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# The time-varying correlation between uncertainty, output, and inflation: Evidence from a DCC-GARCH model

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ABSTRACT

Using a new uncertainty index from Baker et al. (2012), we evaluate the time-varying correlation between macroeconomic uncertainty, inflation, and output. Estimation results from a multivariate DCC-GARCH model reveal that the sign of the correlation between macroeconomic uncertainty and inflation changed from negative to positive during the late 1990s, whereas the correlation between uncertainty and output is consistently negative.



## 1. Introduction

Since the financial crisis of 2008, a literature examining the macroeconomic effects of uncertainty has developed. Bloom (2009), Bloom et al. (2009), Gilchrist et al. (2010), and Panousi and Papanikolaou (2012) develop models in which uncertainty shocks adversely affect output. On the other hand, Bachmann et al. (2010) find little empirical evidence supporting such a causal relationship and conclude that recessions breed uncertainty. One disagreement in the current literature regards the appropriate measure of uncertainty. Recently, Baker et al. (2012) addressed this by developing a policy-related uncertainty index. Our aim is to explore the historical uncertainty-output and uncertainty-inflation relationships using Engle's (2002) dynamic conditional correlation (DCC) GARCH model. The time-varying nature of our approach allows us to capture the uncertainty-output and uncertainty-inflation relationships in different states of the business cycle since the late 1980s. We find (1) the correlation between inflation and uncertainty turns from negative to positive during the late 1990s and early 2000s, and (2) the correlation between uncertainty and output is consistently negative.

## 2. Methodology

As seen in Fig. 1, all three time series exhibit heteroskedastic characteristics (shown formally in Table 1). Therefore, we choose to follow Hamilton (2008) and model the series as GARCH processes. In particular, we adopt Engle's (2002) multivariate GARCH model allowing for time-varying correlations.

Let $y_t = [y_{1t}, y_{2t}]'$ be a $2 \times 1$ vector containing the data series. We represent the conditional mean equations by the following reduced-form VAR:

$$A(L)y_t = \varepsilon_t \qquad \varepsilon_t \sim N(0, H_t) \quad t = 1, \ldots T \tag{1}$$

where $A(L)$ is a matrix in the lag operator $L$, and $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}]'$ is a vector of innovations. The $\varepsilon_t$ vector has the following conditional variance–covariance matrix:

$$H_t = D_t R_t D_t$$

where $D_t = diag\{\sqrt{h_{it}}\}$ is a $2 \times 2$ matrix containing the time-varying standard deviations from univariate GARCH models and $R_t = \{\rho_{ij}\}_t$ for $i, j = 1, 2$ is a correlation matrix containing conditional correlation coefficients. The standard deviations in $D_t$ are governed by the following univariate GARCH $(P, Q)$ process:

$$h_{it} = \gamma_i + \sum_{p=1}^{P_i} \alpha_{ip} \varepsilon_{it-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{iq-q} \quad \forall i = 1, 2. \tag{2}$$

Engle's (2002) framework consists of the following $DCC(M, N)$ structure:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1},$$

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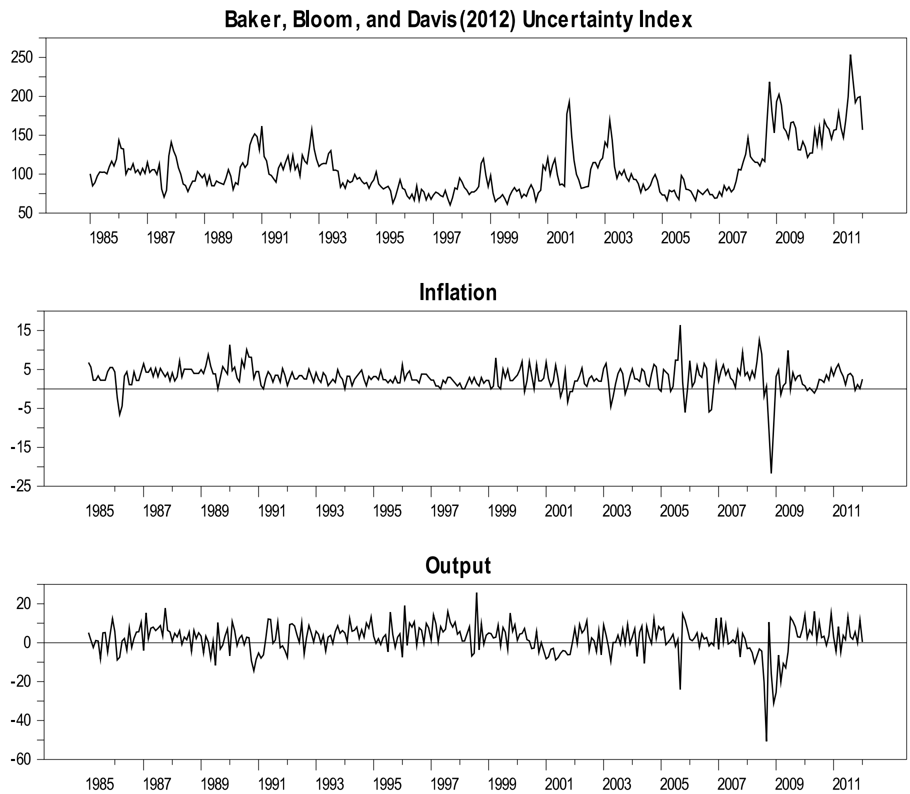


**Fig. 1.** Time series plots of uncertainty index, inflation, and output.

**Table 1**
Unit root and heteroskedasticity tests.

| Unit root tests[a]: | Variable: | | |
|---|---|---|---|
| | Uncertainty | Inflation | Output |
| Augmented D-F | −1.39 | −5.06*** | −4.35*** |
| Zivot–Andrews[b] | −5.31** | | |
| Heteroskedasticity test: | | | |
| ARCH (12) LM Test | 243.794*** | 38.184*** | 38.25*** |

** Denotes statistical significance at the 95% level.
*** Denotes statistical significance at the 99% level.
[a] Under the null hypothesis, the series is a unit root process.
[b] The estimated break date is August 2007.

where

$$Q_t = \left(1 - \sum_{m=1}^{M} a_m - \sum_{n=1}^{N} b_n\right)\overline{Q} + \sum_{m=1}^{M} a_m(\varepsilon_{t-m}\varepsilon_{t-m}) + \sum_{n=1}^{N} b_n Q_{t-n}. \quad (3)$$

$\overline{Q}$ is the time-invariant variance-covariance obtained from estimating (2), and $Q_t^*$ is a $2\times2$ diagonal matrix containing the square root of the diagonal elements of $Q_t$. Our primary focus is on the conditional correlation $\rho_{12,t} = q_{12,t}/\sqrt{q_{11,t}q_{22,t}}$ in $Rt$.

## 3. Data

We use the monthly, policy-related uncertainty index by Baker et al. (2012) which spans from January 1985 through January 2012 and combines three index components. The first quantifies the number of references to policy-related uncertainty in ten leading newspapers. The next component is the number of federal tax code provisions set to expire in future years, and the final is the extent of disagreement among economic forecasters over future federal government purchases and consumer price index (CPI) levels. Output is defined as 1200 times the log monthly change in industrial production and inflation is defined as 1200 times the log monthly change in the consumer price index (CPI). Before estimating the DCC model, we implement unit root and ARCH tests to ensure stationarity and test for heteroskadasticity. Table 1 contains the results.

Using augmented Dickey–Fuller tests, output and inflation are found to be stationary while the uncertainty index contains a unit root. However, since it seems unlikely that macroeconomic uncertainty follows a random walk and Perron's (1989) analyses showing that structural breaks can lead to erroneously accepting unit roots, we also implement the Zivot and Andrews (1992) unit root test. The Zivot and Andrews test indicates that uncertainty is stationary in levels with a structural break occurring in August 2007. To account for the structural break, we estimate the conditional mean of uncertainty in Eq. (1) with a dummy variable (i.e. $D_L = 1$) for all $t \geq$ August 2007 (i.e. $D_L = 0$ otherwise). The ARCH LM test rejects the null hypothesis of homoskedasticity for all three variables indicating that ARCH-type models are appropriate.

## 4. Results

To investigate the results of Bachmann et al. (2010), we include the conditional variances $h_{i,t}$ of each variable in the mean equations in (1). If their hypothesis that recessions breed uncertainty is correct, then the coefficients on the conditional variances of output and inflation should be positive and statistically significant in the conditional mean equation of uncertainty.

Table 2 reports the results from the estimated models. Panel A contains the results from the mean equations, Panel B contains the conditional variance estimates, and Panel C contains the diagnostic tests. Because of the limited number of uncertainty observations, we select the lag lengths in the mean equations using the minimum number of lags it takes to rid the standardized and

**Table 2**
Bivariate DCC–GARCH model.

Panel A: Mean estimates (with standard errors in parentheses):

| Model 1: Uncertainty/Inflation | | | Model 2: Uncertainty/Output | | |
|---|---|---|---|---|---|
| | $u_t$ | $\pi_t$ | | $u_t$ | $y_t$ |
| Constant | 9.620 | 1.725 | Constant | 13.772 | −2.099 |
| | (3.744) | (0.559) | | (0.414) | (0.294) |
| $\pi_{t-1}$ | 0.094 | 0.345 | $y_{t-1}$ | −0.097 | −0.004 |
| | (0.241) | (0.061) | | (0.059) | (0.048) |
| $\pi_{t-2}$ | 0.116 | −0.075 | $y_{t-2}$ | −0.077 | 0.262 |
| | (0.241) | (0.061) | | (0.065) | (0.043) |
| $\pi_{t-3}$ | 0.459 | 0.058 | $y_{t-3}$ | −0.098 | 0.188 |
| | (0.235) | (0.059) | | (0.054) | (0.035) |
| $\pi_{t-4}$ | 0.146 | 0.039 | $y_{t-4}$ | −0.142 | 0.099 |
| | (0.251) | (0.057) | | (0.063) | (0.040) |
| $\pi_{t-5}$ | −0.088 | 0.068 | $y_{t-5}$ | −0.085 | 0.064 |
| | (0.257) | (0.055) | | (0.072) | (0.042) |
| $\pi_{t-6}$ | −0.101 | −0.042 | $y_{t-6}$ | −0.006 | 0.084 |
| | (0.246) | (0.058) | | (0.065) | (0.047) |
| $\pi_{t-7}$ | 0.862 | 0.072 | $y_{t-7}$ | −0.093 | −0.021 |
| | (0.225) | (0.052) | | (0.057) | (0.039) |
| $\pi_{t-8}$ | −0.277 | −0.071 | $y_{t-8}$ | −0.023 | 0.047 |
| | (0.235) | (0.052) | | (0.067) | (0.039) |
| $\pi_{t-9}$ | −0.144 | 0.054 | $y_{t-9}$ | 0.171 | 0.054 |
| | (0.212) | (0.046) | | (0.087) | (0.029) |
| $u_{t-1}$ | 0.694 | −0.003 | $u_{t-1}$ | 0.671 | −0.066 |
| | (0.053) | (0.007) | | (0.004) | (0.003) |
| $u_{t-2}$ | 0.068 | −0.006 | $u_{t-2}$ | 0.181 | −0.018 |
| | (0.061) | (0.007) | | (0.004) | (0.003) |
| $u_{t-3}$ | −0.239 | 0.020 | $u_{t-3}$ | −0.304 | −0.013 |
| | (0.072) | (0.008) | | (0.004) | (0.003) |
| $u_{t-4}$ | 0.230 | −0.016 | $u_{t-4}$ | 0.193 | 0.082 |
| | (0.041) | (0.008) | | (0.004) | (0.003) |
| $u_{t-5}$ | 0.035 | 0.010 | $u_{t-5}$ | 0.054 | −0.040 |
| | (0.032) | (0.007) | | (0.004) | (0.003) |
| $u_{t-6}$ | −0.170 | 0.013 | $u_{t-6}$ | −0.094 | 0.054 |
| | (0.052) | (0.009) | | (0.004) | (0.003) |
| $u_{t-7}$ | 0.069 | 0.001 | $u_{t-7}$ | −0.002 | −0.012 |
| | (0.061) | (0.009) | | (0.004) | (0.003) |
| $u_{t-8}$ | 0.034 | −0.018 | $u_{t-8}$ | 0.104 | −0.002 |
| | (0.063) | (0.008) | | (0.004) | (0.003) |
| $u_{t-9}$ | 0.111 | 0.003 | $u_{t-9}$ | 0.034 | 0.033 |
| | (0.051) | (0.007) | | (0.004) | (0.003) |
| $hu_t$ | 0.007 | −0.001 | $hu_t$ | 0.001 | 0.001 |
| | (0.005) | (0.000) | | (0.002) | (0.001) |
| $h\pi_t$ | 0.133 | −0.037 | $hy_t$ | 0.058 | 0.015 |
| | (0.086) | (0.026) | | (0.007) | (0.006) |
| $D_L$ | 12.755 | | $D_L$ | 11.173 | |
| | (2.776) | | | (1.516) | |

Panel B: Conditional variance estimates (with standard errors in parentheses): $H_t = \Gamma'\Gamma + A'e_{t-1}e'_{t-1}A + B'H_{t-1}B$

| Model 1: Uncertainty/Inflation | | | Model 2: Uncertainty/Output | |
|---|---|---|---|---|
| | $hu_t$ | $h\pi_t$ | $hu_t$ | $hy_t$ |
| $\gamma_1$ | 49.67 | 0.395 | 17.85 | 24.90 |
| | (17.02) | (0.163) | (3.12) | (1.66) |
| $\alpha_1$ | 0.615 | 0.285 | 0.446 | 0.473 |
| | (0.129) | (0.0515) | (0.03) | (0.048) |
| $\beta_1$ | 0.284 | 0.692 | 0.564 | 0.023 |
| | (0.106) | (0.049) | (0.017) | (0.042) |
| $a$ | 0.017 | | 0.0405 | |
| | (0.010) | | (0.015) | |
| $b$ | 0.982 | | 0.935 | |
| | (0.011) | | (0.032) | |

Panel C: Ljung-Box Q-Statistics (with significance values in parenthesis)

| Standardized residuals (Lags) | Model 1: Uncertainty/Inflation | | Model 2: Uncertainty/Output | |
|---|---|---|---|---|
| | Uncertainty | Inflation | Uncertainty | Output |
| 4 | 2.617 | 1.716 | 2.328 | 0.965 |
| | (0.62) | (0.78) | (0.67) | (0.91) |
| 8 | 8.17 | 7.181 | 4.580 | 4.379 |
| | (0.41) | (0.517) | (0.80) | (0.82) |
| 12 | 16.87 | 19.66 | 9.883 | 6.658 |
| | (0.15) | (0.07) | (0.62) | (0.87) |

(*continued on next page*)

Table 2 (*continued*)

| | | | | |
|---|---|---|---|---|
| Squared residuals | | | | |
| 4 | 0.597 | 2.69 | 0.478 | 2.718 |
| | (0.96) | (0.60) | (0.97) | (0.60) |
| 8 | 2.31 | 4.72 | 2.260 | 5.133 |
| | (0.96) | (0.78) | (0.97) | (0.74) |
| 12 | 16.34 | 13.37 | 8.175 | 8.261 |
| | (0.17) | (0.34) | (0.77) | (0.76) |

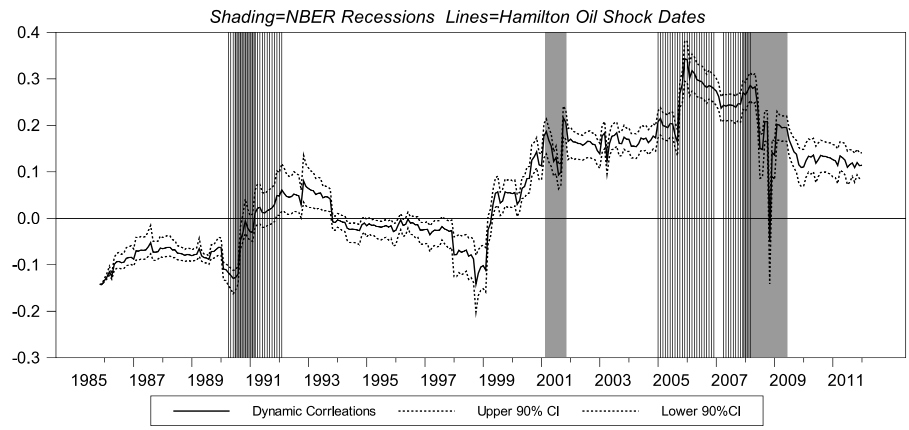


**Fig. 2.** Correlations between uncertainty and inflation.

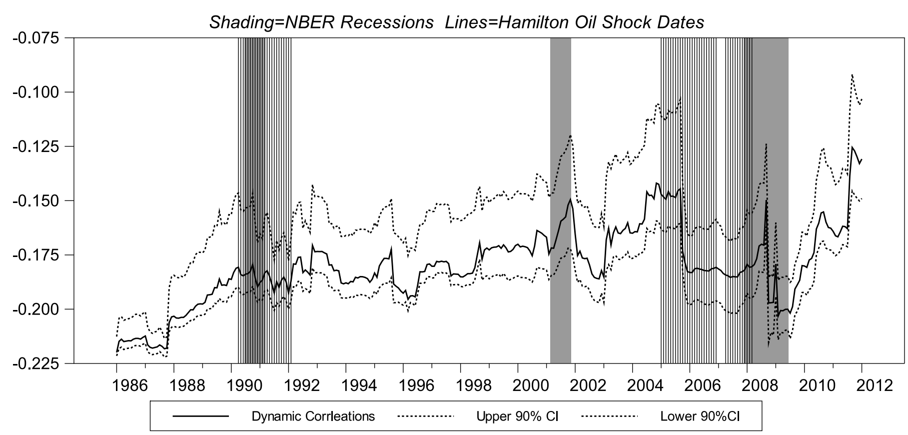


**Fig. 3.** Correlations between uncertainty and output.

squared standardized residuals of serial correlation. The Ljung-Box Q-statistics in Panel C suggest both of the models are adequately estimated.

The uncertainty conditional variance coefficient has a statistically significant negative effect on the inflation rate (displayed in Model 1 of Table 2) but no significant impact on output. Interestingly, the output conditional variance coefficient has a statistically positive effect on the level of uncertainty consistent with the Bachmann et al. (2010) results.

Figs. 2 and 3 display the time-varying correlations and 90% confidence intervals from the estimated models.[1] Shaded portions of the figures are NBER recession dates and the lines are dates during which the U.S. experienced oil price shocks as determined by Hamilton (2009). The most striking feature of the figures is the change in the correlation between uncertainty and inflation in Fig. 2. The correlation between uncertainty and inflation ranges from −0.14 in the 1980s to +0.30 in 2006. As expected, during the simultaneous recession and oil price shock of 1991–1992 the correlation between inflation and uncertainty increases. During the subsequent two recessions in 2001 and 2007–2009 the correlation falls, but increases again during the oil shocks of 2005–2008.

In Fig. 3, the correlation between uncertainty and output is consistently negative regardless of the state of the business cycle. There is no material change in the correlation during the oil price shock of 1991, but it does become more negative during the 2005–2008 oil price shock. Note that the correlation has become less negative since the onset of the European debt crisis in 2010.

## 5. Conclusion

Using a new uncertainty index from Baker et al. (2012), we evaluate the correlation between macroeconomic uncertainty, inflation, and output. Empirical results based on a DCC–GARCH model confirm that the correlation between uncertainty and output is consistently negative since the 1980s. Somewhat unexpectedly, our results also indicate that the correlation between uncertainty and inflation became positive during the late 1990s and early

[1] Program and data can be found at www.bama.ua.edu/~jones381.

2000s. One hypothesis for this change in the correlation is the increase in crude oil prices which begins during the early 2000s and continues until the financial crisis in 2008. During the crisis, crude oil prices drop precipitously and the correlation briefly turns negative. Pinpointing the factors that cause the change in the correlation between inflation and uncertainty would be an interesting line of future research.

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