of OECD countries (for the 1960–1985 period) and found strong evidence that countries with higher output variability have lower growth. A similar result was obtained by Zarnowitz and Moore (1986) who divided the 1903–1981 period into six subperiods and compared high and low growth periods in terms of output variability (measured by the standard deviation of the annual growth rate in real GNP). In a recent study, Kneller and Young (2001), using a panel-data framework, found that output variability reduces growth. Turnovsky and Chattopadhyay (2003) found a similar, although small, effect in a sample of 61 developing countries allowing in their model for various types of volatility to have an impact on growth.

More recent studies use the time series techniques of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models to proxy for output uncertainty rather than variability (Caporale and McKiernan 1996, 1998; Speight 1999). The first two papers use UK and US data, respectively, and find a positive association between output variability and growth, whereas the last paper uses UK data and finds no association. Grier and Perry (2000) using the GARCH-M model and monthly US data find no evidence that uncertainty about output affects the rate of growth. Henry and Olekalns (2002) find evidence in favour of a negative association using post-war real GDP data for the United States. Allowing for asymmetries, Grier et al. (2004) find US evidence for a positive effect. Fountas et al. (2002) find no evidence for an effect of output uncertainty on growth using data from Japan and a bivariate GARCH model that includes inflation and growth. This result is confirmed in a recent study by Fountas et al. (2004) using Japanese data and three different univariate GARCH models.

The motivation for our empirical study comes from several factors. First, the inconclusiveness of the existing empirical time series literature, second the sparsity of evidence using international data that cover a long horizon, and third the complete lack of evidence on the effect of growth on its uncertainty. We, therefore, attempt to provide more robust evidence on the bi-directional relationship between the two variables using annual data that span over a long time period for five European countries.

4. The model

The AR(p)-GARCH-in-mean model is given by

$$\Phi(L)y_t = \phi + \delta h_t + \varepsilon_t \quad (t \in \mathbb{Z}) \tag{1}$$

with

$$1 - \Phi(L) \equiv \sum_{i=1}^{p} \phi_i L^i$$

and

$$\varepsilon_t \equiv e_t \sqrt{h_t}$$

where y_t stands for the output growth, $\{e_t\}$ is a sequence of independent, identically distributed random variables with mean zero and variance one, and h_t denotes the conditional variance of the errors $\{\varepsilon_t\}$, $(\varepsilon_t|\Sigma_{t-1}) \sim (0, h_t)$.[1] Regarding h_t, we assume that it follows a GARCH(1,1)-level process

$$h_t = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} + \gamma y_{t-1} \tag{2}$$

By including lagged growth in the conditional variance equation, and the conditional variance in the output growth equation, we can simultaneously test for the Black hypothesis and for the effect of growth on its uncertainty. We will refer to the model given by equations (1)–(2) as the AR(p)-GARCH(1,1)-M(0)-L(1) model.

In what follows we provide the univariate ARMA representations of the process and its conditional variance. We also give the stationarity condition for these representations.

The GARCH(1,1)-level formulation in equation (2) can be readily interpreted as an ARMA(1,1)-level model for the conditional variance. This ARMA representation is given by

$$(1 - \beta_1 L)h_t = \omega + \alpha v_{t-1} + \gamma y_{t-1} \tag{3}$$

where

$$v_t \equiv \varepsilon_t^2 - h_t, \quad \beta_1 \equiv a + \beta$$

Note that v_t is defined as the difference between the squared error and its conditional expectation. Thus, v_t is a serially uncorrelated term with expected value zero. Moreover, the univariate ARMA representation for the process is

$$B(L)y_t = \bar{\phi} + (1 - \beta_1 L)\varepsilon_t + \delta a v_{t-1} \tag{4}$$

with

$$B(L) \equiv \Phi(L)(1 - \beta_1 L) - \delta\gamma L$$

and

$$\bar{\phi} \equiv \delta\omega + (1 - \beta_1)\phi$$

where $\Phi(L)$ is defined in equation (1). In addition, the univariate ARMA representation of the conditional variance is

$$B(L)h_t = \bar{\omega} + \Phi(L)a v_{t-1} + \gamma L\varepsilon_t \tag{5}$$

with

$$\bar{\omega} = \omega\Phi(1) + \gamma\phi$$

where $B(L)$ is given by equation (4).

Assumption 1 All the roots of the autoregressive polynomial $B(L)$ lie outside the unit circle (stationarity conditions for the univariate ARMA representations).

Under assumption 1, and provided $\bar{\omega} > 0$, the first moment of the conditional variance is

$$\mathsf{E}(h_t) = \frac{\bar{\omega}}{\Phi(1)(1 - \beta_1) - \gamma\delta}$$

where $\Phi(1)$, β_1 and $\bar{\omega}$ are defined in equations (1), (3) and (5), respectively.

5. Data and empirical results

We employ annual data that cover more than 100 years. Our sample includes five industrial European countries, namely, France, Germany, Italy, Sweden and the UK, for which historical output statistics are available. The starting point differs across countries of our sample.[2] The choice of annual data is based on the time lags required for investment changes to take place and allows a more accurate test of some theories relating

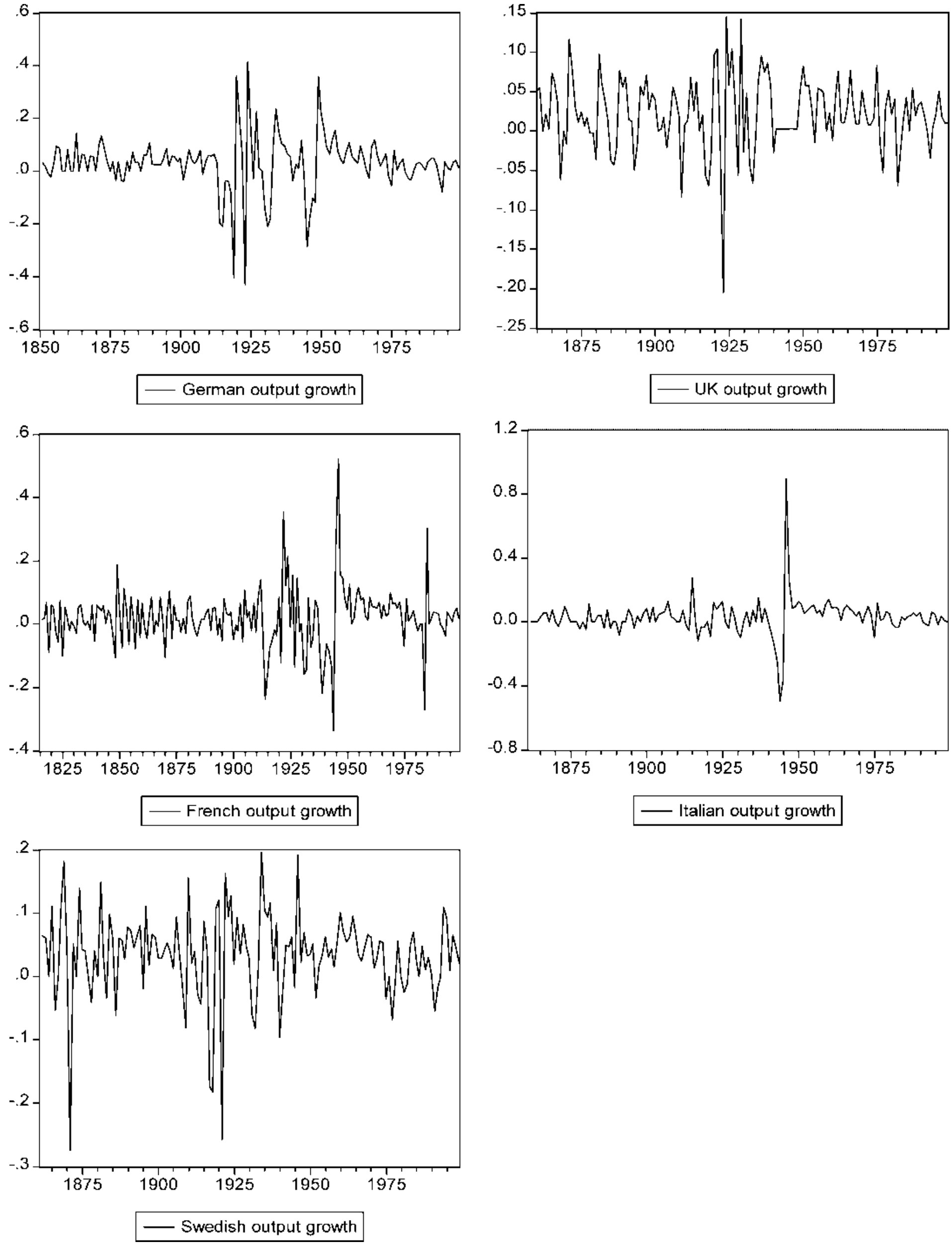

Figure 1. Output growth.

to the variability-growth relationship, such as the theories by Black (1987) and Mirman (1971). Output data are proxied by the index of industrial production (IP). The source of our data series is Mitchell (1998) and the Main Economic Indicators (OECD database). The growth rate of output is measured by the year-to-year changes in the log of industrial production. Figure 1 plots the growth in the IP series in the five countries. The choice of IP as a proxy for output is dictated by data availability considerations. It should be borne in mind that this proxy is not perfect. First, IP is about one quarter of real GDP and is more variable than the latter. Second, due to its large volatility, in the literature on business cycle dating, IP would be inappropriate in detecting cyclical movements. Of course, this argument becomes weaker in the case of annual data, as in the present study.

Next, we employ the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests to test for the stationarity of all growth series, as the estimation of GARCH models requires that all variables are stationary. The unit root test results reported in Table 1 indicate that all five output growth series are I(0). We proceed with the estimation of models from the AR-GARCH-M-L family in order to take into account the serial correlation and the ARCH effects observed in our time series data, and to capture the possible simultaneous feedback between growth and its uncertainty. Growth uncertainty is proxied by the conditional variance of the growth series. Despite the use of low-frequency data, we can still detect the existence of GARCH effects as our very long sample period contains years of considerable variability in output growth (see Figure 1).

We choose the best model for each country on the basis of the minimum value of the Akaike Information Criterion (AIC). These models are reported in Table 2. We choose an AR(0) model for Sweden, an AR(1) for Germany,[3] an AR(3) for UK and France, and an AR(4) for Italy. Moreover, the GARCH(1,1) specification for the conditional variance is chosen for three out of the five countries (Germany, France and Sweden) and the ARCH(1) model is chosen for UK and Italy. The estimated standard errors are determined by the Bollerslev and Wooldridge (1992) procedure that accounts for the non-normality of the residuals. The reported values of the Ljung–Box Q statistic for the standardized and squared standardized residuals indicate the absence of serial correlation. Two important results arise from Table 2. First, the in-mean effect is positive and statistically significant in three out of the five countries providing evidence to Mirman (1971), Black (1987) and Blackburn (1999). Second, the lagged output growth coefficient in the conditional variance equation is negative in all five countries and it is statistically significant in all countries except Sweden. This result is consistent with the theory outlined in Section 2, even though it does not prove that the channel outlined in Section 2 is in effect.[4] More analysis of the mechanism through which

Table 1. Unit root tests.

	Dickey-Fuller: ADF (4)	Phillips-Perron: PP (4)
GERMANY	−5.720	−10.020
UK	−7.050	−10.620
FRANCE	−5.780	−12.120
ITALY	−5.890	−9.480
SWEDEN	−5.190	−11.700

Notes: The tests include a constant. Order of augmentation (ADF) and lag truncation (PP) are in parentheses.
Critical values: −3.45(1%), −2.87(5%), −2.57(10%).

Table 2. AR-GARCH-M-L estimation. Dependent variable is output growth.

	Germany	UK	France	Italy	Sweden
Mean specification					
δ	**2.351**	**7.297**	0.108	**2.838**	−0.236
	[0.030]	[0.075]	[0.870]	[0.001]	[0.852]
ϕ_1	0.496	0.249	0.141	0.354	–
	[0.000]	[0.000]	[0.054]	[0.000]	
ϕ_2	–	–	0.087	–	–
			[0.069]		
ϕ_3	–	−0.279	0.114	0.042	–
		[0.000]	[0.003]	[0.041]	
ϕ_4	–	–	–	0.032	–
				[0.068]	
ϕ	–	0.012	0.008	0.012	0.035
		[0.112]	[0.166]	[0.087]	[0.000]
Variance specification					
γ	**−0.031**	**−0.008**	**−0.043**	**−0.024**	−0.010
	[0.000]	[0.015]	[0.000]	[0.004]	[0.154]
α	0.241	0.536	0.610	0.533	0.303
	[0.011]	[0.031]	[0.000]	[0.001]	[0.063]
β	0.594	–	0.153	–	0.682
	[0.000]		[0.064]		[0.000]
ω	0.002	0.001	0.001	0.003	0.001
	[0.000]	[0.000]	[0.000]	[0.000]	[0.088]
Information Criteria					
SC	−2.236	−3.420	−2.197	−2.465	−2.480
AIC	−2.398	−3.567	−2.357	−2.638	−2.608
Q Statistics					
Q_4	4.321	6.632	5.333	3.413	5.651
	[0.364]	[0.157]	[0.255]	[0.491]	[0.227]
Q_4^2	2.969	1.181	0.895	1.903	0.319
	[0.563]	[0.881]	[0.925]	[0.754]	[0.989]

Notes: Probabilities are given in brackets. δ is the coefficient of the in-mean effect. The ϕ_i's denote the autoregressive parameters. ϕ is the constant term in the conditional mean of the process. γ captures the effect of lagged output growth on its conditional variance. α and β denote the ARCH and GARCH parameters, respectively. ω is the constant term in the conditional variance of the process. SC and AIC are the Schwarz and Akaike information criteria, respectively. Q_4 is the 4th-order Ljung-Box test for standardized residuals. Q_4^2 is the 4th-order Ljung-Box test for squared standardized residuals.

Table 3. Stationarity conditions. Unconditional variance.

	$\widehat{\eta}$	$\widehat{\mathrm{E}}(h_t)$
GERMANY	0.847	0.007
UK	0.458	0.002
FRANCE	0.822	0.009
ITALY	0.681	0.004
SWEDEN	0.988	0.049

Notes: The first column reports the following sum: $\widehat{\eta} \equiv \widehat{\beta}_1 + \widehat{\gamma}\widehat{\delta} + \sum_{i=1}^{p} \widehat{\phi}_i(1 - \widehat{\beta}_1)$. The second column reports the estimated unconditional variance of output growth.

Table 4. Augmented M-L models.

GERMANY / UK / FRANCE

Panel A. In-mean models.

	GERMANY			UK			FRANCE		
δ	3.26 [0.03]	2.33 [0.02]	2.49 [0.02]	6.65 [0.06]	6.69 [0.08]	5.52 [0.00]	0.21 [0.68]	0.11 [0.76]	–
ϕ_π	–	−0.01 [0.00] {3}	–	–	−0.10 [0.05] {3}	–	–	−0.01 [0.82] {1}	–
γ_π	–	–	−0.002 [0.01] {3}	–	–	−0.004 [0.00] {10}	–	–	−0.02 [0.01] {10}

Panel B. In-mean-level models. / Panel C. Inflation equation.

	GERMANY		UK		FRANCE	
Panel B. In-mean-level models.						
δ	2.66 [0.01]	2.84 [0.00]	7.03 [0.13]	4.20 [0.16]	0.54 [0.52]	0.17 [0.82]
γ	−0.03 [0.00]	−0.06 [0.00]	−0.01 [0.01]	−0.01 [0.03] {6}	−0.05 [0.00]	−0.05 [0.00]
ϕ_π	−0.004 [0.18] {3}	–	−0.12 [0.02] {3}	–	−0.13 [0.02] {1}	–
ζ	–	0.09 [0.72]	–	0.76 [0.06]	–	−0.28 [0.48]
Panel C. Inflation equation.						
ϕ_y		**1.83** [0.01] {3}		**0.09** [0.06] {9}		**0.03** [0.14] {4}

ITALY / SWEDEN

Panel A. In-mean models.

	ITALY			SWEDEN		
δ	**2.25** [0.02]	**1.85** [0.02]	**2.13** [0.04]	−0.16 [0.90]	−0.52 [0.71]	−0.16 [0.93]
ϕ_π	–	**−0.12** [0.01] {2}	–	–	**−0.34** [0.00] {1}	–
γ_π	–	–	**−0.01** [0.01] {2}	–	–	−0.01 [0.74] {5}

	ITALY		SWEDEN	
Panel B. In-mean-level models.				
δ	**2.22** [0.02]	**1.37** [0.01]	−0.58 [0.69]	–
γ	**−0.02** [0.00]	**−0.01** [0.09]	−0.002 [0.74]	−0.02 [0.15]
ϕ_π	**−0.09** [0.04] {2}	–	**−0.34** [0.01] {1}	–
ζ	–	**0.19** [0.00]	–	−0.35 [0.49]
Panel C. Inflation equation.				
ϕ_y		**0.19** [0.00] {3}		0.05 [0.33] {3}

Notes: Probabilities are given in brackets. δ is the coefficient of the in-mean effect. γ captures the effect of lagged growth on its variance. ϕ_π (γ_π) captures the effect of inflation on growth (real uncertainty). ζ is the asymmetry coefficient. ϕ_y captures the effect of growth on inflation. The numbers in $\{\cdot\}$ indicate the order of the lag.

growth affects its uncertainty is offered in the following section. Moreover, this finding is in broad agreement with the predictions of the analysis of Blackburn and Pelloni (2005) for a negative correlation between output growth and its variability. It should be kept in mind though that our evidence is in terms of causality rather than correlation.

Our results on the positive effect of output uncertainty on growth square with the findings of some recent studies. Our UK evidence is consistent with Caporale and McKiernan (1996). Our US evidence squares with the US evidence reported in Caporale and McKiernan (1998). Overall, these findings suggest that macroeconomic theory should continue the recent trend and examine explicitly the interrelationship between economic growth and the variability of the business cycle rather than treat them independently.

Moreover, note that the condition for the existence of the unconditional variance is $\eta \equiv \beta_1 + \gamma\delta + \sum_{i=1}^{p} \phi_i(1-\beta_1) < 1$. Table 3 reports the estimated values of $\eta(\hat{\eta})$ for the five AR-GARCH-M-L models. In all cases $\hat{\eta}$ is less than one. The five estimated unconditional variances are also reported in the last column of Table 3. Recall that for the positivity of the unconditional variance we need $\bar{\omega} \equiv \omega\Phi(1) + \gamma\phi > 0$.

6. Robustness tests

6.1. *Alternative models*

In this subsection, we examine the robustness of the results obtained above to various alternative model specifications. These specifications include an in-mean model, an in-mean-level model with asymmetric effects, and allowance for the impact of inflation[5] on growth and output uncertainty. Table 4 provides estimates of the various model specifications. In Panel A, we report estimates of the in-mean model (where no lagged output growth term appears in the conditional variance equation). In this specification,

Table 5. AR-GARCH-M-L estimation for the entire sample (Dummy Variables).

	GERMANY	UK	FRANCE	ITALY	SWEDEN
δ	**3.987**	9.810	**4.598**	**5.727**	4.975
	[0.026]	[0.182]	[0.000]	[0.003]	[0.351]
γ	**−0.036**	**−0.008**	**−0.042**	−.007	**−0.009**
	[0.000]	[0.103]	[0.000]	[0.103]	[0.396]
WWI	−0.192	−0.012	−0.164	−0.147	−0.116
	[0.000]	[0.523]	[0.000]	[0.071]	[0.142]
DEPR	−0.134	−0.041	−0.139	−0.049	−0.058
	[0.001]	[0.003]	[0.000]	[0.011]	[0.041]
WWII	−0.042	−0.012	−0.271	−0.273	−0.025
	[0.305]	[0.062]	[0.001]	[0.144]	[0.473]
OS1	−0.018	−0.002	0.047	0.055	0.038
	[0.597]	[0.621]	[0.000]	[0.067]	[0.081]
OS2	0.031	−0.003	0.033	0.040	−0.006
	[0.535]	[0.812]	[0.006]	[0.000]	[0.775]

Notes: δ is the coefficient of the in-mean effect. γ captures the effect of lagged output growth on its conditional variance. WWI and WWII denote the two World Wars. DEPR is the Great Depression. OS1 and OS2 are the two oil shocks. Probabilities are given in brackets.

Table 6. AR-GARCH-M-L estimation for subsamples.

	GERMANY		UK		FRANCE		ITALY		SWEDEN	
PERIODS	δ	γ	δ	γ	δ	γ	δ	γ	δ	γ
start-1970	**2.294**	**−0.037**	**6.136**	**−0.007**	0.614	**−0.026**	**2.342**	−0.025	−1.282	**−0.015**
	[0.010]	[0.000]	[0.068]	[0.042]	[0.599]	[0.038]	[0.000]	[0.004]	[0.479]	[0.000]
1920-1999	**4.000**	**−0.029**	**3.392**	−0.003	0.406	**−0.062**	**2.409**	**−0.029**	**13.352**	0.013
	[0.000]	[0.000]	[0.012]	[0.426]	[0.483]	[0.000]	[0.001]	[0.015]	[0.000]	[0.510]
1946-1999	**1.607**	**−0.026**	–	–	**3.803**	**−0.028**	1.583	**−0.061**	–	–
	[0.000]	[0.105]			[0.098]	[0.009]	[0.557]	[0.000]		

Notes: δ is the coefficient of the in-mean effect. γ captures the effect of lagged output growth. Probabilities are given in brackets. No GARCH effects were found for the sample period 1946-99 in the UK and Sweden.

an allowance has been made for the effect of inflation on growth (second column) and its associated uncertainty (third column).[6] Hence, Panel A includes in total three different specifications. In Panel B we report estimates of two specifications for the in-mean-level model. These are variations of the model presented in the main part of the paper (Section 4). The first of these modifications accounts for asymmetric effects (as captured by the ζ coefficient)[7] and the other for the effect of inflation on growth (as captured by the ϕ_π coefficient). In Panel C we report evidence on the effect of growth on inflation on the basis of a GARCH model of inflation.

The results of the alternative specifications for the five countries lead to the following conclusions. First, according to Panel A (first column), the in-mean coefficient is statistically insignificant only for France and Sweden, a result confirming the empirical analysis of the previous section. Second, this result holds for two alternative specifications that include the impact of inflation on growth in both the in-mean model (second column of Panel A) and the in-mean-level model (first column of Panel B). Third, the impact of inflation on growth uncertainty (third column of Panel A) is in four out of five countries negative and significant. In addition, according to panel C, growth has a positive impact on inflation. Hence, combining these two effects, we see that growth has a negative impact on its uncertainty via the inflation channel. Fourth, according to the regression estimates reported in the third column of Panel A, the result referred to in the first conclusion regarding the effect of growth uncertainty on growth stands. Fifth, when asymmetries are taken into consideration (second column of Panel B), the results regarding the bidirectional causality between growth and its associated uncertainty stand in all countries. The asymmetry coefficient is significant in only two cases. All in all, the analysis of this subsection confirms the conclusions of the previous section regarding the bi-directional causality between growth and its associated uncertainty.

6.2. *Dummy variable and subperiod analysis*

The previous analysis established two important results regarding the relationship between economic growth and its variability. As our long sample period encompasses two World Wars, the Great Depression and two oil shocks, it is sensible to examine the sensitivity of our conclusions to these important events. To control for these events, we proceed in two ways.[8] First, we estimate AR-GARCH-M-L models as above for the full sample period including World War, Great Depression and oil shock dummies in both the output growth and conditional variance equations (see Table 5).[9] Second, we estimate similar models for subperiods that control for one or more of these events. For example, the subperiod from the start of the sample to 1970 controls for the oil shocks; the period 1920–1999 controls for the first World War, and the period 1946–1999 controls for the two World Wars and the Great Depression (see Table 6). These models that refer to subperiods were also estimated with the inclusion of dummy variables (results not reported). Tables 5 and 6 report the estimated coefficients of γ and δ. In most cases, the results confirm our earlier conclusions regarding the bidirectional relationship between output growth and output uncertainty that applies in most countries.

7. Conclusions

We have used long time series of annual data that span over the 20th century and a part of the 19th century for five European countries to test for the relationship between output growth and its variability. Our empirical approach employs a GARCH model that allows lagged growth to appear in the conditional variance equation. Various alternative specifications are estimated in order to confirm the robustness of our results. These specifications allow for asymmetric effects of shocks on uncertainty and effects of growth on its uncertainty via the inflation channel. In addition, our models are estimated for various periods in order to establish robustness to major events such as oil shocks, world wars, and the Great Depression. We derive two main conclusions. First, we find evidence supporting Black (1987) and Blackburn (1999) in three of the five countries considered. Second, we find strong evidence in favour of a relationship between growth and its variability which, in most of the cases considered, is bi-directional (with the causal effect of the former on the latter being negative). These results support the recent emphasis on the treatment of the variability of the business cycle in tandem with the theory of economic growth. Furthermore, our evidence for bi-directional causality between growth and its variability with mixed signs concurs with the predictions of theoretical models by Blackburn and Galinder (2003) and Blackburn and Pelloni (2004) for either type of correlation (positive or negative) between the two variables depending on the type of learning and the type of shocks hitting the economy.

Acknowledgements

We are grateful to two anonymous referees for their helpful comments and suggestions. We also thank Keith Blackburn and Marika Karanassou for useful comments on an earlier draft. The usual disclaimer applies.

Notes

1. h_t is positive with probability one and is a measurable function of Σ_{t-1}, which in turn is the sigma-algebra generated by $\{\varepsilon_{t-1}, \varepsilon_{t-2}, \ldots\}$.
2. The sample period for France, Germany, Italy, Sweden and the UK starts in 1815, 1850, 1861, 1861 and 1860, respectively. In all countries, the sample period ends in 1999.
3. The autoregressive model of Germany includes two dummy variables: the first dummy captures Germany's separation in 1946 and the second the reunification of 1990.
4. An alternative channel regarding the effect of growth on growth uncertainty works via inflation uncertainty. Growth raises inflation and inflation uncertainty, which reduces growth uncertainty (the Taylor effect). We do not attempt to test for this channel and hence estimate a bivariate GARCH-M-L model, as our relatively short sample size is likely not to produce reliable results.
5. Inflation is measured by the annual growth in the Consumer Price Index (CPI).
6. That is, in equation (1) we add the term: $\phi_\pi \pi_{t-l}$ where π_{t-l} denotes the inflation at time $t - l$. Similarly, in equation (2) we add the term: $\gamma_\pi \pi_{t-l}$.
7. That is, in equation (2) we add the term: $\zeta D_{t-1}\varepsilon_{t-1}^2$ where $D_{t-1} = 1$ if $\varepsilon_{t-1} < 0$ and 0 otherwise.
8. An alternative approach to account for structural breaks is the regime-switching model proposed by Hamilton (1989) and used by Bhar and Hamori (2003) to model the volatility process in the growth rate of Japanese real GDP.
9. The years of the Great Depression differ among countries and are taken from Romer (2007). They are 1930–1932 for France, the UK and Sweden, 1928–1932 for Germany, and 1929–1933 for Italy.

References

Ball, Laurence, N., Gregory Mankiw, and David Romer. 1988. The new Keynesian economics and the output-inflation trade-off. *Brookings Papers on Economic Activity* 1: 1–65.

Bernanke, Ben. 1983. Irreversibility, uncertainty, and cyclical Investment. *Quarterly Journal of Economics* 98, no. 1: 85–106.

Bhar, Ramaprasad, and Shigeyuki Hamori. 2003. Alternative characterisation of the volatility in the growth rate of real GDP. *Japan and the World Economy* 15, no. 2: 223–31.

Black, Fischer. 1987. *Business Cycles and Equilibrium*. New York: Basil Blackwell.

Blackburn, Keith. 1999. Can stabilisation policy reduce long-run growth? *Economic Journal* 109, no. 1: 67–77.

Blackburn, Keith, and Ragchaasuren Galinder. 2003. Growth, volatility and Learning. *Economics Letters* 79, no. 3: 417–21.

Blackburn, Keith, and Alessandra Pelloni. 2004. On the relationship between growth and volatility. *Economics Letters* 83, no. 1: 123–7.

Blackburn, Keith, and Alessandra Pelloni. 2005. Growth, cycles and stabilisation policy. *Oxford Economic Papers* 57, no. 2: 262–82.

Bollerslev, Tim, and Jeffrey M. Wooldridge. 1992. Quasi-maximum likelihood estimation and inference in dynamic models with time varying covariances. *Econometric Reviews* 11, no. 2: 143–72.

Briault, C. 1995. The costs of inflation. *Bank of England Quarterly Bulletin* February: 33–45.

Caporale, Tony, and Barbara McKiernan. 1996. The relationship between output variability and growth: evidence from post war UK data. *Scottish Journal of Political Economy* 43, no. 2: 229–36.

Caporale, Tony, and Barbara McKiernan. 1998. The Fischer Black hypothesis: some time-series evidence. *Southern Economic Journal* 64, no. 3: 765–71.

Fountas, Stilianos, Menelaos Karanasos, and Jinki Kim. 2002. Inflation and output growth uncertainty and their relationship with inflation and output growth. *Economics Letters* 75, no. 3: 293–301.

Fountas, Stilianos, Menelaos Karanasos, and Alfonso Mendoza. 2004. Output variability and economic growth: the Japanese case. *Bulletin of Economic Research* 56, no. 4: 353–63.

Friedman, Milton. 1968. The role of monetary policy. *American Economic Review* 58, no. 1: 1–17.

Grier, Kevin, Olan T. Henry, Nilss Olekalns, and Kalvinder Shields. 2004. The asymmetric effects of uncertainty on inflation and output growth. *Journal of Applied Econometrics* 19, no. 5: 551–65.

Grier, Kevin, and Mark Perry. 2000. The effects of real and nominal uncertainty on inflation and output growth: Some GARCH-M evidence. *Journal of Applied Econometrics* 15, no. 1: 45–58.

Grier, Kevin, and Gordon Tullock. 1989. An empirical analysis of cross-national economic growth: 1951-1980. *Journal of Monetary Economics* 24, no. 2: 259–76.

Grinols, Earl, and Stephen J. Turnovsky. 1998. Risk, optimal government finance, and monetary policies in a growing economy. *Economica* 65, no. 259: 401–27.

Hamilton, James. 1989. A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica* 57, no. 2: 357–84.

Henry, Olan, and Nilss Olekalns. 2002. The effect of recessions on the relationship between output variability and growth. *Southern Economic Journal* 68, no. 1: 683–92.

Keynes, John, M. 1936. *The General Theory of Employment, Interest, and Money*. London: Macmillan.

King, Robert, Charles Plosser, and Sergio Rebelo. 1988. Production, growth, and business cycles: II. New directions. *Journal of Monetary Economics* 21, no. (2-3): 309–41.

Kneller, Richard, and Garry Young. 2001. Business cycle volatility, uncertainty, and long-run growth. *Manchester School* 69, no. 5: 534–52.

Kormendi, Roger, and Philip Meguire. 1985. Macroeconomic determinants of growth: cross-country evidence. *Journal of Monetary Economics* 16, no. 2: 141–63.

Kydland, Finn, and Edward Prescott. 1982. Time to build and aggregate Fluctuations. *Econometrica* 50, no. 6: 1345–70.

Long, John, and Charles Plosser. 1983. Real business cycles. *Journal of Political Economy* 91, no. 1: 39–69.

McConnell, Margaret, and Gabriel Perez-Quiros. 2000. Output fluctuations in the United States: What has changed since the early 1980s? *American Economic Review* 90, no. 5: 1464–76.

Mirman, Leonard. 1971. Uncertainty and optimal consumption decisions. *Econometrica* 39, no. 1: 179–85.

Mitchell, Robert. 1998. *International Historical Statistics: Europe*. Macmillan.

Pindyck, Robert. 1991. Irreversibility, uncertainty, and investment. *Journal of Economic Literature* 29, no. 3: 1110–48.

Ramey, Garey, and Valerie Ramey. 1991. Technology commitment and the cost of economic fluctuations. NBER Working Paper No. 3755.

Ramey, Garey, and Valerie Ramey. 1995. Cross-country evidence on the link between volatility and growth. *American Economic Review* 85, no. 5: 1138–51.

Romer, Christina. 2007. Great depression. In *Encyclopaedia Britannica*. Encyclopaedia Britannica, Incorporated.

Sandmo, A. 1970. The effect of uncertainty on saving decisions. *Review of Economic Studies* 37, no. 3: 353–60.

Smith, William, T. 1996. Taxes, uncertainty and long-term growth. *European Economic Review* 40, no. 8: 1647–64.

Speight, Alan. 1999. UK output variability and growth: some further evidence. *Scottish Journal of Political Economy* 46, no. 2: 175–84.

Stock, James, and Mark Watson. 2002. Has the business cycle changed and why? National Bureau of Economic Research Working Paper no. 9127, September.

Turnovsky, Stephen J. 2000. Government policy in a stochastic growth model with elastic labor supply. *Journal of Public Economic Theory* 2, no. 4: 389–433.

Turnovsky, Stephen J., and Pradip Chattopadhyay. 2003. Volatility and growth in developing economies: some numerical results and empirical evidence. *Journal of International Economics* 59, no. 2: 267–95.

Woodford, Michael. 1990. Learning to believe in sunspots. *Econometrica* 58, no. 2: 277–307.

Zarnowitz, Victor, and Geoffrey Moore. 1986. Major changes in cyclical Behaviour. In *The American Business Cycle*, ed. Robert Gordon. Chicago: University of Chicago Press.