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The link between macroeconomic performance and variability in the UK

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ABSTRACT

This paper examines the link between inflation, output growth and their respective variabilities. We employ a bivariate GARCH model, which incorporates mean and level effects, to investigate in a unified empirical framework all the possible interactions between the four variables. We show that not only does variability affect performance but the latter influences the former as well. Specifically, inflation has a positive impact on both variabilities.

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1. Introduction

This paper uses the bivariate unrestricted extended constant conditional correlation (UECCC) GARCH model to investigate the interactions between inflation, growth, and their respective variabilities. The UECCC-GARCH specification, examined in [Conrad and Karanasos \(2009\)](#), allows for feedback between the two variabilities, which can be of either sign, i.e. positive or negative, and so no a priori restriction is imposed.² We extend this specification by including in-mean and level effects. Many researchers who have worked on this field over the last decade have endorsed the GARCH methodology (see, for example, [Grier and Perry, 2000](#); [Fountas et al., 2002](#); [Grier et al., 2004](#); [Fountas and Karanasos, 2007](#)). Our work has many distinguishing features. We examine in a unified empirical framework all the possible causal relationships among the four variables that are predicted by economic theory.

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² More specifically, [Conrad and Karanasos \(2009\)](#) derive necessary and sufficient conditions which ensure the positive definiteness of the conditional covariance matrix even in the case of negative volatility feedback. While negative values of the GARCH coefficients were commonly thought of as resulting either from sampling error or model misspecification, [Conrad and Karanasos \(2009\)](#) show that this is not necessarily the case. Interestingly, negative volatility spillovers may be in line with economic theory.

In our bivariate formulation lagged values of inflation and growth are included in the variance specifications (the so called level effects). Furthermore, any relationship where macroeconomic performance is influenced by its variability (the so called in-mean effects) takes time to materialize and cannot be fairly tested in a model that restricts the effect to being contemporaneous. Therefore, we estimate a system of equations that allows various lags of the two variabilities to affect the conditional means. Previous studies utilize formulations that allow only the current values of the two conditional variances to affect the means. Hence, in contrast with the existing literature, which focuses almost exclusively on the effect of variability on performance, we examine the bidirectional causality between the four variables simultaneously. Previous empirical work that ignored the level effects might have been based on misspecified models.

Although much has been written in applied theory regarding the potential welfare costs of business cycles, surprisingly little work has been carried out to identify how inflation might affect the variability of output. In particular, this is because we can think of inflation as being primarily influenced by central bank policy. Of significant importance is our finding that inflation has a positive impact on macroeconomic variability as predicted by [Ungar and Zilberfarb \(1993\)](#) and [Dotsey and Sarte \(2000\)](#).

Moreover, the significance and even the sign of the in-mean effects vary with the choice of the lag length. Thus our analysis suggests that the behavior of macroeconomic performance depends upon its variability, but also that the nature of this dependence varies with time. For example, at lag one, the impact of real variability on growth

is positive as predicted by Blackburn (1999), but at lag three it turns to being negative as predicted by Pindyck (1991).

The remainder of this article is organized as follows. In Section 2 we describe the time series model for inflation and growth. Section 3 discusses the economic theory concerning the performance–variability link. In Section 4 we report the empirical results and in Section 5 some robustness issues are discussed. Section 6 contains summary remarks and conclusions.

2. Model

We use a bivariate model to simultaneously estimate the conditional means, variances, and covariances of inflation and growth. Let π_t denote the former, y_t the latter, $\mathbf{x}_t = (\pi_t, y_t)'$ represent the 2×1 column vector with the two variables, and define the residual vector ε_t as $\varepsilon_t = (\varepsilon_{\pi t}, \varepsilon_{y t})'$. Regarding ε_t we assume that it is conditionally normal with mean vector 0, variance vector \mathbf{h}_t where $\mathbf{h}_t = (h_{\pi t}, h_{y t})'$ and covariance $h_{\pi y, t}$.

Note that a general bivariate vector autoregressive (BVAR) GARCH-in-mean model can be written as

$$\left(\mathbf{I} - \sum_{l=1}^p \Phi^{(l)} L^l \right) \mathbf{x}_t = \phi + \Delta \mathbf{h}_{t-n} + \varepsilon_t, \quad t \in \mathbb{N}, \tag{1}$$

where \mathbf{I} is a 2×2 identity matrix, ϕ is a 2×1 column vector given by $\phi = (\phi_{\pi}, \phi_y)'$; $n = 0, 1, 2, 3$, and the ij th ($i, j = \pi, y$) elements of the 2×2 matrices $\Phi^{(l)}$ and Δ are denoted by $\phi_{ij}^{(l)}$ and δ_{ij} respectively.

Following Conrad and Karanasos (2009), we impose the UECCC-GARCH(1,1)-structure on the conditional variance vector \mathbf{h}_t and, additionally, introduce level effects:

$$(\mathbf{I} - \mathbf{B}\mathbf{L})(\mathbf{h}_t - \Gamma \mathbf{x}_{t-1}) = \omega + \mathbf{A} \varepsilon_{t-1}^{\wedge 2}, \tag{2}$$

where ω is a 2×1 column vector given by $\omega = (\omega_{\pi}, \omega_y)'$; the ij th ($ij = \pi, y$) elements of the 2×2 matrices \mathbf{A} , \mathbf{B} and Γ are denoted by a_{ij} , b_{ij} and γ_{ij} respectively; \wedge denotes elementwise exponentiation. Moreover, $h_{\pi y, t} = \rho \sqrt{h_{\pi t}} \sqrt{h_{y t}}$, ($-1 \leq \rho \leq 1$). We will use the acronym BVAR(p)-UECCC-GARCH(1,1)-ML($n, 1$) to refer to this model.

It is worth reiterating in just a few sentences what we see to be the main benefits of our model. First, instead of imposing a contemporaneous in-mean relationship several lags of the conditional variances are added as regressors in the mean equation. Second, we can distinguish empirically between the in-mean and level effects, which is extremely important from a theoretical perspective. Finally, the model does not require us to make the dubious assumption that there is a positive link between the two variabilities. That is, the coefficients that capture the volatility-relationship ($b_{\pi y}, b_{y \pi}$) are allowed to be negative.³

3. Economic theory

In this section, we briefly discuss the economic theories (of interest) concerning the relationship between macroeconomic variability and performance. Ungar and Zilberfarb (1993) provide a theoretical framework in order to specify the necessary conditions for the existence of a positive impact of inflation on its variability. Dotsey and Sarte (2000) present a model which suggests that as average money growth rises nominal variability increases and real growth rates become more volatile. The inflation bias-producing mechanism in Cukierman and Gerlach (2003) implies a positive relationship between inflation and the

³ Let ϕ_1 and ϕ_2 denote the inverse roots of $\mathbf{I} - \mathbf{B}\mathbf{L}$. Following Conrad and Karanasos (2009) it can be shown that the following conditions are necessary and sufficient for $\mathbf{h}_t > 0$ for all t : (i) $\mathbf{x}_t \geq 0$ for all t , (ii) $(1 - b_{yy})\omega_{\pi} + b_{\pi y}\omega_y > 0$ and $(1 - b_{\pi\pi})\omega_y + b_{y\pi}\omega_{\pi} > 0$, (iii) ϕ_1 is real and $\phi_1 > |\phi_2|$, (iv) $\mathbf{A} \geq 0$ and $\Gamma \geq 0$, (v) $[\mathbf{B} - \max(\phi_2, 0)\mathbf{I}]\mathbf{A} > 0$. Note that $>$ denotes elementwise inequality. Since inflation and/or growth can also take negative values the condition $\mathbf{x}_t \geq 0$ is violated. Therefore in the empirical application we also employ $|\mathbf{x}_t|$ (results not reported) and find that our conclusions still hold.

Table 1
Economic theories.

Effects	Coefficients	Theories
Level effects of inflation:	$\gamma_{\pi\pi}$ $\gamma_{y\pi}$	Ungar and Zilberfarb (1993): + Dotsey and Sarte (2000): +
In-mean effects of output growth:	$\delta_{\pi y}$ $\delta_{y y}$	Cukierman and Gerlach (2003): + Blackburn (1999): +, Pindyck (1991): –
Volatility feedback:	$b_{y\pi}, b_{\pi y}$	Fuhrer (1997): –

variability of growth, where causality runs from the latter to the former. Further, Pindyck (1991), among others, proposes a theory for which the negative impact of real variability on growth relies on uncertainty through the link of investment. In another class of models the relationship between the short-term variance and long-term growth is positive (see Blackburn (1999), and the references therein).⁴ Finally, Fuhrer (1997) explores the nature of the long-run variance trade-off. The short-run trade-off between the two variables that exists in the models he explores implies a long-run trade-off in their variabilities.⁵

Table 1 presents a summary of the signs implied by the respective theories for the parameters of our model (see also Fountas and Karanasos (2007); Fountas and Karanasos (2008)).

4. Empirical results

Monthly data, obtained from the OECD Statistical Compendium, are used to provide a reasonable number of observations. The inflation and output growth series are calculated as the monthly difference in the natural log of the Consumer Price Index and Industrial Production Index respectively. The data range from 1962:01 to 2004:01. Allowing for differencing this implies 504 usable observations. For the two series, based on unit root tests (not reported), we are able to reject the unit root hypothesis. The estimates of the various formulations were obtained by maximum likelihood estimation (MLE) as implemented in the Time Series Modelling software. The best AR(GARCH) specification is chosen on the basis of Likelihood Ratio tests and three alternative information criteria. For the conditional means[variances] of inflation and growth, we choose AR(14)[GARCH(1,1)] and AR(2) [ARCH(1)] models respectively. For all specifications we choose the \mathbf{B} matrix such that only $b_{\pi\pi} \neq 0$. When we tried to estimate ML models, with $b_{\pi y} \neq 0$, the estimation routines did not converge. When we allowed $b_{y\pi} \neq 0$ we found that nominal variability had an insignificant impact on real variability (results not reported).

Next, we analyze the results from four alternative specifications and examine the sign and the significance of the estimated coefficients to provide some statistical evidence on the nature of the relationship between the four variables.⁶ Table 2 presents the parameters of interest, that is i) the level effects of inflation, $\Gamma = \begin{bmatrix} \gamma_{\pi\pi} & - \\ \gamma_{y\pi} & - \end{bmatrix}$, and ii) the in-mean coefficients, $\Delta = \begin{bmatrix} \delta_{\pi\pi} & \delta_{\pi y} \\ \delta_{y\pi} & \delta_{y y} \end{bmatrix}$.⁷

⁴ In his Nobel address, Friedman (1977) explains a possible positive correlation between inflation and unemployment by arguing that high inflation produces more uncertainty about future inflation. This variability then lowers economic efficiency and temporarily reduces output and increases unemployment. Moreover, one possible reason for greater nominal variability to precede lower inflation is that an increase in variability is viewed by policymakers as costly, inducing them to reduce inflation in the future (Holland, 1995).

⁵ Some researchers find evidence that inflation negatively Granger causes growth (see Gillman and Kejak (2005), and the references therein). Briault (1995) argues that there is a positive relationship between the two variables, at least over the short run, with the direction of causation running from higher growth (at least in relation to productive potential) to higher inflation.

⁶ In all cases inflation affects growth negatively, whereas growth has a positive effect on inflation (results not reported). That is, there is strong evidence supporting the Gillman–Kejak theory and the Briault conjecture.

⁷ Macroeconomic variability appears to be independent of changes in growth. That is, when we estimate models with the Γ matrix full, $\gamma_{\pi y}$ and $\gamma_{y y}$ are negative and insignificant (results not reported).

Table 2
Empirical results.

Panel A1. UECCC-GARCH ML model ($n=0$)		Panel A2. UECCC-GARCH ML model ($n=0$)	
In-mean effects	Level effects	In-mean effects	Level effects
$\Delta = \begin{bmatrix} -0.14 & 0.02^* \\ (0.31) & (0.01) \\ -0.40 & -0.05 \\ (0.55) & (0.08) \end{bmatrix}$	$\Gamma = \begin{bmatrix} 0.07^{***} & - \\ (0.03) & \\ 0.53^{***} & - \\ (0.08) & \end{bmatrix}$	$\Delta = \begin{bmatrix} -0.11 & 0.02^* \\ (0.28) & (0.01) \\ -0.77^* & -0.01 \\ (0.51) & (0.06) \end{bmatrix}$	$\Gamma = \begin{bmatrix} 0.07^{***} & - \\ (0.03) & - \end{bmatrix}$
Panel B. UECCC-GARCH ML model ($n=1$)		Panel C. UECCC-GARCH ML model ($n=3$)	
In-mean effects	Level effects	In-mean effects	Level effects
$\Delta = \begin{bmatrix} -0.15 & 0.003 \\ (0.23) & (0.01) \\ -0.18 & 0.04^{**} \\ (0.43) & (0.02) \end{bmatrix}$	$\Gamma = \begin{bmatrix} 0.07^{**} & - \\ (0.03) & \\ 0.50^{***} & - \\ (0.08) & \end{bmatrix}$	$\Delta = \begin{bmatrix} 0.06 & -0.01 \\ (0.19) & (0.01) \\ 0.47 & -0.05^* \\ (0.50) & (0.03) \end{bmatrix}$	$\Gamma = \begin{bmatrix} 0.12^{***} & - \\ (0.04) & \\ 0.45^{***} & - \\ (0.09) & \end{bmatrix}$

Notes: Table 2 reports estimates of the parameters of interest. The numbers in parentheses are robust standard errors. ***, ** and * denote significance at the 0.01, 0.05 and 0.10 levels respectively. In Panels A1, B and C there is a bidirectional feedback between inflation and growth whereas in Panel A2 the latter is independent of changes in the former. In all specifications, **A** is a diagonal matrix and in the **B** matrix only $b_{m\pi} \neq 0$.

We find strong evidence in favor of the Ungar–Zilberfarb theory and the Dotsey–Sarte conjecture that higher inflation has a positive impact on nominal and real variability respectively ($\gamma_{m\pi}, \gamma_{ym} > 0$). We also demonstrate the invariance of the above finding to changes in the specification of the model (see Table 2, Panels A1, B and C). Moreover, we find evidence for a positive indirect causal effect from growth on macroeconomic variability. The indirect impact works through the channel of inflation. That is, higher growth increases inflation (see footnote 5), which leads to increased macroeconomic variability. So far, this effect has been overlooked in the literature.

Of particular theoretical interest has been the relationship between growth and its variability with different studies reaching different conclusions depending on what type of model is employed, what values for parameters are assumed and what types of disturbance are considered (see Blackburn and Pelloni (2004, 2005), and the references therein). We find that, at lag one, the impact of real variability on growth is positive ($\delta_{yy} > 0$) as predicted by Blackburn but at lag three it turns to being negative ($\delta_{yy} < 0$) as predicted by Pindyck (see Table 2, Panels B and C). In addition, at lags one to three there is no causal effect from real variability on inflation whereas at lag zero a positive impact ($\delta_{m\pi} > 0$) appears, offering support for the Cukierman–Gerlach theory (see Table 2, Panels A1/2).

An empirically important issue is that it is difficult to separate the nominal variability from inflation as the source of the possible negative impact of the latter on growth. As a policy matter this distinction is important. As Judson and Orphanides (1999) point out: 'If inflation volatility is the sole culprit, a high but predictably stable level of inflation achieved through indexation may be preferable to a lower, but more volatile inflation resulting from an activist disinflation strategy. If on the other hand, the level of inflation per se negatively affects growth, an activist disinflation strategy may be the only sensible choice'. When we set the $\phi_{ym}^{(l)}$ s and γ_{ym} to zero, we find that the effect of nominal variability on growth is negative ($\delta_{ym} < 0$) as predicted by Friedman (see Table 2, Panel A2). However, when we control for the impact of inflation on growth and real variability, the evidence in support of the Friedman hypothesis disappears (see Table 2, Panels A1, B and C). Finally, there is no direct impact of nominal variability on inflation. In contrast, the indirect effect that works via the output growth is negative. That is, the nominal variability has a negative impact on growth, which in turn affects inflation positively (see Table 2, Panel A2).

5. Robustness

The previous analysis established a few important results regarding the relationship between macroeconomic performance and its var-

iability. As our sample period includes various monetary policy regimes, it is sensible to examine the sensitivity of our conclusions with respect to these important events. In particular, from 1979 onwards Thatcher's government emphasized a strong anti-inflation objective. To control for this event we proceed as follows. We generate a dummy variable defined as $D_t = 0$ before 1979 and $D_t = 1$ thereafter. We estimate our bivariate models as above for the full sample period including the dummy in both the level effects of inflation and the cross effects between growth and inflation (results not reported).⁸ In all cases, our results confirm our earlier conclusions regarding the in-mean effects. It is interesting to note that after 1979 the impact of inflation on its variability/growth becomes weaker/stronger (in size).

In order to have a sufficient number of observations for estimating our flexible bivariate in-mean-level specification we followed Grier et al. (2004), Elder (2004), and Grier and Grier (2006) and employed monthly data. Since the variability in monthly data is often attributed to measurement error/noise rather than intrinsic volatility we also examine how our findings regarding the inflation–growth link and the level effects change when the level model is estimated with quarterly data (results not reported). As with the monthly data there is a bidirectional feedback between the two variables, and inflation affects its variability positively. However, the impact of inflation on real variability becomes weaker/disappears.

Finally, we would like to mention that our results concerning the in-mean effects are broadly in line with the findings in other recent studies employing US data. In particular, Conrad and Karanasos (2008), who analyze volatility spillovers between the variabilities of US inflation and output growth, provide evidence for a positive relation between real variability and output growth while the effect of higher nominal variability on growth is found to be negative. Similar results are reported in Grier et al. (2004) and Elder (2004). Since we are not aware of any bivariate study that considers level effects for US data, we extended the analysis in Conrad and Karanasos (2008) by introducing level effects. As for the UK, we find that inflation tends to increase both nominal and real uncertainty.

6. Conclusions

In this study we have investigated the link between UK inflation, growth and their respective variabilities. The variables under consideration are inextricably linked. We know from the previous literature how hard it is to arrive at definitive conclusions on this

⁸ An alternative approach to account for structural breaks would be to estimate similar models for subperiods. Due to the limited number of observations we do not consider this option.

topic. One of the objectives of our analysis was to consider several changes in the formulation of the bivariate model and discuss how these changes would affect the twelve interlinkages among the four variables.

Most studies that focus on the impact of variability on performance simultaneously estimate a system of equations that allows only the current values of the two conditional variances to affect the two means. However, any relationship where inflation and growth are influenced by their variabilities takes time to show up and cannot be fairly tested in a model that restricts the effect to being contemporaneous. In this paper we estimate a specification that allows various lags of the two variances to affect the means. Interestingly, real variability is associated with increased output at shorter lags, consistent with a precautionary savings motive, and the opposite at longer lags, consistent with decreased investment in the presence of fixed costs (and thus lower output).

We also draw attention to one particularly dramatic finding. Some in-mean effects are found to be quite robust to the various specifications that were considered. In particular, inflation is independent of changes in its variability. Some others are found to be 'fragile' in the sense that either their statistical significance disappears or their sign changes when a different formulation is used. Slight variations in the specification of the regressions appear to yield substantially different results for the influence of the two variances on growth. In particular, when we control for the impact of inflation on growth the evidence for the Friedman hypothesis disappears. The interlinkage between the levels of the two variables may, therefore, be an important element masking the negative effects of nominal variability on growth.

Moreover, inflation has a positive impact on macroeconomic variability. Whereas the link between inflation and its variability is well documented, not much attention has been paid to its effect on real variability. We also find evidence for a positive indirect causal effect from growth on macroeconomic variability. The indirect impact works through the channel of inflation. This effect has also been overlooked in the literature. There has been surprisingly little work of this kind. Most of the empirical studies which have been carried out in this area concentrate on the impact of variability on performance and do not examine the effects in the opposite direction. Our ideas about the mechanism linking performance to uncertainty offer plenty of opportunities for further research.

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