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Inflation Expectation Uncertainty, Inflation and the Output Gap

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Angela Fuest and Torsten Schmidt¹

Inflation Expectation Uncertainty, Inflation and the Output Gap

Abstract

Uncertainty about the future path of inflation affects consumption, saving and investment decisions as well as wage negotiations and price setting of firms. These decisions are based on inflation expectations which are a key determinant of inflation in the New Keynesian Phillips Curve. In this paper we therefore explicitly analyse the relationship between inflation expectations, the inflation rate and the output gap and the variance of these variables as uncertainty measures by using a VAR-GARCH-in-mean model. Our main finding is that inflation expectation uncertainty is positively related to expected inflation and to the inflation rate.

JEL Classification: C22, E31, E32

Keywords: Inflation expectations; inflation uncertainty; VAR-GARCH-M models

January 2017

¹ Angela Fuest, RWI and RUB; Torsten Schmidt, RWI. – We thank Roland Dörm and Boris Blagov for valuable comments. – All correspondence to: Angela Fuest, RWI, Hohenzollernstr. 1-3, 45128 Essen, Germany, e-mail: angela.fuest@rwi-essen.de

1. Introduction

Uncertainty about the future path of inflation makes the decision-making of firms and private households more difficult. Whether this has an effect on economic activity and inflation is still subject to debate. Empirical studies typically analyse the direct relationship between inflation and inflation uncertainty. However, economic agents base their decisions on inflation expectations, which are one of the key determinants of inflation. Hence, in order to achieve their objective of price stability, it is vital for monetary authorities to gain insight into economic agents' expectation formation and the role uncertainty plays in forming these expectations.

In this paper we analyse the relationships between economic variables and different sources of economic uncertainty against the backdrop of the New Keynesian Phillips curve (NKPC). This approach emphasises three sources of uncertainty: inflation uncertainty, real uncertainty, which is related to the output gap, and inflation expectation uncertainty. Previous studies have focused on the relationships between inflation uncertainty, real uncertainty, the inflation rate and output growth, or between inflation expectations and the inflation rate (e.g. Grier and Perry 2000; Fountas 2010; Canova and Gambetti 2010). We add to the literature by directly investigating the link between inflation expectation uncertainty and inflation expectations and the link between inflation expectation uncertainty and the inflation rate in a multivariate GARCH framework. The use of a GARCH measure for inflation expectation uncertainty distinguishes our approach from previous studies.

Economic theories about the link between inflation uncertainty and inflation are ambiguous as regards the direction and the sign of the relationship. In his Nobel Lecture Friedman (1977) argues that in a high inflation environment the monetary policy response becomes more unpredictable, which leads to increased uncertainty about future inflation. Ball (1992) formalises this idea in a Barro-Gordon (1983) type model, in which there is asymmetric information between the public and the monetary policymaker. In a low inflation environment the public expects the monetary authority to keep the inflation rate low. However, in a high inflation environment the public does not know whether future policymakers will readily disinflate or be reluctant to bear the costs of disinflation. Hence, a higher level of inflation increases uncertainty about future inflation.

However, Ungar and Zilberfarb (1993) suggest that higher inflation may actually reduce inflation uncertainty. During high inflation episodes forecast errors become more costly. Thus, economic agents have a stronger incentive to invest in inflation forecasting, which might diminish or offset the effect predicted by the Friedman-Ball hypothesis or even result in a negative relationship between inflation and inflation uncertainty.

Causality may also run into the reverse direction. Cukierman and Meltzer (1986) use a Barro-Gordon type model to show that inflation uncertainty affects the level of the inflation rate. In this model with asymmetric information the policymaker prefers a certain degree of ambiguity and control mechanisms that are less efficient. This enables the monetary authority to create large positive monetary surprises to stimulate output. As a result uncertainty about inflation causes inflation to be higher on average. Conversely, Holland (1995) postulates that inflation uncertainty may decrease inflation. Because a rise in uncertainty creates welfare costs, monetary authorities may respond to increased uncertainty by taking actions to reduce inflation.

Inflation uncertainty may also affect the real economy. Friedman (1977) argues that inflation

uncertainty undermines the signalling effect of prices and distorts the efficient allocation of resources and thus may reduce real growth. Uncertainty may also dampen growth by inhibiting irreversible investment (Pindyck 1991). However, in a cash-in-advance framework by Dotsey and Sarte (2000) inflation variability increases investment and growth via a precautionary savings motive. Other theories concern the relationship between real uncertainty and inflation or output. Increased output uncertainty may lead to a higher inflation rate (Devereux 1989) and to higher real output growth (Black 1987). While many studies have focused on inflation and output growth and their uncertainty, the relationship between these variables and inflation expectations and the uncertainty surrounding these expectations has not been considered so far in the literature.

The empirical evidence for these theories is mixed. Overall, the findings give support to the Friedman-Ball hypothesis that inflation positively affects inflation uncertainty (Grier and Perry 1998; Fountas and Karanasos 2007). However, evidence for the Cukierman-Meltzer hypothesis is rather mixed. Fountas (2010), for instance, finds a positive impact of inflation uncertainty on the inflation rate for eleven industrialised countries, whereas the results of Grier and Perry (1998) indicate that more uncertainty lowers average inflation in the UK, the US and Germany, in accordance with the conjecture by Holland (1995). On the other hand, Kontonikas (2004), Grier and Perry (2000) and Fountas (2010) find no effect of inflation uncertainty on the inflation rate in the UK, the US and Germany, respectively.

The relationship between inflation expectations and inflation is analysed mainly empirically. Two strands of this literature in particular use survey data as a direct measure of inflation expectations. The first one employs VAR analyses (e.g. Clark and Nakata 2008; Canova and Gambetti 2010), showing that expectations are an essential part of inflation dynamics. Leduc *et al.* (2007) find that shocks to expectations play a greater role for the variability of inflation than monetary policy shocks. The other branch of literature estimates versions of the New Keynesian Phillips curve, employing survey data as a proxy for inflation expectations to study the relationship between the inflation rate and expectations. Roberts (1995) shows that inflation dynamics in the US may be well represented by a forward-looking NKPC in which expectations are approximated by data from the Michigan Surveys of Consumers. However, in these studies of inflation dynamics the role of uncertainty is neglected.

The link between inflation expectations and uncertainty has been investigated in few studies only. Some authors investigate the relationship between the level of inflation and the uncertainty of inflation expectations. For instance, Ungar and Zilberfarb (1993) examine inflation forecasts of economists and executives in Israel and their unpredictability measured by forecast errors. The level of the inflation rate has a positive effect on uncertainty surrounding inflation expectations. This link, however, is only significant during episodes in which inflation is high. Further, Arnold and Lemmen (2008) observe inflation expectations from the European Commission's Consumer Survey and find a positive relationship between inflation and disagreement within the Eurozone.

Other analyses focus on the relationship between the level of inflation expectations and measures of uncertainty about these expectations. Zarnowitz and Lambros (1987) examine disagreement and uncertainty on the basis of the ASA-NBER survey¹ in the US. Their results

¹The ASA-NBER survey was taken over by the Federal Reserve Bank of Philadelphia in 1990 and renamed Survey of Professional Forecasters.

give support to the hypothesis that higher expected inflation leads to more uncertainty about inflation expectations. However, there is only a weak influence of disagreement on the mean inflation forecast. In contrast, in the analysis by Rich and Tracy (2010) disagreement and inflation expectations based on the Survey of Professional Forecasters are positively correlated, whereas no link between forecast uncertainty and expected inflation is found.

In this paper we incorporate the variables of the New Keynesian Phillips curve in a VAR-GARCH-in-mean model. This approach allows us to analyse the link between the levels and the variance of these variables as uncertainty measures simultaneously (Elder 2004; Hartmann and Roestel 2013). Following a wide range of literature (e.g. Roberts 1997; Leduc *et al.* 2007; Canova and Gambetti 2010; Adam and Padula 2011), we employ survey data to approximate inflation expectations. These inflation forecasts are obtained from the Surveys of Consumers by the University of Michigan. In order to analyse the effects of different properties of expectation uncertainty on inflation and real activity we employ two different measures. The first is the conditional variance obtained from the GARCH model. This measure relates uncertainty to changes of expectations over time. The second measure is the dispersion of survey responses which is employed in the literature about disagreement among forecasters (e.g. Mankiw *et al.* 2004). In this case uncertainty arises from diverse expectations at a single point in time.

We find positive links between inflation expectation uncertainty and expected inflation and between inflation expectation uncertainty and the inflation rate. Thus, increased uncertainty about future price level trends is associated with a higher average inflation forecast. Further, inflation expectation uncertainty and the output gap are negatively related. Accordingly, expectations are an important channel through which uncertainty affects the economy.

Furthermore, the results reveal a positive relationship between inflation uncertainty and the level of inflation and a negative relation between inflation uncertainty and the output gap. This is in line with the theories by Cukierman and Meltzer (1986) and Friedman (1977) that inflation uncertainty causes inflation to be higher on average and is detrimental to the real economy. In addition, we find that real economic uncertainty, measured by the conditional variance of the output gap, is positively linked to the output gap and negatively to the inflation rate.

The outline of the paper is as follows. In the following section we describe the measures of inflation expectations and uncertainty employed in this analysis. We also present the main features of the VAR-GARCH-in-mean model, the data and the estimation procedure. In section three we discuss the empirical results. Section four concludes.

2. Empirical Specification

2.1. Measures of Inflation Expectations

A critical issue of our analysis is the choice of an appropriate measure of inflation expectations. Following a wide range of literature, we employ a direct measure of inflation expectations obtained from surveys (e.g. Roberts 1995; Canova and Gambetti 2010). There is no clear consensus in the literature whether expectations in the NKPC are to be modelled by rational expectations or approximated by other measures such as survey data. Fuhrer (2012) and Nunes (2010) employ both rational and survey expectations in the estimation of the NKPC to analyse the role of expectations for inflation dynamics. However, while Fuhrer (2012) concludes that

price setting is dominated by survey expectations, Nunes (2010) finds a greater role for rational expectations. Roberts (1995) as well as Adam and Padula (2011) find that inflation dynamics in the US may be well represented by a forward-looking NKPC when expected inflation is approximated by survey data. Conversely, other studies suggest that a version of the NKPC with backward-looking components – the so-called Hybrid NKPC – performs better than the forward-looking version when survey expectations are employed in the estimation (Henzel and Wollmershäuser 2008; Zhang *et al.* 2009).

Another strand of literature also uses survey data in a direct approach to examine inflation dynamics. Instead of a Phillips curve these studies employ vector autoregressive (VAR) models in which survey forecasts of inflation enter as an endogenous variable (e.g. Leduc *et al.* 2007; Clark and Nakata 2008; Canova and Gambetti 2010). Moreover, survey expectations have been shown to outperform model-based forecasts by e.g. Ang *et al.* (2007), Grothe and Meyler (2015) and Gil-Alana *et al.* (2012). Taken together these studies suggest that survey data contain information about inflation expectations that can be used in empirical analyses.

An additional issue is whether some individuals have better information about future inflation and therefore form more precise expectations. Surveys usually reflect either the expectations of professional forecasters or the perceptions of private households. The most prominent surveys in the US are the Survey of Professional Forecasters (SPF), the Livingston Survey and the Surveys of Consumers by the University of Michigan. The first two target economists and industry professionals; the SPF is conducted quarterly, while the Livingston survey is published bi-annually. The Michigan Survey was established in 1946 and is based on monthly interviews with a representative sample of approximately 500 US households, which are asked about different aspects of their personal finances, business conditions and buying conditions, including their perception of past and future price developments.²

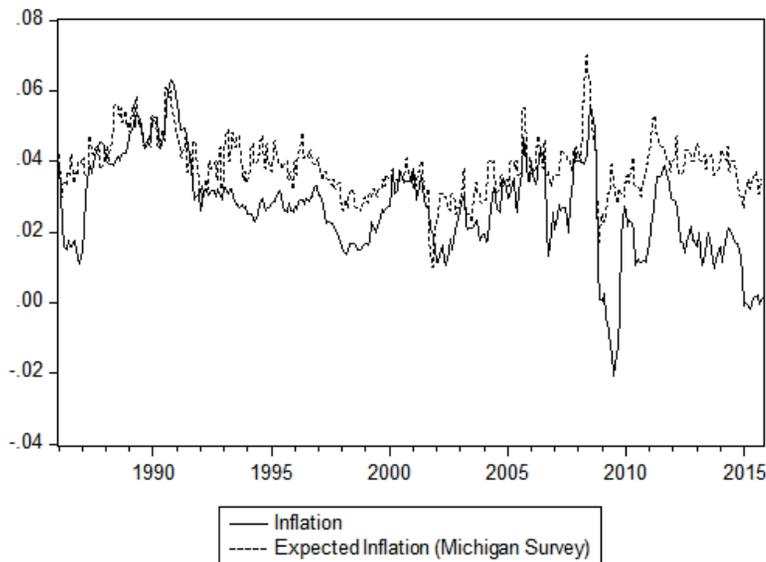
Research by Ang *et al.* (2007) points to the accuracy of households' forecasts of inflation in the Michigan Survey, which perform well relative to professional forecasts from the SPF and the Livingston survey. While survey inflation expectations may have become less accurate in recent years (Trehan 2015), Fuhrer (1988) points out that even in case survey forecasts are inefficient and subject to measurement errors, they may contain independent information. He shows that consumer sentiment data from the Michigan Survey provide useful information above that which is given in standard macroeconomic variables.

A further argument for using consumer survey data is provided by Coibion and Gorodnichenko (2015). They argue that small and medium-sized enterprises are influential drivers of price setting in the US, and that the attitudes of these firms are well represented by the sentiments of private households. In their study consumers' expectations from the Michigan Survey are more relevant than professional forecasts for inflation dynamics in a Phillips curve framework.

Consequently, we employ expectations from the Surveys of Consumers from the University of Michigan in our study, which allows us to conduct the analysis on the basis of monthly data. Figure 1 shows monthly US inflation rates based on the Consumer Price Index as well as average

²The assessment of households' inflation expectations is based upon two questions. Consumers are first asked "During the next 12 months, do you think that prices in general will go up, or go down, or stay where they are now?" and subsequently "By about what percent do you expect prices to go (up/down), on the average, during the next 12 months?". For further information on the procedure to construct estimates of households' price expectations see Curtin (1996).

Figure 1: US Inflation and Michigan Consumer Survey Inflation Expectations



inflation expectations captured in the Michigan Surveys of Consumers between 1986 and 2015. Expected inflation has a lower standard deviation than the inflation rate, however consumers tend to overestimate actual inflation. This is particularly true since the Great Recession.

2.2. Uncertainty Measures

In this study we ask how economic variables and different sources of uncertainty are interlinked, considering in particular the uncertainty about inflation expectations. To answer this question we use two measures of expectation uncertainty.

The first uncertainty measure originates from the time-series literature. Recent studies usually employ GARCH models (Bollerslev 1986) to analyse the links between inflation uncertainty, real uncertainty, inflation and real growth (e.g. Grier and Perry 2000; Fountas and Karanasos 2007). In this approach uncertainty is approximated by the conditional variance. Accordingly, in line with the literature we employ a standard multivariate GARCH framework as a baseline model to analyse the relationship between the variables and their uncertainties. That is, the uncertainty measures are represented by the endogenously determined conditional variances. In particular, also the uncertainty about inflation expectations is represented by this measure, accounting for the variability of expectations over time.

The second measure of expectation uncertainty that we use in this study is driven by the survey data itself. It originates from the literature on disagreement among forecasters, which is defined as the cross-sectional dispersion of survey responses. While some authors make use of the standard deviation of survey forecasts around the mean (e.g. Zarnowitz and Lambros 1987; Holland 1995), in recent studies disagreement is quantified by the interquartile range of

point forecasts (Mankiw *et al.* 2004; Dovern *et al.* 2012). To what extent disagreement is an appropriate proxy for uncertainty is subject to debate in the literature. While e.g. Zarnowitz and Lambros (1987) find that disagreement understates uncertainty, Giordani and Söderlind (2003) conclude that disagreement approximates inflation uncertainty reasonably well.

In our analysis we employ both measures to assess the uncertainty surrounding inflation expectations. For inflation uncertainty and real uncertainty we use endogenous measures from the GARCH model in all our specifications.

2.3. Empirical Model

We start our analysis by estimating a GARCH model in which the uncertainty measures of inflation, inflation expectations and the output gap are determined endogenously. Specifically, we employ bivariate GARCH-in-mean (GARCH-M) models as is common in the literature (e.g. Elder 2004; Hartmann and Roestel 2013; Caporale *et al.* 2015). This approach allows us to analyse the link between the variables and their uncertainty simultaneously by adding the conditional variances as additional regressors in the mean equation.

Due to the small sample size we opt to specify a bivariate model and run three pairwise regressions to take the three variables of interest into account. The bivariate VAR model is given by

$$Y_t = \mu + \Lambda Y_{t-1} + \Gamma h_t + \varepsilon_t \quad (1)$$

$$Y_t = \begin{pmatrix} y_{1,t} \\ y_{2,t} \end{pmatrix}, h_t = \begin{pmatrix} h_{11,t} \\ h_{22,t} \end{pmatrix}, \varepsilon_t = \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix},$$

$$\Lambda = \begin{pmatrix} \lambda_1 & \lambda_2 \\ \lambda_3 & \lambda_4 \end{pmatrix}, \Gamma = \begin{pmatrix} \gamma_1 & \gamma_2 \\ \gamma_3 & \gamma_4 \end{pmatrix}.^3$$

Variables y_1 and y_2 denote a pair of regressors out of the variables inflation, output gap and inflation expectations. The conditional variances of y_1 and y_2 are indicated by h_{11} and h_{22} respectively, and Λ and Γ are parameter matrices. Time index t denotes monthly values.

As described above, expected changes in prices from the Michigan Survey of Consumers serve as a proxy for inflation expectations ($E_t \pi_{t+12}$) in our analysis. Data for the other variables are obtained from the FRED database by the Federal Reserve Bank of St. Louis. The measure for inflation (π_t) is the log change of the Consumer Price Index for All Urban Consumers. The output gap (x_t) is determined as the difference between industrial production and potential output, where potential output is obtained by employing the HP-filter (Hodrick and Prescott 1997) to the industrial production series. Our sample runs from January 1986 to October 2015, resulting in 358 monthly observations.⁴

We assume the conditional variance to follow a GARCH process, taking the form of the BEKK representation (Engle and Kroner 1995)⁵:

³Based on the Schwarz information criteria for the three bivariate specifications we select 1 lag for the VAR framework.

⁴We test the variables for non-stationarity and reject the presence of unit roots (Table A1 in the Appendix).

⁵This is assumed also by e.g. Caporale *et al.* (2015) and Rahman and Serletis (2012).

$$H_t = C'C + \sum_{k=1}^K \sum_{j=1}^q A'_{kj} \varepsilon_{t-j} \varepsilon'_{t-j} A_{kj} + \sum_{k=1}^K \sum_{j=1}^p B'_{kj} H_{t-j} B_{kj} \quad (2)$$

$$\text{where } H_t = \begin{pmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{pmatrix},$$

$$C = \begin{pmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{pmatrix}, A = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}, B = \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}.^6$$

A_{kj} , B_{kj} and C are 2×2 parameter matrices, with C being an upper diagonal matrix. H_t is the variance-covariance matrix with the conditional variances on the diagonal and the covariances on the off-diagonal. We assume the innovations vector $\varepsilon_t | \Omega_{t-1} \sim (0, H_t)$ to be normally distributed, with Ω_{t-1} being the information set available at time $t-1$. The model structure of the BEKK representation ensures positive definiteness of the conditional variance-covariance matrix. One drawback of this specification, however, is the large number of parameters, which makes the estimation of this model cumbersome. Since the GARCH process is not linear in parameters, convergence may be tricky to obtain. Consequently, to ease the computational burden we assume $K = p = q = 1$ as is common in applications of the BEKK model (Silvennoinen and Teräsvirta 2009).⁷ Because we are foremost interested in the effects of the conditional variances in the mean equation of the model, we impose the restriction that there are no volatility spillovers and the conditional variances depend only on their own squared residuals and lagged values of themselves. Hence, we restrict matrices A and B to be diagonal, so that the number of parameters decreases further from 11 to 7. Accordingly, we obtain the diagonal BEKK model

$$H_t = C'C + A' \varepsilon_{t-1} \varepsilon'_{t-1} A + B' H_{t-1} B \quad (3)$$

$$C = \begin{pmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{pmatrix}, A = \begin{pmatrix} a_{11} & 0 \\ 0 & a_{22} \end{pmatrix}, B = \begin{pmatrix} b_{11} & 0 \\ 0 & b_{22} \end{pmatrix}.$$

Under the assumption of normally distributed innovations the log likelihood function for our model is

$$\ln(\theta) = -\frac{1}{2} \left[TN \ln(2\pi) + \sum_{t=1}^T (\ln |H_t| + \varepsilon'_t H_t^{-1} \varepsilon_t) \right], \quad (4)$$

where θ is the set of parameters to be estimated, $T = 358$ is the number of observations and $N = 2$ is the dimension of our VAR model.⁸

In a second step we estimate bivariate GARCH models with the cross-sectional dispersion of consumers' forecasts in the Michigan survey as an exogenous expectation uncertainty variable. This measure of disagreement is given by the interquartile range of inflation forecasts.

Figure 2 illustrates both uncertainty measures for inflation expectations used in this study. The two time series display higher peaks at several points during the sample period. Most

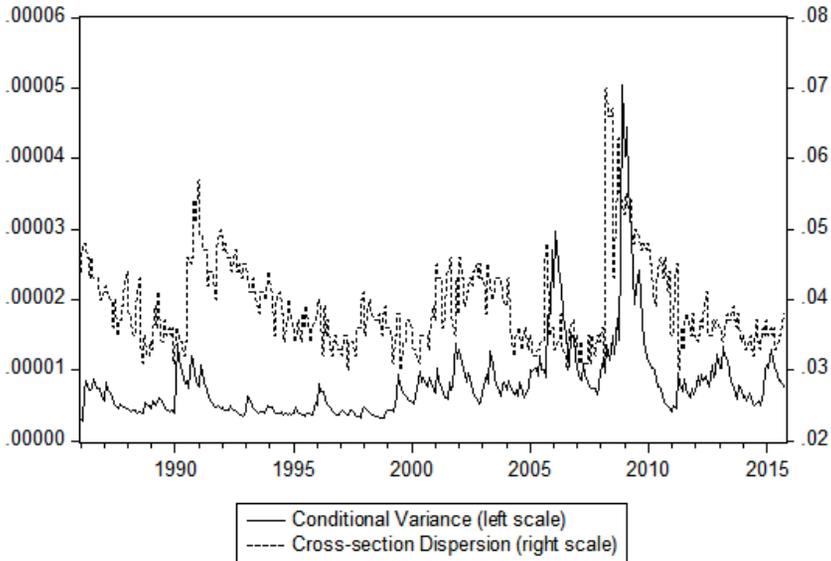
⁶The generality of the process is governed by K .

⁷In the uncertainty literature this is assumed also by e.g. Grier and Perry (2000), Elder and Serletis (2009) as well as Rahman and Serletis (2012).

⁸We use EViews legacy – a particular Gauss-Newton procedure – with Marquard steps in EViews 9.5 for maximizing the likelihood function.

notably in 2005 and 2008 both measures soar at the same time. During the financial crisis the expectations of US households became more dispersed. At the same time uncertainty inherent in the conditional variance of the inflation forecast increased strongly.

Figure 2: Measures of Inflation Expectation Uncertainty



3. Results

Estimation results from the bivariate GARCH-M models are presented in Table 1. The upper part of the table shows the coefficients of the mean equations, both for the endogenous level variables and for the conditional variances which represent measures of uncertainty. The lower part of the table depicts the coefficients of the conditional variance equations. The results for the mean equations indicate significant links between our variables of interest and the uncertainty measures. In particular, panel B illustrates that the conditional variance of inflation expectations is positively related to their level. Thus, increased uncertainty about future price level trends is associated with a higher average inflation forecast. Similarly, also the link between uncertainty about inflation expectations and the actual inflation rate is positive. Furthermore, uncertain expectations are negatively related to the output gap (panel A). Accordingly, this implies that expectations are an important channel through which uncertainty affects the economy.

Panel C further indicates that inflation uncertainty is negatively linked to the output gap. Hence, our results are in line with Friedman (1977) and Pindyck (1991), who argue that uncertainty curbs real economic growth. Moreover, there is a positive relationship between inflation uncertainty and the inflation rate, which conforms to the model by Cukierman and Meltzer (1986), implying that inflation uncertainty causes inflation to be higher on average. The condi-

Table 1: Estimation results: Bivariate GARCH-in-mean models

	A		B		C	
	Output Gap	Infl. Exp.	Infl. Exp.	Inflation	Output Gap	Inflation
MEAN EQUATION						
Level						
Constant	0.0007*** (0.0000)	0.0058*** (0.0010)	0.0083*** (0.0000)	0.0027*** (0.0006)	0.0008*** (0.0000)	0.0018*** (0.0004)
Output Gap t_{-1}	0.9462*** (0.0076)	0.0484*** (0.0102)			0.9148*** (0.0175)	0.0037 (0.0084)
Inflation Expectations t_{-1}	0.0566*** (0.0217)	0.8467*** (0.0262)	0.7909*** (0.0103)	-0.0238* (0.0142)		
Inflation t_{-1}			0.3524*** (0.0904)	0.4962*** (0.0459)	0.2553*** (0.0614)	0.4508*** (0.0391)
Conditional Variance						
Output Gap	15.9177 (12.7853)	-13.2783*** (0.3732)			20.1286*** (0.0953)	-42.4832*** (0.5853)
Inflation Expectations	-129.2520*** (49.0494)	-9.9201 (28.5939)	2.8875*** (1.0261)	0.9163*** (0.0097)		
Inflation			-56.1730 (39.6996)	-26.1917 (30.3745)	-255.9724*** (2.8089)	44.7196*** (0.9912)
VARIANCE EQUATION						
Squared Residuals t_{-1}	0.5704*** (0.0412)	0.4276*** (0.0450)	0.3355*** (0.0583)	0.3785*** (0.0460)	0.4815*** (0.0222)	0.3978*** (0.0283)
Conditional Variance t_{-1}	0.5117*** (0.0825)	0.7499*** (0.0335)	0.6637*** (0.1094)	0.8831*** (0.0265)	0.5982*** (0.0199)	0.8782*** (0.0133)
Log Likelihood	2919.26		3179.74		3068.04	
Obs.	358		358		358	

tional variance of the output gap is positively linked to the output gap. This result is related to Black's (1987) view that higher real uncertainty leads to more output growth. In addition, the results of specification C imply a negative relationship between output gap uncertainty and inflation. While this finding does not correspond to Devereux's (1989) notion that increased real uncertainty leads to a higher average inflation rate, this link is not well-established in the empirical literature (e.g. Grier and Perry 2000; Fountas *et al.* 2006). Similarly, uncertainty about the output gap is negatively related to inflation expectations (panel A).

The coefficients of the lagged values of the three level variables in the mean equation indicate significant and positive relationships. The output gap exhibits the highest persistence with a coefficient larger than 0.9. The relationship between the lagged output gap and inflation expectations is significant and positive, however the coefficient is rather small (panel A). An increasing output gap tends to create price pressures, as captured by the dynamics of the Phillips curve. Consequently, a change in the output gap is considered an indicator for future price developments. Inflation expectations are likely to be adjusted upwards when the output gap increases.

Panel B indicates a significant positive relationship between the lagged inflation rate and inflation expectations. This finding gives support to the adaptive expectations hypothesis. The current inflation level plays a role in the formation of individuals' inflation forecasts. Moreover, as can be seen in panel C, the link between lagged inflation and the output gap is positive as well. Higher inflation is associated with an acceleration of economic activity and therefore a positive output gap. This relationship is depicted in the Phillips curve as well.

Results for the alternative specification of our model in which we replace the conditional variance of inflation expectations by the exogenous interquartile range of survey answers are given in Table 2. They may be compared to panels A and B in Table 1. For the level variables of the mean equation the results of the modified specification do not differ substantially from those of our baseline specification. The majority of the coefficients remains significant and exhibits similar though slightly lower magnitudes compared to the previous specification. However, there are some notable differences in the links between the conditional variances and the level variables. While for instance, panel A2 displays a similar link between output gap variability and inflation expectations, in panel B2 the sign of the relationship between inflation uncertainty and the level of inflation has changed. Such a negative link would be in line with the conjecture of Holland (1995) that monetary authorities act stabilising and will thus tighten policy in response to increased inflation uncertainty in order to reduce welfare losses. The empirical findings of Grier and Perry (1998) and Berument and Nergiz Dincer (2005) support this view. Moreover, the relation between the uncertainty measure for inflation expectations and the level of inflation is not significant anymore in the alternative specification.

Table 2: Estimation Results: Dispersion as a Measure of Expectation Uncertainty

	A2		B2	
	Output Gap	Infl. Exp.	Infl. Exp.	Inflation
MEAN EQUATION				
Level				
Constant	0.0077*** (0.0014)	0.0047** (0.0019)	0.0063*** (0.0021)	0.0018 (0.0011)
Output Gap t_{-1}	0.8958*** (0.0195)	0.0254 (0.0179)		
Inflation Expectations t_{-1}	0.0160** (0.0075)	0.8153*** (0.0342)	0.8019*** (0.0427)	0.0087 (0.0214)
Inflation t_{-1}			0.274** (0.1100)	0.413*** (0.0673)
Conditional Variance				
Output Gap	9.1845 (23.0357)	-26.6622* (16.1132)		
<i>Survey Dispersion</i>	-0.2154*** (0.0351)	0.0826** (0.0385)	0.0292 (0.0331)	-0.0151 (0.0199)
Inflation			-64.2790 (44.6264)	-33.8058*** (0.3763)
VARIANCE EQUATION				
Squared Residuals t_{-1}	0.4664*** (0.0740)	0.1814*** (0.0760)	0.3025*** (0.0687)	0.2937*** (0.0406)
Conditional Variance t_{-1}	0.7224*** (0.0853)	0.6934*** (0.3502)	0.7862*** (0.0944)	0.9325*** (0.0204)
Log Likelihood	2835.55		3109.68	
Obs.	358		358	

4. Conclusion

Economic uncertainty has several dimensions and therefore affects the economy in different ways. With regard to inflation dynamics it is an important question what kind of uncertainty has an effect and through which channel. In this paper we use the New Keynesian Phillips curve as a framework to analyse the relationship between economic uncertainty and real activity and inflation dynamics. This concept stresses the importance of inflation expectations as a determinant of the inflation rate, which is the target variable of monetary policy. Therefore, in this study we particularly analyse the role of inflation expectation uncertainty for expectations and inflation dynamics. We estimate a multivariate GARCH-in-mean model, examining links between inflation, inflation expectations, the output gap and the conditional variances of these variables as uncertainty measures.

The empirical results reveal that different dimensions of economic uncertainty are related to the dynamics of inflation. High output gap uncertainty, i.e. high uncertainty about the future path of economic activity, is accompanied by lower inflation expectations and by lower inflation. Moreover, we find negative relationships between inflation uncertainty and the output gap and between inflation expectation uncertainty and the output gap.

Our main result, however, is that inflation expectation uncertainty has a positive effect on inflation expectations and on the inflation rate. Thus, expectations are an important channel through which uncertainty affects the economy. In contrast, we find no significant relation between inflation uncertainty and inflation expectations. Moreover, the results show that the origin of inflation expectation uncertainty is important. While large changes of aggregate expectations over time are significantly related to the level of inflation, disagreement among consumers is not.

For monetary policy that focuses on stabilising the level of inflation expectations to control the future path of inflation it is hence important to reduce the uncertainty about inflation expectations. This requires monetary authorities to better understand how expectations are formed and what the main determinants of expectation uncertainty are.

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Appendices

A. Additional Table

Table A1: Unit Root Tests

	ADF
Output Gap	-5,84***
Inflation Expectations	-5,64***
Inflation	-11,89***

Notes: H_0 : Variable has a unit root; ADF denotes the Augmented Dickey-Fuller test statistic (with constant); automatic lag length based on SIC; *** denotes significance at the 1% level.