Mgarch Modeling of the Relationships among Inflation, Output, Nominal and Real Uncertainty in Turkey

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Abstract
In this paper, we estimate bivariate GARCH models of inflation and output growth to examine the causality relationships among inflation, output growth, nominal (inflation) uncertainty and real (output) uncertainty for Turkey over the period 1997:01-2008:05. The empirical results of the study support some of the well known hypotheses which are designed to explain the relationships between inflation, output growth rate, real and nominal uncertainty. Firstly, we find the evidence that increased inflation raises nominal uncertainty, confirming Friedman (1977) and Ball (1992) hypotheses. Secondly, the results also support the Cukierman-Meltzer (1986) hypothesis that nominal uncertainty causes to more inflation. Thirdly, the findings of the study indicate that there is a causal relation between real uncertainty and inflation. This finding is in agreement with Taylor (1979) and Deveraux (1989) hypotheses. Finally, the effect of output growth on real uncertainty is significant as predicted by Taylor (1979).

Keywords: Inflation, Nominal Uncertainty, Output Growth, Real Uncertainty, Bivariate GARCH Estimates, BEKK parameterization, Conditional Variance, Granger Causality.

Jel Classification: C32, C51, C52, E30, E0

Introduction

The analyzing the causal relationships among the inflation, output growth, nominal (inflation) uncertainty and real (output) uncertainty has become an important issue in applied macroeconomics, since it might provide very helpful answers to a number of interesting questions, such as is there a bidirectional causality between inflation and inflation uncertainty?; is it possible to increase economic growth rate to reducing inflation, thus inflation uncertainty?, and can a less volatile growth rate cause a higher output rate? And also, we can have chance to test for the empirical relevance of different theories that have some implications about these four important macroeconomic variables in Turkey; thus implementing the right policy measures to sustain more stable economic growth rate in a low and less volatile inflationary environment, since Turkey has been suffering high and very volatile inflation and less stable growth rates.

Therefore, in this study, we try to provide answers to the above questions using the bivariate GARCH models introduced by Bollerslev (1986), which enables us to derive proxies for both inflation and output uncertainties using the conditional variance of inflation and output growth. The paper is organized as follows. In section 2, we discuss the theoretical relationships among the four important macroeconomic variables. In section 3, we present the econometric model. In section 4 and 5, we report, discuss and summary our results and mention some policy implications respectively.

Theory

The direction of the causality between inflation and inflation uncertainty has been the subject of many empirical studies[1]. There are three generally accepted hypotheses which try to formalize the relationship between inflation and inflation uncertainty. The first of them is the Friedman (1977)-Ball hypothesis (1992), which states that higher inflation causes the more inflation uncertainty. According to Friedman, an increase in inflation may force monetary authorities develop erratic policy response going from one direction to another, encouraging wide variation in actual and expected rate of inflation, which can lead to increase inflation uncertainty. Later, Ball formalized Friedman's argument using an asymmetric information game between the public and the policymaker (Ball, 1992, p.371-388). In his model, Ball considers two types of policymakers who alternate in power: conservative and liberal. When inflation is low, both types of policymakers will try to keep it so, thus uncertainty concerning future inflation will also be low. But when inflation is high, the uncertainty about the future monetary situation and the future path of inflation will be also higher, since in this situation these two types of policymakers will differ in decision-making: conservative will prefer to disinflation, whereas liberal will be unwilling to this, because of fear of causing a recession. So the public doesn’t know how long it will take before a tough type comes along and implement actions for disinflation. In addition, the policies create inflation uncertainty because their timing and short-run impact on inflation are uncertain. This is partly due to fact of existence of short-run tradeoffs among the goals of the monetary policy, which makes the timing of disinflation policy uncertain.

The second of them is Cukierman-Meltzer hypothesis (1986), which indicates that higher inflation uncertainty causes more inflation. Cukierman-Meltzer hypothesis is based on so-called Barro-Gordon model (Barro-Gordon, 1983, p. 589-610). The policymaker tries to maximize his own objective function, modeled as random variable, which is related positively to economic stimulation through monetary surprises and negatively related to monetary growth. The process of money supply is also modeled as random variable, due to imprecise monetary control procedures. So, trying to distinguish between persistent changes in the objectives and transitory monetary control errors, the public faces an inference problem. Although expectations are rational, the information is imperfect because of inexact mechanism of monetary control. As a result, increase in inflation uncertainty will raise the optimal average inflation rate by motivating the policy-makers to produce inflation surprise. Thus, the increase inflation uncertainty causes more inflation.

[1] For detailed explanation of such studies see Fountas et al., 2002.

The third of them, which is considered as an alternative to Friedman-Ball and Cukierman-Meltzer hypotheses (Holland, 1995, p.827-837), is Holland's hypothesis, also known 'stabilization hypothesis. According to Holland's hypothesis, greater inflation uncertainty precedes lower inflation. As a possible explanation of this hypothesis, Holland adopts the stabilization motivation of policymakers, who may consider inflation uncertainty as a welfare cost. According to Holland, when inflation uncertainty increases due to rising inflation, the monetary authority responds with anti-inflation actions (for example, by contracting money supply growth) in order to decrease inflation uncertainty, thus trying to eliminate the negative welfare effects associated with inflation uncertainty.

According to Friedman (1977), we should expect adverse output effect of higher inflation uncertainty, since higher inflation uncertainty distorts the allocative efficiency feature of the price system through its effect on the interest rate, relative prices in the presence of nominal rigidities, and also investment. According to Pindyck (1991), uncertainty regarding price levels in the future could force investors to delay investment decisions, because investment is a sunk cost and largely irreversible (Pindyck, 1991, 110-1148). He adds that there could be a better future planning by producers and consumers without this uncertainty. But, on the other hand, we should expect a positive relationship between output growth and inflation uncertainty. Because of short-run Phillips curve, as higher output growth causes more inflation, so is inflation uncertainty (Friedman hypothesis) (Fountas et al., 2002, p.295). On the other hand, according to Friedman, an increase in average inflation rate will cause more inflation uncertainty and more inflation uncertainty will lead to less output uncertainty as a result of the trade off between inflation and real uncertainty found by Taylor (1979).

After explaining the direction of the causal relationships between inflation and inflation uncertainty; inflation, inflation uncertainty and output; we can now focus on relationship between output growth uncertainty and other key macroeconomic variables output growth, inflation and inflation uncertainty. First of all, as shown in Deveraux (1989), using the Barro-Gordon model, increase in output growth uncertainty causes more inflation, since more output growth uncertainty reduces the optimal amount of wage indexation and leads to policymaker to produce more inflation surprises to create positive real effects. Secondly, it is expected that more output growth uncertainty will cause more output growth, according to Black (1987), because investing in more risky technology might have chance to create higher average output growth. Finally, we should expect that higher output growth will lead to higher output growth uncertainty, since as the output growth increase and an inflationary pressure is created, to prevent the rising inflation, policymaker should reduce the money supply which will cause the fall in average inflation rate and inflation uncertainty, and eventually leading to more output growth uncertainty (Fountas et al., 2002, p. 295).

Model

Generally, many univariate time series (Y_t) displays non-constant variability (heteroscedasticity), and these time series can be analyzed by means of the model $Y_t=\mu_{t+} \varepsilon_t$.

Where (μ_t) is the conditional mean of (Y_t), and (μ_t) could be an ARMA process. Furthermore, error term (ε_t) can be a GARCH (p,q) process[2] as following;

$$\varepsilon_t = \sqrt{h_t} v_t , \quad (1)$$

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_j h_{t-j} \quad (2)$$

α_i, β_j denote ARCH and GARCH parameters respectively. Non-negativite condition is $\alpha_i + \beta_j$<1, and v_t~ i.i.d.(0,N). In addition, let W_t= (X_t, Y_t)$^{/}$ denotes bivariate time series. Conditional mean is $W_t = M_t + \varepsilon_t$, where conditional mean (M_t) could be a VAR (Vector Autoregressive Model) or VECM (Vector Error Correction Model) if (X_t) and (Y_t) are cointegrated.

GARCH models estimate the variance of unpredictable shocks in a variable. These models allow determining whether fluctuations in the conditional variance of a variable over long time are statistically significant. Furthermore, these models can be used to estimate the conditional variance and the conditional mean equations.

Since the aim of this study is to determine the causality relationships among inflation, output growth and uncertainty[3] variables, we use a bivariate GARCH model in the style of the BEKK[4] proposed by Engle and Kroner (1995) to simultaneously estimate the conditional means, variances and covariances of inflation and output growth.[5] Engle and Kroner (1995) propose a new parameterization, because it is difficult to guarantee the positivity of H_t (conditional variance-covariance matrix). This parameterization, the so-called BEKK (named after Baba, Engle, Kraft and Kroner), imposes positivity of H_t easily. Furthermore, the BEKK parameterization of H_t can significantly reduce the number of parameters to be estimated. The simple BEKK model requires the estimation of (5/2 N^2+1/2N) parameters for a system of N

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[2] See for further information about ARCH/GARCH models; Engle, R.F., 1982, 987-1007, Bollerslev, T., 1986, 307-327., Glosten, L.R., Jagannathan, R. and Runkle, D.E., 1993,1779-1801., Nelson, D.B., 1991,347-370., Rabemananjara, R. and Zakoian J. M., 1993,31-49.

[3] The conditional variance of a variable is one measure of uncertainty.

[4] There are a number of possible parameterizations of the multivariate GARCH model. See for more information; Bauwens, L., Laurent, S. and Rombouts, J.V.K., 2006, 79-109, Kearney, C. and Patton, A.J., 2000, 29-48, Engle, R., 2002, 339-350, Silvennion, A. and Terasvirta, T., 2008, 1-25, Hafner, C.M. and Herwartz H., 2004, 1-24, Lütkepohl, H., 2005, 562-584, Kroner, K.F. and Ng, V.K., 1998, 817-844.

[5] Early articles on multivariate ARCH and GARCH models are Engle, Granger &Kraft (1984), Diebold &Nerlove (1989), Bollerslev, Engle & Wooldridge (1988). The Vec model which was introduced by Bollerslev, Engle and Wooldridge (1988) is expressed as;

$$\mathrm{vec}(H_t) = A_0 + \sum_{j=1}^{q} B_j \mathrm{vec}(H_{t-j}) + \sum_{j=1}^{p} A_j \mathrm{vec}(\varepsilon_{t-j}\varepsilon_{t-j}^{'})$$

Here, H_t is the conditional variance-covariance matrix, $\varepsilon_t = \eta_t \sqrt{H_t}$, $\eta_t \sim \mathrm{i.i.d.N}(0,1)$. See for more information; Kearney, C. and Patton, A., 2000, 35-36, Lütkepohl, H., 2005, 563-564, Scherrer, W. and Ribarits, E., 2007, 468-470.

variables.[6] Let $\inf_t$ and out_t denote the inflation rate and output growth, respectively. The bivariate VAR(1) model[7] estimates of the inflation rate and the output growth can be written as;

$$\mathrm{inf}_{t} = \varphi_{\mathrm{inf0}} + \sum_{i=1}^{1} \varphi_{\mathrm{infinf},\, i}\, \mathrm{inf}_{t-i} + \sum_{i=1}^{1} \varphi_{\mathrm{infout},\, i}\, \mathrm{out}_{t-i} + \varepsilon_{\mathrm{inf}_t} \tag{3}$$

$$\mathrm{out}_{t} = \varphi_{\mathrm{out0}} + \sum_{i=1}^{1} \varphi_{\mathrm{outinf},\, i}\, \mathrm{inf}_{t-i} + \sum_{i=1}^{1} \varphi_{\mathrm{outout},\, i}\, \mathrm{out}_{t-i} + \varepsilon_{\mathrm{out}_t} \tag{4}$$

Where ε_t denotes residual vector as $\varepsilon_t = (\varepsilon_{\mathrm{inf}_t}, \varepsilon_{\mathrm{out}_t})'$, and $((\varepsilon_t \mid \Omega_{t-1}) \sim N(0, H_t)$

To derive the empirical results of the study, we imposed the BEKK-GARCH(1,1) model on the conditional covariance matrix H_t. In other words, H_t is defined as following[8]:

$$\varepsilon_t = \sqrt{H_t}\, v_t \tag{5}$$

$$H_t = CC' + \underbrace{\sum_{i=1}^{q} A\varepsilon_{t-1}\varepsilon_{t-1}' A'}_{\text{ARCH Term}} + \underbrace{\sum_{i=1}^{p} BH_{t-1}B'}_{\text{GARCH Term}} \tag{6}$$

For q=1, p=1, where parameter matrices;

$$C = \begin{bmatrix} c_{\mathrm{infinf}} & c_{\mathrm{infout}} \\ c_{\mathrm{outinf}} & c_{\mathrm{outout}} \end{bmatrix}, \quad A = \begin{bmatrix} \alpha_{\mathrm{infinf}} & \alpha_{\mathrm{infout}} \\ \alpha_{\mathrm{outinf}} & \alpha_{\mathrm{outout}} \end{bmatrix}, \quad B = \begin{bmatrix} \beta_{\mathrm{infinf}} & \beta_{\mathrm{infout}} \\ \beta_{\mathrm{outinf}} & \beta_{\mathrm{outout}} \end{bmatrix}$$

In this the BEKK model, $\{\varepsilon_t\}$ is weak (covariance) stationary if all eigenvalues of $A \otimes A + B \otimes B$ are less than one.[9]

In the bivariate BEKK-GARCH models variance system can be written as[10]

$$h_{inf,t} = c_{inf\,inf}^{2} + c_{infout}^{2} + \alpha_{inf\,inf}^{2}\varepsilon_{inf,t-1}^{2} + 2\alpha_{inf\,inf}\alpha_{inf\,out}\varepsilon_{inf,t-1}\varepsilon_{out,t-1} + \alpha_{inf\,out}^{2}\varepsilon_{out,t-1}^{2} +$$
$$\beta_{inf\,inf}^{2} h_{inf,t-1} + 2\beta_{inf\,inf}\beta_{inf\,out} h_{inf\,out,t-1} + \beta_{inf\,out}^{2} h_{out,t-1}$$
(7)

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[6] Holmes, M.J., and Pentecost, E.J., 2006, 17-18., Stelzer, R., 2008, 1131-1136, Scherrer, W. and Ribarits, E., 2007, 464-484., Malo, P. and Kanto, A., 2005, 5.

[7] We estimate VAR models of order up to 12. We use the optimal VAR lag order selection criteria of the Akaike (AIC), Schwarz (SC), Hannan-Quinn (HQ), Final prediction error (FPE). The best VAR model is chosen on the basis of these criteria and VAR residual serial correlation LM test.

[8] Karanasos, M. and Kim, J., 2005, 18, Kearney, C. and Patton, A., 2000, 35-36, Li, H. and Majerowska, E., 2008, 253, Bauwens, L., Laurent, S. and Rombouts, J.V.K., 79-109, Scherrer, W. and Ribarits, E., 2007, 470-478, Palandri, A., 2004, 7.

[9] $\otimes$ shows Kronecker Product. See for stationary condition; Engle, R. and Kroner, K.F., 1995, 122-150, Karanasos, M. and Kim, J., 2005, 18-19, Lütkepohl, H., 2005, 564-567, Stelzer, R., 2008, 1132-1136.

[10] Karanasos, M., and Kim, J., 2005, 18-19, Kearney, C., and Patton, A., 2000, 36, Holmes, M.J. and Pntecost, E.J., 2006, 17-18, Engle, R. and Kroner, K.F., 1995, 125-127.

$$h_{out,t} = c^2_{outout} + c^2_{infout} + \alpha^2_{out\,inf}\varepsilon^2_{inf,t-1} + 2\alpha_{out\,inf}\alpha_{outout}\varepsilon_{inf,t-1}\varepsilon_{out,t-1} + \alpha^2_{outout}\varepsilon^2_{out,t-1} + \beta^2_{out\,inf}h_{inf,t-1} + 2\beta_{out\,inf}\beta_{outout}h_{inf\,out,t-1} + \beta^2_{outout}h_{out,t-1} \quad (8)$$

$$h_{\inf out,t} = c_{\inf\inf}c_{\inf out} + c_{outout}c_{\inf out} + \alpha_{\inf\inf}\alpha_{out\inf}\varepsilon^2_{\inf,t-1} + (\alpha_{\inf\inf}\alpha_{outout} + \alpha_{out\inf}\alpha_{\inf out})\varepsilon_{\inf,t-1}\varepsilon_{out,t-1} + \alpha_{outout}\alpha_{\inf out}\varepsilon^2_{out,t-1} + \beta_{\inf\inf}\beta_{out\inf}h_{\inf,t-1} + (\beta_{\inf\inf}\beta_{outout} + \beta_{out\inf}\beta_{\inf out})h_{\inf out,t-1} + \beta_{outout}\beta_{\inf out}h_{out,t-1} \quad (9)$$

Where $h_{infout,\ t}=h_{outinf,\ t}$. Volatility transmission between inflation and output growth in the bivariate BEKK-GARCH models is captured by coefficients $\alpha_{\inf out}$, $\alpha_{out\inf}$, $\beta_{\inf out}$ and $\beta_{out\inf}$ in the conditional variance-covariance equations. Matrix C is a low-triangle matrix. This property and the dynamic function from H_t could guarantee the positivity of H_t. Based on the matrix properties of A and B, we can get the different types to BEKK models.

These are:

i. A and B in full BEKK model are full matrix
ii. A and B in diagonal BEKK are diagonal matrix[11]
iii. A and B in scalar BEKK are scalar

The BEKK parameterization can be estimated consistently and efficiently using the maximum likelihood method. The joint log likelihood function is[12];

$$L(\theta) = -\frac{TN}{2}ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\left(ln|H_t| + \varepsilon_t' H_t^{-1}\varepsilon_t \right) \quad (10)$$

[11] In our empirical analysis, Diagonal BEKK parameterization has been selected in terms of AIC, SC, HQ and Log L. criteria. The Diagonal BEKK model parameterization is;

$$\begin{bmatrix} h_{infinf,t} & h_{outinf,t} \\ h_{infout,t} & h_{outout,t} \end{bmatrix} = \begin{bmatrix} c_{infinf} & 0 \\ c_{outinf} & c_{outout} \end{bmatrix}\begin{bmatrix} c_{infinf} & c_{outinf} \\ 0 & c_{outout} \end{bmatrix} + \begin{bmatrix} \beta_{infinf} & 0 \\ 0 & \beta_{outout} \end{bmatrix}\begin{bmatrix} h_{infinf,t-1} & h_{outinf,t-1} \\ h_{outinf,t-1} & h_{outout,t-1} \end{bmatrix}\begin{bmatrix} \beta_{infinf} & 0 \\ 0 & \beta_{outout} \end{bmatrix} + \begin{bmatrix} \alpha_{infinf} & 0 \\ 0 & \alpha_{outout} \end{bmatrix}\begin{bmatrix} \varepsilon^2_{inf,t-1} & \varepsilon_{inf,t-1}\varepsilon_{out,t-1} \\ \varepsilon_{out,t-1}\varepsilon_{inf,t-1} & \varepsilon^2_{out,t-1} \end{bmatrix}\begin{bmatrix} \alpha_{infinf} & 0 \\ 0 & \alpha_{outout} \end{bmatrix}$$

From this, conditional variance and covariance equations are;

$h_{infinf,t} = c_{infinf} + \alpha^2_{infinf}\varepsilon^2_{inf,t-1} + \beta_{infinf}h_{infinf,t-1}$,

$h_{outout,t} = (c^2_{outinf} + c^2_{outout}) + \beta^2_{outout}h_{outout,t-1} + \alpha^2_{outout}\varepsilon^2_{out,t-1}$,

$h_{out\inf,t} = c_{\inf\inf}c_{out\inf} + \beta_{\inf\inf}\beta_{outout}h_{out\inf,t-1} + \alpha_{\inf\inf}\alpha_{outout}\varepsilon_{\inf,t-1}\varepsilon_{out,t-1}$. In the Diagonal Model; the number of parameters equals 3(k(k+1)/2) See for more information ; Brooks, C., Burke, S. and Persand, G., 2003, 1-21, Malo, P. and Kanto, A., 2005, 5.

[12] Li, H. and Majerowska, E., 2008, 253-254, Kearney, C. and Patton, A., 2000, 36-37, Holmes, M.J. and Pentecost, E.J., 2006, 17.

Under the assumption of conditional normality, the model can be estimated by maximizing of the log likelihood function. Where T is the number of observations, N is the number of variables in the system and θ denotes the vector of parameters to be estimated[13].

Empirical Analysis

Data

In our empirical analysis, we use monthly data of the Consumer Price Index (CPI) and the Industrial Production Index (IPI), which are used proxies for the price level and output respectively, Turkey over the period of 1997:01-2008:05. Inflation is measured by the monthly difference of the log CPI;

$$Inf = \log(CPI_t / CPI_{t-1})$$

Real output growth is measured by the monthly difference of the log IPI;

$$Out = \log(IPI_t / IPI_{t-1})$$

Figure 1 displays the plots of these variables.

[13] In this study, we estimate bivariate the BEKK-GARCH(1,1) model using Marquart numerical optimization algorithm to obtain maximum likelihood estimates of the parameters with Eviews 6.0.

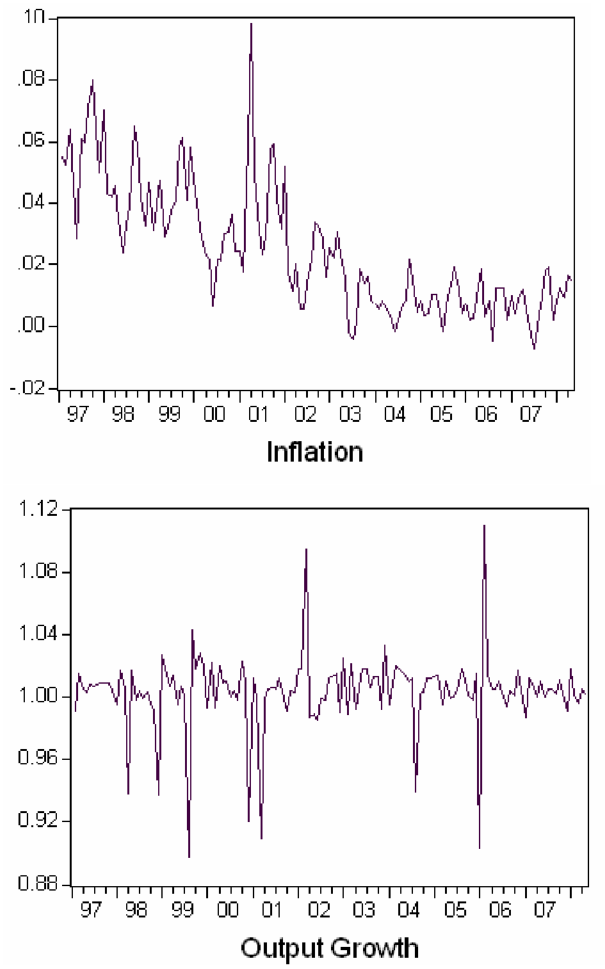

Figure 1: Inflation and Output Growth Series

Empirical Results

We started our empirical analysis investigating properties of inflation and output growth series; simply try to determine whether or not they stationary time series using ADF (Augmented Dickey Fuller), PP (Phillips Perron), and KPSS (Kwiatkowski, Phillips, Schmidt, Shin) unit root tests. Table 1 reports results of the ADF and the PP.

Table 1: Unit Root Tests

	Test Statistics	Critical Value*
Inflation	ADF(4)=-1,840816 PP(11)=-3,661066** KPSS(9)=1,252631	-2,883579 -2,882910 0,463000
Output Growth	ADF(12)=-3,801815** PP(5)=-14,38520** KPSS(7)=0,176438**	-2,885051 -2,882910 0,463000

** denotes Mackinnon critical values of ADF and PP tests for rejection of the null hypothesis of a unit root and Kwiatkowski-Phillips-Schmidt-Shin critical values of KPSS test for the null hypothesis of stationary at the 5% significance level.

Since inflation and output growth variables are not integrated with same order, we estimate simple the VAR model instead of the VECM.

Table 2 represents the results of the bivariate VAR(1)-BEKK GARCH(1,1) model of Section 2.

Table 2: Estimates of the bivariate VAR(1)-BEKK GARCH(1,1) Model

Inflation	$\text{inf}_t = 0{,}039968 + 0{,}774205\text{inf}_{t-1} - 0{,}036265\text{out}_{t-1}$ (0,854390) (16,71639) (-0,779488) $h_{\text{inf},t} = 0{,}0000176 + 0{,}544980\varepsilon^2_{\text{inf},t-1} + 0{,}896382h_{\text{inf},t-1}$ (0,737094) (2,080774) (11,63698)
Output Growth	$\text{out}_t = 1{,}120324 + 0{,}016691\text{inf}_{t-1} - 0{,}114045\text{out}_{t-1}$ (27,24075) (0,363865) (-2,803717) $h_{\text{out},t} = 0{,}0000253 - 0{,}002469\varepsilon^2_{\text{out},t-1} + 0{,}970602h_{\text{out},t-1}$ (1,366942) (-0,020703) (43,66749)

Table 2 represents the parameter estimates for the bivariate VAR (1) BEKK-GARCH(1,1) Model. z statistics are given in parentheses. According to Table 2, for the in equation of inflation, the ARCH and GARCH parameters are statistically significant at the 0,01 level of significance. The sum of these parameters is 0.95088, which is less than one. Moreover, in equation of output growth, the GARCH parameter is significant at the 0,01 significance level, and the sum of the ARCH and GARCH parameters are 0,973071, which is again less than one. Therefore, it can be concluded that information provided by these series will remain important for the forecasts of the conditional variances for long horizons.

In Table 3, Ljung-Box Q statistics at 4, 8 and 12 lags for squares of the standardized residuals of the bivariate VAR(1) BEKK-GARCH(1,1) model are presented. Based on the results of the diagnostic checking of residuals, we find that appropriate model for residual conditional variance covariance is BEKK-GARCH(1,1)[14].

Table 3: The Diagnostics of the bivariate VAR(1)- BEKK GARCH(1,1) Model

	Inflation Equation	Output Equation	Critical Value(5%)
$Q^2(4)$	2,6270	2,6187	9,4877
$Q^2(8)$	5,1783	7,1876	15,5073
$Q^2(12)$	5,3543	9,7539	21,0261

[14] Moreover, Model selection criteria are;

Model	Criteria	Model	Criteria
VAR(1) Dvec-GARCH(1,1)	AIC=-11,43730 SC=-11,11449 HQ=-11,30612 LogL=787,018	VAR(1) CCC-GARCH(1,1)	AIC=-10,74298 SC=-10,46321 HQ=-10,62929 LogL=738,1510
Model	Criteria		
VAR(1) BEKK-GARCH(1,1)	AIC=-11,46372 SC=-11,18395 HQ=-11,35003 LogL=786,8011		

$Q^2(4)$, $Q^2(8)$ and $Q^2(12)$ indicates the Ljung-Box statistics for fourth, eighth and 12th order serial correlation in the squared residuals.

To explore the causal relationships among inflation, output, and nominal and real uncertainty variables, we obtained the conditional variances of monthly inflation and output growth as proxies of nominal and real uncertainty by means of the VAR(1) BEKK-GARCH(1,1) model. And then we perform the Granger Causality tests. Table 4 presents the Granger Causality Test results.

Table 4: The VAR Granger Causality Tests/Block Exogeneity Wald Tests

Dependent Variable:INFLATION	χ^2	d.f.	p
Output	3,711654	2	0,1559
Inf_Uncertainty	**7,704153**	**2**	**0,0212**
Output_Uncertainty	**7,782406**	**2**	**0,0204**
Dependent Variable: OUTPUT	χ^2	d.f.	p
Inflation	1,141255	2	0,5652
Inf_Uncertainty	0,700712	2	0,7044
Output_Uncertainty	0,759850	2	0,6839
Dependent Variable: INF_UNCERTAINTY	χ^2	d.f.	p
Inflation	**61,49925**	**2**	**0,0000**
Output	2,579065	2	0,2754
Output_Uncertainty	1,552482	2	0,4601
Dependent Variable: OUTPUT_UNCERTAINTY	χ^2	d.f.	p
Inflation	0,429725	2	0,8067
Output	**42,76219**	**2**	**0,0000**
Inf_Uncertainty	0,097247	2	0,9525

The results of the Granger causality test indicate bidirectional causality from inflation to nominal uncertainty as an evidence of Friedman (1977) and Ball (1992) hypotheses and Cukierman-Meltzer (1986) hypothesis. Furthermore, the results show that there is unidirectional causality to inflation from real uncertainty, confirming Deveraux (1989) hypothesis, and to real uncertainty from output growth, supporting Taylor (1979).

Figure 2 displays the results of Impulse-Response analysis. When we examine these results, it is easy to conclude that impulse-response analysis also support Granger Causality tests results.

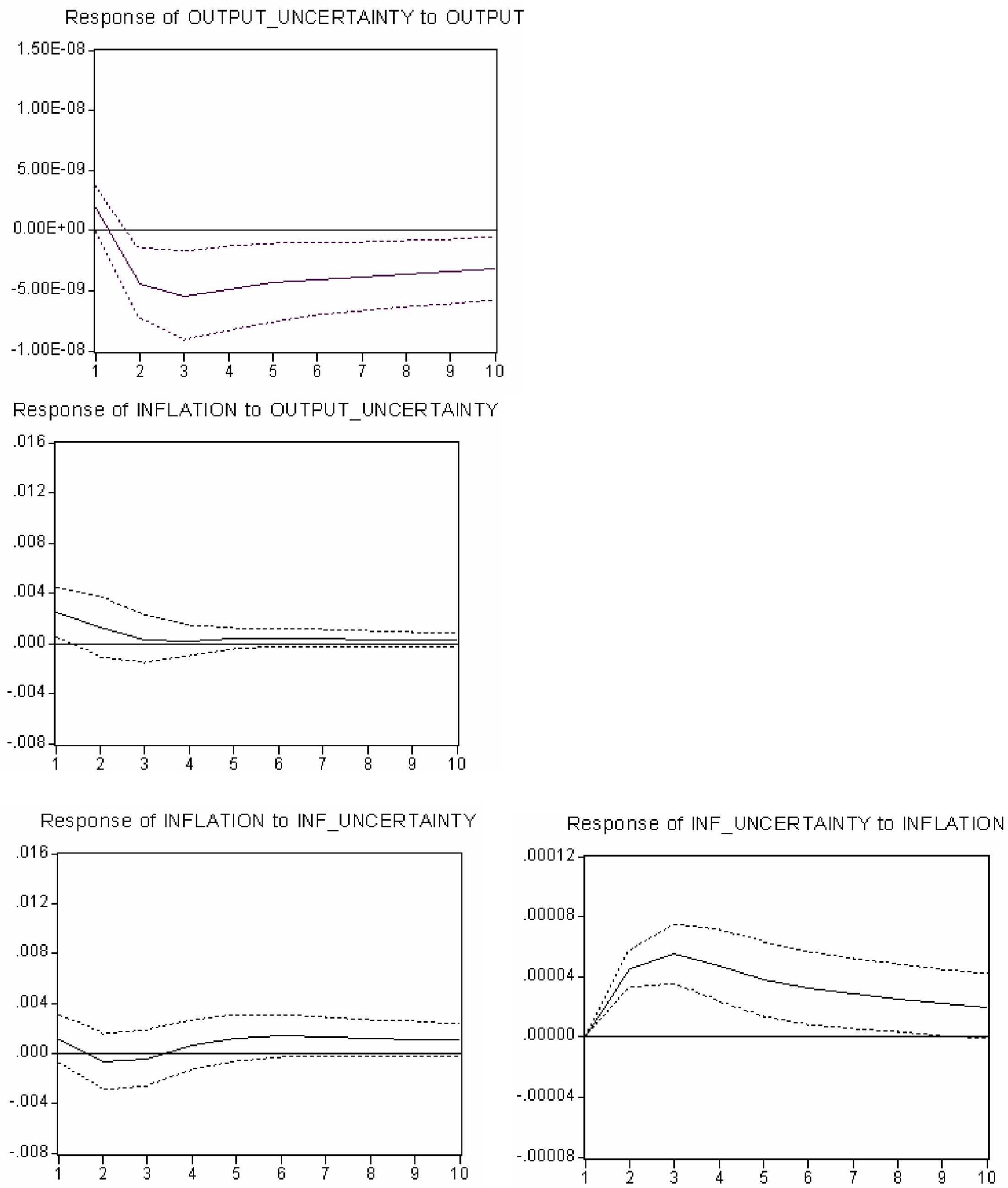

Figure 2: The Impulse Response Functions

Conclusion

In this paper, we try to analyze the empirical relationships among inflation, output growth, nominal uncertainty and real uncertainty variables for Turkey using the bivariate VAR(1) BEKK-GARCH(1,1) model to obtain the proxies for inflation and output growth based on the monthly data on inflation and output growth in over the period of 1997:01-2008:06.

To find out the causal relationships among these important macroeconomic variables, we perform the Granger Causality Test in a VAR system with four variables. The results of the study indicate several important findings which support some of the most well known hypotheses in economic literature. Firstly, increased inflation raises nominal uncertainty, as stated by Friedman (1977) and Ball (1992) hypotheses. Secondly, we have obtained a causality relationship to inflation from nominal uncertainty, as predicted by Cukierman-Meltzer (1986). As a result, monetary authorities should be very careful designing their monetary policies to fight against inflation. Also, they have to be aware of interactions between inflation and inflation uncertainty. Turkey. Thirdly, we have found a causality relationship to inflation from real uncertainty. This finding is in agreement with Taylor (1979) and Deveraux (1989) hypotheses. Therefore, policymakers should be aware of adverse effects of inflation on economic growth. Finally, the effect of output growth on real uncertainty is significant, as confirming the Taylor (1979). On the other hand, we fail to find any causal effect of real and nominal uncertainty on output growth. Thus, as mentioned Fountas et al. (2006), to achieve sustainable and stable economic growth in Turkey, policymakers' should understand that they have to increase the stabilization of the business cycle. Researchers also should understand that analyzing the business cycles and economic growth separately would be better way of analyzing these two issues.

References

Ball, L., 1992, "Why does high inflation raise inflation uncertainty?", Journal of Monetary Economics, 29, 371-388.

Barro, R.J., Gordon D.B., 1983, "A Positive Theory of Monetary Policy in a Natural Rate Model", Journal of Political Economy, August, 589-610.

Bauwens, L., Laurent, S., and Rombouts, J.V.K., 2006, "Multivariate GARCH Models:A Survey", Journal of Applied Econometrics, 21, 79-109.

Bollerslev, T., 1986, "Generalized Autoregressive Conditional Heteroskedasticity", Journal of Econometrics, 31, 307-327.

Bollerslev, T., Engle, R.F. and Wooldridge, J.M., 1988, "A Capital Asset Pricing Model with Time-Varying Covariances", Journal of Political Economy, 96, 116-131.

Brooks, C., Burke, S. and Persand, G., 2003, "Multivariate GARCH Models: Software Choice and Estimation Issues", ISMA Centre Discussion Papers in Finance, 07, 1-21.

Cukierman, A., and Meltzer, A., 1986, "A Theory of ambiguity, credibility, and inflation under discretion and asymmetric information", Econometrica, 54, 1099-1128.

Deveraux, M.B., 1989, "A positive theory of inflation and inflation variance", Economic Inquiry, 27, 105-116.

Diebold, F.X. and M. Nerlove, 1989, "The Dynamics of Exchange Rate Volatility: A Multivariate Latent-Factor ARCH Model", Journal of Applied Econometrics, 4, 1-22.

Engle, R.F., 2002, "Dynamic Conditional Correlation-A Simple Class of Multivariate GARCH Models", Journal of Business and Economic Statistics, 20, 339-350.

Engle, R.F., 1982, "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation", Econometrica, 50(4), 987-1007.

Engle, R. F., Kraft, D., Granger, C.W.J., 1984, "Combining competing forecasts of inflation based on a multivariate ARCH model", Journal of Economic Dynamics and Control, vol. 8, 151 – 165.

Engle, R.F. and Kroner, K.F., 1995, Multivariate Simultaneous Generalized ARCH, Econometric Theory ,Vol.11, No.1, 122-150.

Fountas, S., Karanasos, M. ve Kim J., 2002, “Inflation and Output Growth Uncertainty and their Relationship with Inflation and Output Growth”, Economics Letters, 75, 293-301.
Fountas, S., Karanasos, M. ve Kim J. 2006, “Inflation Uncertainty and Output Growth Uncertainty and Macroeconomic Performance”, Oxford Bulletin of Economics and Statistics, 68,3, 319-343.
Friedman, M., 1977, “Nobel Lecture: Inflation and Unemployment”, Journal of Political Economy, 85, 451-472.
Glosten, L.R., Jagannathan, R. and Runkle, D.E., 1993, “On the Relation between the Expected Value and the Volatility of the Nominal Excess Returns on Stocks”, Journal of Finance, 48(5), 1779-1801.
Hafner, C.M. and Herwartz, H., 2004, “Testing for Causality in Variance using Multivariate GARCH Models”, Economics Working Paper, No 2004-03, 1-24.
Holland, S., 1995, “Inflation and Uncertainty: Tests for temporal ordering. Journal of Money, Credit, and Banking 27, 827-837.
Holmes, M.J. and Pentecost, E.J., 2006, “Volatility Transmission and Growth: An International Perspective”, International Journal of Applied Economics, 3(1), 15-33.
Karanasos, M. and Kim, J., 2005, “The Inflation-Output Variability Relationship in the G3: A Bivariate GARCH (BEKK) Approach”, Risk Letters, 1(2), 17-22.
Kearney, C. and Patton, A.J., 2000, “Multivariate GARCH Modeling of Exchange Rate Volatility Transmission in the European Monetary System”, The Financial Review, 41, 29-48.
Kroner, K.F. and Ng, V.K., “Modeling Asymmetric Comovements of Asset Retuns”, Review of Financial Studies, 11, 817-844.
Li, H. and Majerowska, E., 2008, “Testing Stock Market Linkages for Poland and Hungary: A Multivariate GARCH Approach”, Research in International Business and Finance, 22, 247-266.
Lütkepohl, H., 2005, “New Introduction to Multiple Time Series Analysis, Springer-Verlag Berlin Heidelberg NewYork, ISBN 3-540-26239-3, 562-584.
Malo, P. and Kanto, A., 2005, “Evaluating Multivariate GARCH Models in the Nordic Electricity Markets”, Quantitative Methods in Economics and Management Science, 1-35.
Nelson, D.B., 1991, “Conditional Heteroscedasticity in Asset Returns: A
New Approach”, Econometrica, 59(2), 347-370.
Palandri A (2004), “Multivariate GARCH Models: Inference and Evaluation.", 1-49.Url:http://www.econ.duke.edu/~get/finlunch/past-semesters/ finlunch-documents/2004-02-16b.pdf.
Pindyck, R.S. (1991), “Irreversibility, Uncertainty, and Investment”, *Journal of Economic Literature*, Vol. 29(3), 110-1148.
Rabemananjara, R. and Zakoian J. M., 1993, “Threshold Arch Models and Asymmetries in Volatility”, Journal of Applied Econometrics, Vol. 8, No.1., 31-49.
Scherrer, W. and Ribarits, E., 2007, “On the Parameterization of Multivariate GARCH Models, Econometric Theory, 23, 464-484.
Silvennoinen, A. and Terasvirta, T., 2008, “Multivariate GARCH Models”, http://swopec.hhs.se/hastef/papers/hastef0669.pdf,1-25,Erişim Tarihi: 27.08.2008-14:30.
Stelzer, R., 2008, “On the Relation between the Vec and BEKK Multivariate GARCH Models”, Econometric Theory, 24, 1131-1136.
Taylor, J., 1979, “Estimation and control of a macroeconomic model with rational expectations” , Econometrica, 47, 1267-1286.