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Authors(s)	Bredin, Donal, Fountas, Stilianos
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Macroeconomic Uncertainty and Performance in the European Union and Implications for the Objectives of Monetary Policy

Don Bredin
University College Dublin[*]

Stilianos Fountas
University of Macedonia

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Abstract

We use a very general bivariate GARCH-M model and EU monthly data covering the 1962-2003 period to test for the impact of real (output growth) and nominal (inflation) macroeconomic uncertainty on inflation and output growth. Our evidence supports a number of important conclusions. First, in the majority of countries uncertainty regarding the output growth rate is related to the average growth rate and the effect in most countries is negative. Second, contrary to expectations, inflation uncertainty in most cases improves the output growth performance of an economy. Third, inflation and output uncertainty have a mixed effect on inflation. These results imply that macroeconomic uncertainty may even improve macroeconomic performance. The first two results also imply that the ECB should focus its monetary policy strategy on stabilising output growth rather than inflation.

Keywords: Inflation, Output growth, Macroeconomic Uncertainty, Monetary policy, GARCH models
JEL Classification: C22, C52, E31, E52

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[*] Address for correspondence: Don Bredin, Department of Banking & Finance, Graduate School of Business, University College Dublin, Blackrock, Dublin 4, Ireland; e-mail: don.bredin@ucd.ie; Tel: +353 1-716-8833; fax: +353-1-283-5482. The authors would like to thank Olan Henry for helpful discussions on the methodology. Any errors are our own responsibility.

1 Introduction

Macroeconomists have dedicated a great volume of research efforts to the theoretical and empirical analysis of the welfare costs of inflation. At the policy level, the recent emphasis on price stability among the world's major Central Banks, including the European Central Bank (ECB), is predicated on the assumed adverse impact of inflation on economic efficiency and growth[1]. Considerable ambiguity surrounds the impact of the average rate of inflation on the rate of economic growth at the theoretical level. The issue is also complicated by the fact that the impact of inflation on output growth may take place indirectly, via the inflation uncertainty channel. Friedman (1977) in a much publicised argument claims that a rise in the average rate of inflation leads to more uncertainty about the future rate of inflation, it distorts the effectiveness of the price mechanism in allocating resources efficiently, and thus it creates economic inefficiency and a lower growth rate of output. Moreover, inflation uncertainty by affecting interest rates also impacts on the intertemporal allocation of resources. Hence, a comprehensive empirical study that tests for the real effects of inflation should control for the impact of inflation uncertainty on output. The positive correlation between inflation and inflation uncertainty reported in empirical studies can also arise from a positive causal effect of inflation uncertainty on inflation. Cukierman and Meltzer (1986) provide a theoretical model that explains such a causal effect. In the presence of more inflation uncertainty, less conservative central bankers have an incentive to surprise the public and generate unanticipated inflation, hoping for output gains.

The development of Generalised Autoregressive Conditional Heteroskedasticity (GARCH) techniques allows the measurement of inflation uncertainty by the conditional variance of the inflation series and more accurate testing of the two parts of the Friedman hypothesis (e.g., Baillie et al., 1996, Grier and Perry, 1998, 2000; Fountas et al., 2004). These techniques represent a superior approach to early attempts to measure uncertainty by the moving standard deviation or variance of the inflation series. This superiority arises from the possibility of allowing a separation between anticipated and unanticipated changes (the source of uncertainty) in inflation. By using the variance or standard deviation, the early studies measured inflation variability, not uncertainty.

Both real uncertainty (arising from the variability in output growth) and nominal (or inflation) uncertainty may affect the rate of output growth[2].

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[1] Lucas (2000) estimates that a 10% inflation rate leads to a reduction in US real GNP by 3%.

[2] Our objective is not to examine the determinants of changes in inflation or output growth uncertainty. Moreno (2004) focuses on the causes of a sharp reduction in US inflation uncertainty over the last twenty years.

Macroeconomic analysis before the 1980s treated the theories of the business cycle (and its variability) and economic growth independently. However, this assumption of independence between the variability of the business cycle and economic growth is questionable, as indicated by several theories (Bernanke, 1983; Black, 1987; Pindyck, 1991; Blackburn and Pelloni, 2004, 2006). Empirical evidence has recently emerged that corroborates these theoretical findings (Caporale and McKiernan, 1996, 1998; Grier and Perry, 2000; Henry and Olekalns, 2002; Fountas et al., 2002; Fountas et al., 2004b). This empirical evidence, though, is still scant and it primarily applies to UK, US and Japanese data. A robust set of evidence in support of the relationship between output growth and its variability would provide a solid ground for the development of macroeconomic models that consider such a relationship as a fundamental building block.

Economic theory postulates various causality relationships between macroeconomic uncertainty (nominal and real) and macroeconomic performance (the rate of inflation and the rate of output growth). Including the relationships discussed above, there are twelve causality relationships among the above four variables. The empirical evidence on many of these relationships remains scant or nonexistent, as pertains, in particular, to international data in industrialized economies. The lack of a comprehensive study of the empirical relationships among the above four variables represents the motivation for the present study.

There are various methodological approaches one may choose from to investigate the empirical relationship between macroeconomic uncertainty and performance. First, one may use a univariate GARCH framework where in the first step the conditional variances of inflation and output growth are estimated independently from each other and in the second step Granger causality tests are performed to examine the relationships between pairs of variables. Alternatively, a simultaneous approach can be adopted where a bivariate GARCH-in-mean (GARCH-M) model is estimated to provide estimates of the conditional variances and at the same time test for the impact of uncertainty on macroeconomic performance (Grier and Perry, 2000; Grier et al. 2004). Grier et al. (2004) test for and reject the diagonality and symmetry covariance restrictions of Grier and Perry (2000) and obtain quite different results for the US economy.

In this paper, the above issues are analysed empirically with the use of a bivariate GARCH-M model for the European Union (EU) countries, including all Eurozone countries. This model is similar to the one employed by Grier et al. (2004) and is applied to monthly data from 1962 to 2003. Our estimated model is used to generate the conditional variances of inflation and output growth as proxies of inflation and output growth uncertainty, respectively, and to test for the effect of real (output growth) and nominal (inflation) uncertainty on inflation and output growth. In total, four hypotheses are tested. The focus on a small set of hypotheses is chosen in order to concentrate our interest on a set of hypotheses that have considerable theoretical foundations.

Our results are likely to have important implications for policymaking. In particular, ECB's objective of maintaining a low inflation rate under 2% is predicated on the adverse effects of inflation on economic efficiency and growth. Some of these effects, as Friedman (1977) has argued, take place via changes in inflation uncertainty. It is therefore important to test for whether inflation uncertainty is indeed costly. Moreover, the emphasis on stabilising inflation may be associated with large variability in output growth and hence more uncertainty regarding the growth rate (the so-called Taylor effect predicting a trade-off between variability in inflation and output growth). This increasing output uncertainty may be associated with less output growth, thus making the empirical testing of such a hypothesis an interesting task. Our results on the effects of nominal and real uncertainty on output growth will therefore have important implications for the choice of inflation versus output stabilisation on the part of the ECB. Fountas et al. (2004a) have tested for the impact of inflation uncertainty on output growth in six European countries. They find that, in the overwhelming majority of cases, inflation uncertainty does not reduce output growth. However, their study uses the two-step approach and does not take into consideration the interdependence between inflation and output uncertainty in the estimation procedure.

The paper is outlined as follows. Section 2 summarises the theories tested in the paper. Section 3 presents the empirical literature to date. Section 4 outlines our econometric model and section 5 reports and discusses our results and relates them to some recent studies. Finally, Section 6 offers our main conclusions and draws some policy implications.

2 Theory

2.1 The impact of inflation uncertainty on growth

In his Nobel lecture, Friedman (1977) outlined an informal argument regarding the real effects of inflation. Friedman's point comes in two parts: In the first leg of the Friedman hypothesis, an increase in inflation may induce an erratic policy response by the monetary authority and therefore lead to more uncertainty about the future rate of inflation. In the second leg of the Friedman hypothesis, the increasing uncertainty about inflation distorts the effectiveness of the price mechanism in allocating resources efficiently, thus leading to negative output effects. Friedman's argument represents one of the few existing arguments on the rationalisation of the welfare effects of inflation.

The second part of Friedman's hypothesis predicts that increased inflation uncertainty would increase the observed rates of unanticipated inflation and hence will be associated with the costs of unanticipated inflation.[3] Such costs arise from the effect of inflation uncertainty on both the intertemporal and intratemporal allocation of resources. Nominal uncertainty affects interest rates (the inflation premium) and hence all decisions relating to the intertemporal allocation of resources. In a world of nominal rigidities, inflation uncertainty also affects the real cost of the factors of production and the relative prices of final goods, and therefore, the intratemporal allocation of resources. The effect of inflation uncertainty on output growth has been addressed formally by Dotsey and Sarte (2000). In a cash-in-advance model that allows for precautionary savings and risk aversion, they show that more inflation uncertainty can have a positive output growth effect. According to the authors' argument, an increase in the variability of monetary growth, and therefore inflation, makes the return to money balances more uncertain and leads to a fall in the demand for real money balances and consumption. Hence, agents increase precautionary savings, and the pool of funds available to finance investment increases. This result is analogous to the literature's finding that fiscal policy uncertainty is conducive to growth by encouraging precautionary savings.

2.2 The impact of inflation uncertainty on inflation

The opposite direction of causality to that examined by Friedman in the inflation/inflation uncertainty relationship has also been addressed by the theoretical literature. This literature examines the impact of a change in inflation uncertainty on the average rate of inflation. Cukierman and Meltzer (1986) employ a Barro-Gordon model, where agents face uncertainty about the rate of monetary growth and therefore, inflation. In the presence of this uncertainty, the policymaker applies an expansionary monetary policy in order to surprise the agents and enjoy output gains. This argument implies a positive causal effect from inflation uncertainty to inflation and has been dubbed by Grier and Perry (1998) the Cukierman-Meltzer hypothesis. Holland (1995) has supplied a different argument based on the stabilisation motive of the monetary authority, the so-called "stabilising Fed hypothesis". He claims that, as inflation uncertainty rises due to increasing inflation, the monetary authority responds by contracting money supply growth, in order to eliminate inflation uncertainty and the associated negative welfare effects.

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[3] This part draws on Huizinga (1993).

Hence, Holland's argument supports the opposite sign in the causal relationship, i.e., a negative causal effect of inflation uncertainty on inflation. The theoretical ambiguity surrounding this causal relationship necessitates an empirical investigation of the sign of the effect.

2.3 The impact of output uncertainty on inflation and output growth

The effect of output growth uncertainty on inflation has been examined by Devereux (1989) who extends the Barro-Gordon model by introducing wage indexation endogenously. He considers the impact of an exogenous increase in real (output) uncertainty on the degree of wage indexation and the optimal inflation rate delivered by the policymaker. He shows that more real uncertainty reduces the optimal amount of wage indexation and induces the policymaker to engineer more inflation surprises in order to obtain favourable real effects. The prediction of Devereux's theory regarding the positive causal effect of output uncertainty on the inflation rate is borne out also in a recent paper by Cukierman and Gerlach (2003). They show that, even if policymakers target the potential rate of unemployment, inflation bias a la Barro and Gordon obtains in the presence of more uncertainty about the level of output. This result hinges on the assumption that Central banks are more sensitive to employment below than above its normal level. From a theoretical point of view, it is possible for more output uncertainty to reduce inflation. Higher output uncertainty reduces inflation uncertainty[4] and, therefore, the rate of inflation, according to the Cukierman-Meltzer hypothesis. Hence, the testable implication of these two effects combined is that more output growth uncertainty should lead to a lower rate of inflation.

The effect of output uncertainty on output growth has received considerable attention in the theoretical macroeconomic literature. However, there is a lack of consensus among macroeconomists on the direction of this effect. Macroeconomic theory offers three possible scenarios regarding the impact of output variability on output growth. 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. For example, 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 may be traced back to Keynes (1936), who argued that entrepreneurs, when estimating the

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[4] The negative association between inflation and output variability is known in the literature as the Taylor effect.

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, according to the theoretical literature, a positive effect of real uncertainty on output growth can be justified by a number of economic theories. For example, according to Black (1987), 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 obtain in empirical studies utilizing low-frequency data.

A number of recent studies based on endogenous growth caused by learning-by-doing also examine the relationship between output variability and growth. Blackburn (1999) shows that business cycle volatility raises the long-run growth of the economy. Blackburn and Pelloni (2004, 2006) examine the correlation between average output growth and its variability in an endogenous growth setup. Blackburn and Pelloni (2004) in a stochastic monetary growth model show that the correlation between output 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 (2006) 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.

All the theories presented in section 2 are summarised in the following Table.

Testable hypotheses-Theories	Sign of the effect
1) Inflation uncertainty affects inflation.	
Cukierman-Meltzer (1986)	+
Holland (1995)	-
2) Inflation uncertainty affects output growth.	
Friedman (1977)	-
Dotsey and Sarte (2000)	+
3) Output uncertainty affects inflation.	
Devereux (1989), Cukierman-Gerlach (2003)	+
Taylor effect and Cukierman-Meltzer (1986)	-
4) Output uncertainty affects output growth.	
Business cycle models	zero
Keynes (1936), Bernanke (1983), Woodford (1990), Pindyck (1991), Ramey and Ramey (1991)	-
Black (1987), Blackburn (1999)	+

3 The empirical evidence

Early empirical studies on the relationship between inflation and its uncertainty used the variance (or standard deviation) as a measure of uncertainty and hence measured inflation variability as opposed to uncertainty. Following the development of the ARCH approach by Engle (1982), several studies measured inflation uncertainty using the conditional variance of the inflation process. The majority of these studies tests for the impact of inflation on inflation uncertainty. The evidence on the impact of inflation uncertainty on growth is more limited and is summarised in Holland (1993). GARCH studies of this issue that represent a more accurate test of the hypothesis that inflation uncertainty has negative welfare effects are mostly based on US data (e.g., Coulson and Robins, 1985; Jansen, 1989; Grier and Perry, 2000, Grier et al., 2004, Elder, 2004). Exceptions are the studies of Fountas et al. (2002) who focus on Japan, Fountas and Karanasos (2004) who use G7 data, and Fountas et al. (2004a) who focus on six European countries. The evidence is rather mixed. Grier and Perry (2000) and Grier et al. (2004) find evidence for a negative effect for the US. In contrast, Coulson and Robins (1985) and Jansen (1989) find evidence for a positive and zero effect, respectively. Fountas et al. (2002) find that inflation uncertainty is costly in Japan. Fountas et al (2004a) and Fountas and Karanasos (2004) find mixed evidence using a two-step approach that combines the estimation of a GARCH model with the implementation of Granger-causality tests.

The causal impact of inflation uncertainty on inflation is tested empirically using the GARCH approach in Baillie et al (1996), Grier and Perry

(1998, 2000), Grier et al. (2004) and Fountas et al (2004a). Grier and Perry (2000) and Grier et al. (2004) use only US data, whereas the rest of the studies use international data. In general, the evidence is mixed. Baillie et al (1996) find evidence supporting the link between the two variables for the UK and some high-inflation countries, whereas Grier and Perry (1998) in their G7 study find evidence in favour of the Cukierman-Meltzer hypothesis for some countries and in favour of the Holland hypothesis for other countries. Fountas et al. (2004a) also obtain mixed evidence. Finally, Grier and Perry (2000) and Grier et al. (2004) find evidence for a zero and negative effect of inflation uncertainty on inflation in the US, respectively.

The empirical evidence to date on the association between output variability and output growth is mixed. Early studies employed cross section (Kormendi and Meguire, 1985) or pooled data (Grier and Tullock, 1989) and find evidence for a positive association. Ramey and Ramey (1995) use a panel of 92 countries and a sample of OECD countries (for the 1960-1985 period) and find strong evidence that countries with higher output variability have lower growth. A similar result is obtained by Zarnowitz and Moore (1986), who divide the 1903-1981 period into 6 subperiods and compare high and low growth periods in terms of output growth variability (measured by the standard deviation of the annual growth rate in real GNP). Empirical evidence on the causal effect of output growth uncertainty (as opposed to variability) on output growth has appeared only recently. Caporale and McKiernan (1996, 1998) obtain evidence of a positive causal effect using UK and US data, respectively, supporting, among others, the Black hypothesis. Speight (1999) and Fountas et al. (2004b) find no relationship between output growth uncertainty and output growth in the UK and Japan, respectively. Henry and Olekalns (2002) find evidence of a negative effect in the US. In contrast, Grier et al. (2004) finds US evidence for the Black hypothesis. Fountas and Karanasos (2004) obtain significant evidence for the same hypothesis in most of the G7. Finally, the available empirical evidence on the Devereux hypothesis is rather limited. Grier and Perry (2000) and Grier et al. (2004) find no evidence using US data and Fountas and Karanasos (2004) find supportive evidence for Italy and the UK.

4 Econometric Methodology

In equation (1) below we show the approach used to model both output growth (y_t) and inflation (π_t) simultaneously. A VARMA (vector autoregressive moving average) GARCH-M model is adopted (see Grier et al., 2004). This approach simultaneously estimates equations for both inflation and output growth and takes into account the conditional standard deviations as explanatory variables. The standard information criteria, Schwartz

(SBC) and Akaike (AIC), will be used to test for the lag length for both p and q.

$$Y_t = \mu + \sum_{i=1}^{p} \Gamma_i Y_{t-i} + \Psi \sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \epsilon_{t-j} + \epsilon_t \quad \textit{where } \epsilon_t \sim (0, H_t) \qquad (1)$$

$$H_t = \begin{pmatrix} h_{y,t} & h_{y\pi,t} \\ h_{\pi y,t} & h_{\pi,t} \end{pmatrix}$$

$$\textit{where} \quad Y_t = \begin{pmatrix} y_t \\ \pi_t \end{pmatrix}; \epsilon_t = \begin{pmatrix} \epsilon_{y,t} \\ \epsilon_{\pi,t} \end{pmatrix}; \sqrt{h_t} = \begin{pmatrix} \sqrt{h_{y,t}} \\ \sqrt{h_{\pi,t}} \end{pmatrix}; \mu = \begin{pmatrix} \mu_y \\ \mu_\pi \end{pmatrix}$$

$$\Gamma_i = \begin{pmatrix} \Gamma_{11}^{(i)} & \Gamma_{12}^{(i)} \\ \Gamma_{21}^{(i)} & \Gamma_{22}^{(i)} \end{pmatrix}; \Psi = \begin{pmatrix} \Psi_{11} & \Psi_{12} \\ \Psi_{21} & \Psi_{22} \end{pmatrix}; \Theta_j = \begin{pmatrix} \Theta_{11}^{(j)} & \Theta_{12}^{(j)} \\ \Theta_{21}^{(j)} & \Theta_{22}^{(j)} \end{pmatrix}$$

where $\epsilon_t \mid \Omega_t \sim (0, H_t)$, and Ω_t is the information set available at time t. The model will be estimated using maximum likelihood subject to H_t, the conditional covariance matrix, being positive definite.

The GARCH-M approach is adopted in order to take account of the possible influence of uncertainty about output growth and inflation on average growth and inflation. The effects of uncertainty on inflation and output growth are captured by the elements of matrix Ψ. Ψ_{11} and Ψ_{21} test for the impact of output growth uncertainty on output growth and the inflation rate, respectively. Positive and significant values for these two coefficients would lend support to the Black and Devereux hypotheses, respectively. Ψ_{12} and Ψ_{22} test for the impact of inflation uncertainty on output growth and the inflation rate, respectively. Respective (significant) negative and positive values for these two coefficients would lend support to the Friedman and Cukierman-Meltzer hypotheses, respectively.

An important distinction between the approach adopted here and the vast majority of previous studies is that the present model takes account of possible non-diagonality and asymmetry in the covariance structures. In this sense, the model follows Grier et al. (2004) who test for, rather than assume, diagonality and symmetry using US data. The conditional covariance expressed in quadratic form to ensure positive definiteness can be written as

$$H_t = C_0^{*'} C_0^* + B_{11}^{*'} H_{t-1} B_{11}^* + A_{11}^{*'} \epsilon_{t-1} \epsilon_{t-1}' A_{11}^* + D_{11}^{*'} \xi_{t-1} \xi_{t-1}' D_{11}^* \qquad (2)$$

$$where \quad C_0^* = \begin{pmatrix} c_{11}^* & c_{12}^* \\ 0 & c_{22}^* \end{pmatrix}; B_{11}^* = \begin{pmatrix} \beta_{11}^* & \beta_{12}^* \\ \beta_{21}^* & \beta_{22}^* \end{pmatrix}; A_{11}^* = \begin{pmatrix} \alpha_{11}^* & \alpha_{12}^* \\ \alpha_{21}^* & \alpha_{22}^* \end{pmatrix};$$

$$D_{11}^* = \begin{pmatrix} \delta_{11}^* & \delta_{12}^* \\ \delta_{21}^* & \delta_{22}^* \end{pmatrix}; \xi_t^2 = \begin{pmatrix} \xi_{y,t}^2 \\ \xi_{\pi,t}^2 \end{pmatrix}$$

Equation (2) is the standard BEKK model augmented with the final term to take account of possible asymmetry of the impact of shocks on the conditional variances. The model is rich enough to allow us to answer the following questions. First, does the volatility in one series spillover into the volatility of another series? In equation (2), such a volatility spillover would imply a nondiagonal covariance process. In other words, it requires that the off-diagonal elements of the A_{11}^*, B_{11}^* and D_{11}^* matrices be jointly significant. Therefore, assuming a priori diagonality may lead to potentially serious problems as persistence in the conditional variance may be ignored. Second, does *bad news* lead to greater volatility than *good news*? Specifically, bad news in terms of inflation (output growth) taken as higher (lower) than expected inflation (output growth) will correspond to a positive (negative) residual. We set the model up in such a way that $\xi_{\pi,t}$ be the $\max(\epsilon_{\pi,t}, 0)$ which is the positive innovations regarding inflation or *bad news*. The $\xi_{y,t}$ is the $\min(\epsilon_{y,t}, 0)$ which is the negative innovations regarding output growth or *bad news*. If there were no asymmetry present, then the coefficient matrix D_{11}^* would not be statistically significant and equation (2) would be the symmetric *BEKK* model (Engle and Kroner, 1995).

5 Data and results

5.1 Data

We use monthly data on the Industrial Production Index (IPI) and a price index (PI), like the Consumer Price Index (CPI) or the Producer Price Index (PPI), as proxies for output and the price level, respectively[5]. The data refer to fourteen European Union countries (the EU-15 minus Luxembourg), cover the period 1962-2003 and are taken from the International Financial Statistics (IMF). The precise sample period and measure of the price index in each country is given in Table 1. We measure inflation by

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[5] The IPI data are seasonally adjusted and are subject to some limitations, e.g., the share of industrial production in GDP is known to be falling over time. Nevertheless, the availability of production data at a high frequency allows to proxy uncertainty by the conditional variance of shocks to the rate of growth of industrial production.

the annualized monthly difference of the logarithm of the price index PI [$\pi_t = \log(\frac{\text{PI}_t}{\text{PI}_{t-1}}) \times 1200$] and real output growth by the annualized monthly difference in the logarithm of the IPI [$y_t = \log(\frac{\text{IPI}_t}{\text{IPI}_{t-1}}) \times 1200$]. Summary statistics on inflation and output growth are given in Table 1. We first test for the stationarity properties of our data using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results of these tests indicate that we can treat the inflation rate and the growth rate of industrial production in each country as stationary processes[6].

5.2 Results

We estimate the model of equations (1) and (2) using the quasi-maximum likelihood estimation proposed by Bollerslev and Wooldridge (1992). Following the estimation, we test for various nested models and report the results of these specification tests in Table 2. On the basis of these results we conclude the following. First, the statistical significance of the A^*_{11}, B^*_{11} and D^*_{11} matrices provides evidence for heteroskedastic conditional variances. The results of Table 2 indicate that these three matrices are jointly significant at the 1% level. Second, the joint statistical significance of the off-diagonal elements of the same three matrices indicates that lagged conditional variances and lagged squared innovations in inflation (output growth), tend to affect the conditional variances of output growth (inflation). More specifically, the joint significance of the off-diagonal elements of the A^*_{11} and D^*_{11} matrices at 1% implies that shocks to inflation or output growth tend to influence with a lag uncertainty about the other macroeconomic variable, i.e., output growth or inflation. Third, the joint significance of the elements of the D^*_{11}matrix at 1% leads us to conclude that the covariance process is asymmetric in all countries, except Belgium and Finland. Finally, the joint significance of the elements of the Ψ matrix indicates the presence of GARCH-M effects. Furthermore, we perform a number of tests to ensuse the models fit the data well. First, the values of the Ljung-Box statistics indicate the absence of serial correlation up to 4th and 12th order in the standardised and squared standardised residuals in both the inflation and output growth equations. Second, we test for the model's predictions that $\text{E}(\varepsilon^2_{it}) = h_{i,t}, i = y, \pi$, and $\text{E}(\varepsilon_{y,t}\varepsilon_{\pi,t}) = h_{y\pi,t}$. These moment-based test results reported in Table 2 show that the above conditions cannot be rejected at 5%.

We focus our attention on the statistical significance and signs of the elements of matrix Ψ in order to test for the four economic hypotheses

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[6] Results are available from the authors upon request.

presented in section 2 regarding the impact of macroeconomic uncertainty on macroeconomic performance, namely inflation and output growth. The estimates of Ψ and the associated standard errors are reported in Table 3. Our results on these hypotheses are summarised as follows. First, regarding the effect of output uncertainty on output growth, we find evidence for a negative effect in six countries and positive effect in three countries. Hence, in the majority of cases (nine of fourteen) uncertainty about the growth rate and the average growth rate are indeed related, thus supporting recent theoretical work by Blackburn and Pelloni (2004, 2006). Second, inflation uncertainty affects output growth in ten of the fourteen countries. However, in the majority of cases (nine of fourteen), inflation uncertainty tends to enhance growth, thus supporting the theory of Dotsey and Sarte (2000). In only one country (Denmark), inflation uncertainty seems to be costly. Third, quite strong evidence for Devereux hypothesis (positive effect of output uncertainty on inflation) obtains in six countries. Fourth, in the majority of cases (nine of fourteen), inflation uncertainty seems to raise inflation, as predicted by Cukierman and Meltzer (1986). On the basis of these results, we conclude that real uncertainty is quite costly in terms of loss in output growth and increase in inflation. However, nominal uncertainty does not seem to be costly in terms of lower output but quite costly in terms of higher inflation.

5.3 Discussion of results and related recent literature

Our results carry noteworthy implications for macroeconomic modeling and policymaking. Our evidence that in nine of the fourteen countries output uncertainty and output growth are related suggests that macro theorists should incorporate the analysis of output uncertainty into growth models, along the lines of recent research by Blackburn and Pelloni (2004, 2006). Moreover, in most countries of our sample where output uncertainty and growth are related, we find support for Pindyck (1991), among others, implying that output uncertainty is a negative determinant of output growth. Regarding the causal effect of output uncertainty on the inflation rate, our time series evidence provides significant support to the Devereux hypothesis in several countries. It should be emphasised that the available empirical studies on the Devereux hypothesis are rather limited and include mostly US data. To the best of our knowledge the present study and Fountas and Karanasos (2004) are the only exceptions.

Regarding the impact of nominal (inflation) uncertainty on output growth, we obtain mostly evidence against the hypothesis advanced by Friedman that uncertainty about inflation is detrimental to growth (the exception being Denmark). It is noteworthy that in the majority of the EU countries (nine of fourteen), we find evidence for a positive effect of inflation uncertainty on growth, thus supporting Dotsey and Sarte (2000) and contradicting Friedman (1977). Hence, inflation uncertainty, contrary to expectations, seems to be a contributing factor to growth. This result suggests that inflation stabilisation that is undoubtedly the primary objective of the ECB can be detrimental to growth. The relative mixity of the impact of inflation uncertainty on growth across countries squares with the lack of a consensus that has been established by the broad empirical research on this matter. This literature, summarised in Holland (1993), reports mixed results that are sensitive to factors such as the measure of inflation uncertainty, the chosen econometric methodology, the countries examined, and the sample period. As far as the effect of nominal uncertainty on inflation is concerned, our country-specific evidence on the Cukierman-Meltzer hypothesis is anticipated given that national central banks adjust their rate of money growth differently to inflation uncertainty depending on their relative preference towards inflation and output stabilisation.

Our results are likely to have important implications for policymaking. In particular, it is well known that ECB's objective of maintaining a low inflation rate is predicated on the adverse effects of inflation on economic efficiency and growth. Some of these effects, as Friedman (1977) has argued, take place via changes in inflation uncertainty. However, this study has provided evidence that inflation uncertainty is, in the majority of cases, not costly. Moreover, the ECB's emphasis on stabilising inflation may be associated with large variability in output growth and hence more uncertainty regarding the growth rate (the so-called Taylor effect predicting a trade-off between variability in inflation and output growth). We have shown above that output uncertainty is in fact associated with less output growth in several countries. Our results on the effects of nominal and real uncertainty on output growth have therefore important implications for the choice of inflation versus output stabilisation on the part of the ECB. In particular, they seem to suggest that the ECB should focus its monetary policy strategy on output rather than inflation stabilisation.

The most closely related studies to the present work are Grier and Perry (2000), Grier et al. (2004), Fountas and Karanasos (2004) and Fountas et al. (2004a). There are several differences among these studies. Grier and Perry (2000) and Grier et al. (2004) use US data and the simultaneous approach. Fountas and Karanasos (2004) and Fountas et al. (2004a) use the two-step approach and G7 and European data, respectively. Grier and Perry (2000) use monthly US data for 1948-1996. Out of the four hypotheses tested the authors find support only for the Friedman hypothesis. Grier et al. (2004) use monthly US data for the 1947-2000 period. They find evidence supporting Black, Friedman and Holland.

Fountas and Karanasos (2004) use monthly G7 data for the 1957-2000 period and find evidence for the Black hypothesis in most countries, and mixed evidence on the Friedman and Devereux hypotheses. Fountas et al. (2004a) use quarterly data from 1960-1999 on six EU countries and test for the effects of inflation uncertainty on macroeconomic performance in a two-step approach. They find considerable evidence against the Friedman hypothesis and mixed evidence on the Cukierman-Meltzer hypothesis. The present study differs in several respects from these two studies. First, our sample includes a large number of EU countries and all Eurozone countries. Second, we treat inflation and output growth uncertainty in a simultaneous framework that allows for asymmetric effects of uncertainty. It is not surprising then that some of our results, in particular those regarding the effects of macroeconomic uncertainty on output growth, are quite different.

6 Conclusions

We have used a bivariate GARCH-M model that allows for asymmetries in the EU to examine the effects of real and nominal uncertainty on average inflation and output growth. This methodology is quite general as it nests other simpler GARCH models and allows us to test for four economic theories associated with the Friedman, Cukierman-Meltzer, Black, and Devereux hypotheses. Our simultaneous approach that proxies uncertainty by the conditional variance of unanticipated shocks to the time series of inflation and output growth leads to a number of important conclusions.

First, contrary to popular belief, the uncertainty associated with the rate of inflation seems to have mostly a positive effect on output growth. In other words, Friedman's claim that inflation uncertainty can be detrimental to the economy's real sector receives very little support in our study. In addition, in none of the countries that are currently members of the Euro zone, we find evidence that inflation uncertainty is costly. Therefore, on the basis of these results, it seems that the European Central Bank has put undue emphasis on its price stability objective which may jeopardise the growth prospects of the member countries. Second, we obtain mixed evidence in favour of the Cukierman-Meltzer hypothesis. Thus, as expected, countries are anticipated to react differently to a change in the degree of uncertainty surrounding the inflation rate. Third, we find that in most countries output growth uncertainty is a negative determinant of the growth rate as predicted by Pindyck (1991), whereas in some countries the effect is positive. This result has important implications for the development of macroeconomic theory as it supports the recent emphasis in macroeconomic modelling on the simultaneous analysis of economic growth and business cycle variability. Finally, some support for the positive contribution of output uncertainty to inflation, i.e., the Devereux hypothesis, obtains. In summary, our results imply that macroeconomic uncertainty tends to influence macroeconomic performance. It is important to note though that macroeconomic uncertainty in several cases may even improve macroeconomic performance, as it is associated with a higher average output growth rate.

Our consideration of a very recent sample period and data for all EU countries and our comparison with other relevant studies that use only US or G7 data, points towards the sensitivity of the results to the methodological approach and the time period examined. Therefore, our empirical study highlights the need for further work on the causal relationships between inflation, output growth, and real and nominal uncertainty.

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Table 1: Summary Statistics

Variable	Mean	Std. Error	Min	Max
Inflation				
Austria	3.68	6.94	-28.92	58.54
Belgium	3.02	17.21	-5.29	19.70
Denmark	5.03	7.09	-30.48	51.38
Finland	5.68	7.21	-18.14	42.75
France	5.10	4.58	-4.72	22.98
Germany	2.27	4.69	-18.69	34.14
Greece	9.75	21.51	-40.68	80.03
Holland	4.02	17.45	-35.82	56.78
Ireland	4.20	10.10	-30.11	47.10
Italy	7.51	6.88	37.12	6.87
Portugal	10.03	17.34	-61.55	109.88
Sweden	5.37	39.13	-11.83	7.33
Spain	8.02	9.39	-24.14	53.34
UK	5.34	11.35	-12.56	46.80
Industrial Production				
Austria	3.77	29.87	-149.55	127.73
Belgium	2.13	30.02	-124.78	120.10
Denmark	2.07	77.72	-261.38	254.55
Finland	4.21	37.23	-155.35	183.03
France	2.68	31.10	-60.57	62.09
Germany	2.12	21.23	-114.12	136.44
Greece	4.14	99.03	-385.60	395.09
Holland	2.80	28.55	-60.09	57.94
Ireland	8.26	50.53	-110.73	92.35
Italy	3.65	28.82	-172.72	117.41
Portugal	3.96	43.72	-160.24	232.99
Sweden	2.22	34.24	-310.35	303.35
Spain	4.15	31.10	-160.87	158.87
UK	1.62	17.05	-99.05	11.53

All data is taken from the International Financial Statistics (IFS) of the IMF. Producer price index is used for Germany and the UK. Consumer Price Index is used for Austria, Belgium, Denmark, Finland, Greece, Holland, Ireland, Portugal, Spain, Sweden, France and Italy. The sample is January 1962 to December 2003, except Denmark the sample starts January 1974 and Ireland January 1976.

Table 2: Specification Tests

Austria	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Belgium	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.17]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Denmark	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Finland	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.99]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
France	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Germany	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Greece	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0 \textbf{ for all } i, j$	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**

Specification Tests (cont)

Holland	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Ireland	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta ij = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.05]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Italy	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Portugal	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Sweden	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.03]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
Spain	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**
UK	**Diagonal VARMA**	$H_0 : \Gamma^i_{12} = \Gamma^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	**[0.00]**
	No GARCH	$H_0 : \alpha_{ij} = \beta_{ij} = \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	No GARCH-M	$H_0 : \psi_{ij} = 0$ **for all** i, j	**[0.00]**
	No Asymmetry	$H_0 : \delta_{ij} = 0$ **for all** i, j	**[0.00]**
	Diagonal GARCH	$H_0 : \alpha^*_{12} = \alpha^*_{21} = \beta^*_{12} = \beta^*_{21} = \delta^*_{12} = \delta^*_{21} = 0$	**[0.00]**

Note: The marginal significance levels are in squared brackets.

Table 3: The Values of the Ψ Matrix

	Ψ_{11}	Ψ_{12}	Ψ_{21}	Ψ_{22}
Austria	0.06	0.27	0.02	0.01
	(0.04)	(0.16)	(0.00)	(0.00)
Belgium	-1.17	2.36	0.19	0.04
	(0.26)	(0.62)	(0.06)	(0.26)
Denmark	1.81	-1.74	-0.09	0.09
	(0.50)	(0.53)	(0.05)	(0.04)
Finland	-0.27	0.50	0.02	2.09
	(0.02)	(0.09)	(0.00)	(0.03)
France	-0.01	2.99	0.01	0.10
	(0.04)	(5.37)	(0.01)	(0.10)
Germany	-0.97	10.54	-0.04	0.57
	(0.39)	(0.07)	(0.04)	(0.17)
Greece	-0.02	0.08	-0.02	0.76
	(0.08)	(0.05)	(0.03)	(0.11)
Holland	-0.07	-0.05	-0.27	0.16
	(0.07)	(0.03)	(0.09)	(0.03)
Ireland	-0.22	0.77	-0.05	-0.03
	(0.03)	(0.19)	(0.01)	(0.08)
Italy	0.30	4.02	0.03	0.18
	(0.30)	(0.19)	(0.02)	(0.04)
Portugal	0.41	0.18	0.05	0.46
	(0.04)	(0.16)	(0.01)	(0.04)
Spain	0.10	-0.02	-0.07	1.04
	(0.02)	(0.15)	(0.02)	(0.07)
Sweden	-0.32	0.10	0.06	-0.60
	(0.11)	(0.33)	(0.03)	(0.19)
UK	-0.46	0.75	2.68	-4.93
	(0.20)	(0.41)	(0.20)	(1.07)

Notes: The numbers in brackets are standard errors.