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Original Article

Monetary Policy and Output – Inflation Tradeoff: The Turkish Case

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Abstract - *This study analyses the policy tradeoff between inflation and output volatilities which are also known as the Taylor curve. Besides obtaining and evaluating the Taylor curve phenomenon, we also assess whether there was a change in its position during the analyzing period, how temporary economic shocks influence the volatilities of price increases and production changes and the extent to which monetary authorities' decisions affect policy optimality. To this end, the current study uses multivariate GARCH methodology as the basic model estimation technique. The results obtained indicate that the Taylor curve demonstrates some important inward and outward movements during the period under investigation. Compared with the previous monetary policy regimes applied in Turkey, Taylor curves moves toward origin during the inflation-targeting period. Estimation results also refer to the fact that the economic growth performance of the economy is stronger when the relationship that the Taylor curve demonstrates is prevailing. Aggregate supply and demand shocks create interim impacts on conditional variances of inflation and output deviations targeted or potential levels. The results outlined above indicate in the context of monetary policy that the movement of the Taylor curve and empirical results emerging from the Taylor principle together show the efficiency of the monetary policy after the inflation targeting monetary policy setting.*

Keywords - *Inflation volatility, Output volatility, Taylor rule, Monetary policy*

I. INTRODUCTION

In the face of weak economic growth and increased uncertainty that occurred after the 2007 global financial crisis, the anticipation of the monetary policy to boost the economic growth has changed throughout the world economy. During this period, Turkey faced a couple of supply-side shocks, and the output gap remained at high negative levels. In some years, realized inflation exceeded the upper band of the target level and, therefore, CBRT's (The Central Bank of the Republic of Turkey) inflation forecasts have become permanent at a level that almost equals the upper band of the official inflation target. Inflation expectations also have been settled above the upper band of the target throughout the analyzing period. Monetary Policy Board was constituted after the 2001 financial turmoil faced a hard preference whether to support slowing down economic growth or to pull down the inflation toward the targeted level. In inflation targeting, the main duty of monetary policy is to hold the inflation rate measured by the consumer price index within the determined band. According to the Central Bank Law, the main duty of the Bank is to ensure price stability. The Bank supports policies that accelerate economic growth provided that they do not conflict with price stability. In this legal framework, it is possible to say that Monetary Policy Board should also consider the effects of its policy measures on economic growth. In this case, in order to evaluate the effect of monetary policy on economic growth, it is necessary to understand and measure the correlation between inflation variability and output variability in the country as it is stated in the loss function of the central bank. In other words, the measurement and evaluation require a model in which the dynamic structure of the economy and a loss function in which costs of deviations from inflation target and potential output are described. The tradeoff between inflation and output volatilities is known as the Taylor curve. Since there is a lasting tradeoff between inflation and output gap variances, Taylor (1979) also defines this curve as "a second-order Phillips curve". The reason for the existence of this tradeoff is that these volatilities cannot be simultaneously balanced by monetary policy.

The main purpose of this study is to analyze the output volatility and inflation volatility relationship for an economy. For this purpose, we examine if there is a shift in the Taylor curve during the analyzing period in the Turkish economy. As a second task, we will analyze the influences of structural deviations on conditional volatilities of inflation and production in order to see the feature of departures from the Taylor curve. As a third step, we will evaluate the optimality of monetary policy in light of the Taylor principle. According to this principle, while other things are constant, if there is a permanent shock in the inflation rate, the monetary authority should react by creating an increase in the rate of interest greater than the inflation increment. Thus the real interest adequately increases to pull down the price increase back. By assuming a constant

Taylor curve over time, we will investigate the preferences of the central bank without questioning the optimality of monetary policies followed. Like Pakko (2003) and Cover – Hueng (2003), we estimate the inflation-output gap correlation in a time-varying concept together with a simultaneous relationship between two kinds of volatilities.

To achieve the above-listed tasks, the multivariate GARCH model developed by Engle–Kroner (1995) is used within the framework drawn by Olson et al. (2012). However present study differs from Olson et al. (2015) paper by extending the fundamental equation to include foreign exchange rates for the Turkish economy. The reason to integrate the foreign exchange rate into the fundamental equation can be listed as: (1) Since Turkey is a small open economy, it is necessary to determine the effects of openness in the model. (2) Because of currency substitution and the high level of dollarization in countries with high inflation history, pass through to prices is considerably strong. To reflect this dynamic structure to the analyses, the relationship between inflation and output volatilities is going to be examined by using rolling correlations and impulse–response functions. We use unconditional VAR to find out how fundamental equations' shocks affect unconditional variances in the model.

Our estimation results prove that the Taylor curve has moved in the analyzing period in Turkey. When compared to the period prior to the inflation targeting regime, the Taylor curve shifted inward (toward origin) in the inflation-targeting era. This states that inflation and output volatilities are minimized throughout the period. However, if we compare the pre-financial crisis period (2000-2007) to the crisis period (2007-2013), we conclude that the Taylor curve shifted outward since both types of volatilities have increased. For the rest, results indicate that the growth performance of the economy is rather strong in the periods during which the relationship that the Taylor curve indicates is prevalent (that is, both types of volatilities are minimum). The outcomes produced by the VAR model show that implications of structural (supply and demand) shocks are temporary on both types of volatilities. If the policy response attitude of a central bank fits Taylor rule's advice, dynamic correlations between inflation and output volatilities are used to assess the optimality of monetary policy. When compared to other monetary policy regimes periods rolling correlations obtained indicate that designation and execution of monetary policy converged to optimality in the inflation-targeting period. This shows us that the inflation targeting regime has been used effectively by policymakers in Turkey. Considering the negative effect of price stability on output and the legal requirement about price stability in terms of monetary policy, the CBRT has well-balanced determined the policy preferences against two types of gaps.

The plan of the study is as follows: Section 1 summarizes the development of the Taylor curve from a theoretical perspective and historical developments which emerge Taylor curve. While Part 2 shortly surveys empirical literature, Part 3 reveals the theory behind the Taylor relationship. Part 4 discusses mainly the multivariate GARCH model developed for the Turkish economy and its estimation. Part 5 and 6 analyze the statistical properties of the data used and the estimation process of the model together with the obtained results, respectively. Finally, Section 7 concludes the paper by emphasizing the fundamental results and policy implications of them for Turkey.

II. A Brief Overview of Taylor Curve History

It is crucial to know what monetary policy can or cannot succeed when we discuss how a central bank should conduct the policy. If there isn't an appointed judgement on what the limit of a central bank in controlling economic activities is, it is impossible to make rational preferences over monetary policy. Since the scientific consensus of what a central bank can do has changed over time, prescriptions related to conducting monetary policy have also undergone a change. During the 50s and 60s monetary policy, options were formulated in the context of the negative relationship between inflation and unemployment rates which are so-called Phillips curves. English economist A.W. Phillips identified a negative relationship between wage inflation rate and unemployment rate during the 1861-1957 period in England. In 1960, American economists P.A. Samuelson and R. Solow underlined the negative relationship between price inflation and unemployment rates in the United States and called this relationship a "modified Phillips curve". In subsequent years the term "modified" was disappeared, and the Phillips curve has become a concept that generally expresses the inverse relationship between price inflation and unemployment rates. In this era, economists thought that a central bank could sustain the low (high) level of unemployment by creating a high (low) level of inflation. Hence if the unemployment rate is high in the case of price stability (zero inflation rate), the central bank can support the economy by creating some inflation to reduce unemployment. However, in the early 1970s, the scientific and empirical support for the above-mentioned inverse relationship disappeared. As a result of developments in monetary theory and a clearer perception of monetary phenomena in the economy, economists realized that a high inflation rate could reduce the unemployment rate only temporarily and only in the short run. Iı was understood that long-lasted expansionary monetary policy could eventually lead to inflation without creating a decline in unemployment.

The above-outlined approach to the effectiveness of policy decisions in implementing monetary policy is widely accepted today. In this respect, the problem for monetary policy decision-makers is to designate how monetary policy will achieve the best in an environment in which economic agents know that monetary policy measures can only affect the unemployment rate temporarily. One way to avoid problems caused by the temporary inverse relationship between inflation and unemployment rates is to conduct monetary policy within the framework of a long-term inflation target. Nobel laureate economist Milton Friedman suggested that the central bank should try to sustain a constant money supply growth which is in accord with the long term price stability or a long term moderate inflation rate.

In 1979, John Taylor revived a different possibility in the economic agenda. Taylor insisted that the temporary inverse relationship between inflation and unemployment rates is consistent with the permanent inverse relationship between inflation and output volatilities. Policymakers confront at some point with a choice reflecting on reducing output volatility at the cost of high inflation volatility or reducing inflation volatility at the cost of high output volatility. In his 1979 paper, Taylor estimated the negative relationship between inflation and output volatilities (Taylor, 1979). Taylor expresses his views using the output volatility concept rather than unemployment. However, since these two concepts are closely related, this usage does not create ant problem in practice. In converting the output volatility to unemployment volatility, macroeconomists employ a well-known fundamental rule which states that a 1 percentage point reduction in unemployment is seen with 3 percentage points in production. This rule which is developed in A. Okun's 1971 paper, is known as Okun's Law. For the sake of comparing with the Phillips curve, we will handle Taylor's views in the context of the unemployment rate instead of output volatility. Taylor curve that is occurred as a result of the inverse relationship obtained in Taylor (1979) offers a menu of choices to policymakers when monetary policy has temporary effects on the unemployment rate. The general trend in Taylor curve analysis is to study how policymakers use the temporary inverse relationship between inflation and unemployment in order to reach a point on the Taylor curve in which specified inflation and output volatilities are realized at the same time. Economists call this inverse relationship a "policy menu". Naturally, this process is followed by a discussion of the lessons that can be drawn from the Taylor curve in the conduct of monetary policy. Taylor (1979) states that the shape of the estimated curve gives some information to economists about the general structure of the monetary policy rule that is going to be offered to policymakers. However, economists should not persistently suggest this point until they have knowledge about the effects of different inflation and output volatility combinations (different points on the Taylor curve) on the living standard of a typical household.

III. A Brief Overview of Empirical Literature

First of all, we should remark that there are some opinions in the literature claiming that the Taylor curve has replaced the Phillips curve. For instance, Chatterjee (2002) and Taylor (2006) maintain that, as a policy menu, it would be appropriate to use Taylor curve instead of the Phillips curve since it is more in accord with mainstream macroeconomic theory. They argue that a central bank may prefer to lessen the volatility in inflation if they can bear larger volatility in output (or vice versa). On the other hand, Friedman (2006) expresses the Taylor curve as the efficiency frontier that produces necessary tradeoffs required to ensure optimality in monetary policy. When a central bank follows optimal monetary policy, the economy will be located on this efficiency frontier. This study determines a positive correlation for both volatilities in the United States and argues that this provides satisfactory proof indicating the suboptimality of monetary policy in the country for a long time.

The position and shifting of this curve depend on the variance of supply shocks. If the supply shocks are small enough, the economy will be close to the efficiency frontier. If there is a change in the variability of aggregate supply shocks, the Taylor curve shifts. For instance, the decline invariance of most macroeconomic variables since the 80s indicates a movement of the Taylor curve to the origin.

In a flexible price model Cover-Hueng (2002) claim that correlation will be positive if supply shocks are decisive negative if demand shocks are dominant. Since the degree of price stickiness changes over time, demand shocks create a negative inflation–output relationship {Ball-Mankiw (1994), Judd-Trehan (1995)]. However, den Haan (2000) points out that models including only shocks created by aggregate demand are inadequate for determining the price-output relationship. Therefore, a change in price rigidness alone cannot be the source of this correlation that changes over time. According to Cover-Pecorino (2003) study, the greater the success of monetary policy to balance demand shocks, the lower the possibility of a positive inflation-output relationship is. As a matter of fact, models developed by Cover-Pecorino (2003) and Pakko (2003) proved evidence that monetary policy can alter price-output correlation. Because monetary policy differs in recovery periods of the economy, time-varying relationships can occur. Balancing aggregate demand shocks in order to bring inflation-output correlation closer to zero or to turn it into negative depends to a great extent on how monetary authority reacts to the supply shock.

Lee (1999) examines the volatility tradeoff expressed by the Taylor curve using conditional variances of output and inflation. In this study, by using a univariate GARCH model, the structural instabilities are emphasized in the periods during which monetary policy regime shifts are present. The author determines the inflation-output volatility tradeoff and analyses the effects of changes in money market interest rate on conditional variances. As a result, the existence of volatility tradeoff relation is proved, and it is claimed that the impact of policy decisions in different monetary policy regimes on inflation and output will be different.

Cecchetti et al. (2006) examine whether the monetary policy at the international level has become more effective than in the past. Using the cross-sectional data set consisting of a large number of countries, it is determined that the volatility in output increased on a small scale or decreased, whereas the inflation volatility decreased significantly. The authors attribute the increasing stability tendency to the implementation of more effective monetary policies, the diminishing supply shock volatility and structural change in the economy. According to the authors, the fundamental factor behind the improved economic performance is more effective monetary policies. Most of the findings obtained are consistent with the results of Cecchetti - Ehrmann (2001). In this study, it is concluded that the tendency towards inflation targeting will move countries on the inflation–output volatility curve and decrease the inflation variability by increasing the production volatility.

In the study conducted by Cover - Hueng (2003), the correlation between output and price level shocks is examined by using a multivariate GARCH model. The correlations predicted for the period before 1945 were positive, zero for the period 1945 - 1963, and negative for the period after 1963. Apart from these, the authors obtained significant positive correlations during the recession periods prior to 1945 and determined that these correlations turned negative during expansion periods. The change in the sign of the price-output correlation is considered mainly as a result of the changes observed in the economic structure during periods of economic expansion.

Fuhrer (1997) estimated the output – inflation volatility tradeoff that the monetary policy faced in the United States. Deviations from targeted inflation and potential output represent the limit of optimal monetary policy in terms of the predicted opposite relationship. Obtained results show that a balanced reaction in terms of policy objectives is consistent with the choices related to this volatility.

IV. Theory of Taylor Curve

Minimizing a loss function is the starting point of a traditional Taylor curve [Olson et al. (2012), Chatterjee (2002)]. This situation can be expressed in the standardized form as:

$$L = \lambda(\pi_t - \pi_t^*)^2 + (1-\lambda)(y_t - y_t^*)^2 \qquad (1)$$

Variables in this equation are defined as follows: π_t inflation rate, π^* inflation target, λ weight of inflation assigned by the central bank, y_t output and y^* output target. When the model represents the economy and the value of $\lambda$are given, we can reach a point on the Taylor curve by using equation (1). This point shows the optimum values of inflation and output variances for a given λ value. For a given output gap ($y_t - y^*$) variance, we can draw the efficiency frontier for different values of λ as the geometric place of minimum ($\pi_t - \pi^*$) variance.

As Cecchetti-Ehrmann (2001) states, an economy can be subject to demand and supply disturbances at the aggregate level. While demand shocks drive output and prices in the same direction, an opposite movement in prices and output is observed in the case of an aggregate supply shock. Monetary policy can be used to offset aggregate demand shocks since it drives output and inflation in the same direction. However, monetary authorities confront the tradeoff between inflation and output volatility in the case of aggregate supply shocks. The change in inflation as a result of supply shock should also be permanent. It is considered that the change in inflation is permanent if it is possible to reduce inflation volatility only by enduring higher output volatility (Chatterjee, 2002). The above-mentioned tradeoff allows us to draw an efficiency frontier for monetary policy consisting of points that represent minimum inflation and output volatilities. This approach to the Taylor curve means that this curve, in fact, reflects monetary policy preferences (Friedman, 2006). Naturally, in this process, it is accepted that a central bank can have two types of targets: a target for inflation and a target for output. When the central bank tries to achieve these targets, it actually tries to minimize the loss function in equation (1), indicating the weighted average of two components. A zero weight of inflation means that monetary policy only targets output while monetary policy targets only inflation is the central bank assigns a zero weight for output. The target of monetary policy shifts as weight changes between these points. In other words, if a central bank gives a greater weight for inflation, the output will have a higher variance while inflation will have a lower one. As the weight given to inflation increases, it will be possible to move upward on the Taylor curve. The tradeoff between inflation and output volatilities produces a negatively slopped Taylor curve and, therefore, a point on the Taylor curve shows efficient monetary policy preferences. Taylor curve can move inward or outward over time and, for instance, if it shifts inward, then variances of both inflation and output reduce. Shifting of the curve is based on the nature of shocks and policy reactions in an economy. Considering the explanations made by Taylor (1999), position on the Taylor curve exhibits policy choices for decision-makers. For policymakers who care about inflation volatility, a preference to minimize the volatility of inflation and deviation from the targeted level requires deploying in a point like A. This point results in a low inflation rate with high output volatility. However, point E in the figure reflects the preferences of policymakers who less care about minimizing the deviation of inflation from the target. Therefore, while there is high inflation volatility on point E, lower output volatility is present. In fact, if we think that policymakers must consider both volatilities in the decision-making process, it is possible to say that points like B, D and C are more acceptable since they exhibit volatility combinations on which it is easy to compromise. However, opting for a point on the output-inflation efficiency frontier requires the existence of a central bank that is able to form and conduct independent policies away from political pressure. A discretionary monetary policy formation process allows a central bank to prefer appropriate inflation volatility. Thus, the central bank solves the minimization problem and makes independent policy decisions in a way that positively contributes to the stability and economic growth of the country.

V. Model, Estimation Methodology and Results

This study uses Engle-Kroner's GARCH model as outlined by Olson et al. (2012). However, our study differs from these studies by including the real exchange rate into the fundamental equation to see the effect of openness on the economy. Furthermore, to avoid possible bias, we use the aggregate demand-aggregate supply model, which has been determined as optimal by Mishkin-Hebbel (2007).

$$y_t = c_{1,0} + \sum_{i=1}^{n} \alpha_{1,i} y_{t-i} + \sum_{i=1}^{n} \beta_{1,i} \pi_{t-i} + \sum_{i=1}^{n} \varphi_{1,i} r_{t-i} + \sum_{i=1}^{n} \sigma_{1,i} e_{t-i} + \sum_{i=1}^{n} \gamma_{1,i} o_{t-i} + \varepsilon_{y,t} \quad (2)$$

$$\pi_t = c_{2,0} + \sum_{i=1}^{n} \alpha_{2,i} y_{t-i} + \sum_{i=1}^{n} \beta_{2,i} \pi_{t-i} + \sum_{i=1}^{n} \sigma_{2,i} e_{t-i} + \sum_{i=1}^{n} \gamma_{2,i} o_{t-i} + \varepsilon_{\pi,t} \quad (3)$$

First of all, all of the above variables in (2) and (3) are in the form of deviations from the long-run trend values for each related variable estimated by using Hodrick-Prescott Filtering methodology with λ = 14400. We named these deviation variables with the prefix "gap" in the estimation procedure. Equation (2) is the aggregate demand curve, while Equation (3) is the Phillips curve or the aggregate supply equation. In Equation (2) and (3), i_t is the output gap, π_t is the inflation gap, r_t is the short term interest rate gap, e_t is the real exchange rate gap, and i_t is the world oil price gap. $\varepsilon_{y,\ t}$ and $\varepsilon_{\pi,t}$ refer to aggregate demand and aggregate supply shocks, respectively, with the classical properties of $(\varepsilon_t \parallel \Omega_{t-1}) \sim N(0, H_t)$ Where Ω_t presents all available information at time "t-1". We use Baba-Engel-Kraft-Kroner (1990, also known as BEKK) algorithm to estimate the univariate VAR model through a conditional covariance matrix. In this model, the stochastic behaviour of H_t is parameterized as:

$$H_t = \gamma\,\gamma' + A'\varepsilon_{t-1}(\varepsilon_{t-1})'A + B'H_{t-1}B \forall t = 1,2,\dots,T \quad (4)$$

where the coefficient matrices ϒ, A and B are defined as:

$$\gamma = \begin{bmatrix} \gamma_{yy} & 0 \\ \gamma_{\pi y} & \gamma_{\pi\pi} \end{bmatrix} A = \begin{bmatrix} \alpha_{yy} & 0 \\ \alpha_{\pi y} & \alpha_{\pi\pi} \end{bmatrix} B = \begin{bmatrix} \beta_{yy} & 0 \\ \beta_{\pi y} & \beta_{\pi\pi} \end{bmatrix}$$

H_t matrix in Equation (4) is a 2×2 symmetrical matrix consisting of conditional variances of output and inflation gaps. $(H_t) = (h_{\pi,t},\ h_{\pi y,t},\ h_{y,t})'$ vector is obtained by using the following equations:

$$h_{\pi,t} = \gamma_{\pi\pi}^2 + \gamma_{y\pi}^2 + \alpha_{\pi\pi}^2 \varepsilon_{\pi,t-1}^2 + 2\alpha_{\pi\pi}\alpha_{y\pi}\varepsilon_{\pi,t-1}\varepsilon_{y,t-1} + \alpha_{y\pi}^2 \varepsilon_{y,t-1}^2 + \beta_{\pi\pi}^2 h_{\pi,t-1} + 2\beta_{\pi\pi}\beta_{y\pi} h_{\pi y,t-1} + \beta_{\pi y}^2 h_{y,t-1}$$

$$h_{y,t} = \gamma_{yy}^2 + \gamma_{y\pi}^2 + \alpha_{y\pi}^2 \varepsilon_{\pi,t-1}^2 + 2\alpha_{y\pi}\alpha_{yy}\varepsilon_{\pi,t-1}\varepsilon_{y,t-1} + \alpha_{yy}^2 \varepsilon_{y,t-1}^2 + \beta_{y\pi}^2 h_{\pi,t-1} + 2\beta_{y\pi}\beta_{yy} h_{\pi y,t-1} + \beta_{yy}^2 h_{y,t-1}$$

$$h_{y\pi,t} = \gamma_{\pi\pi}\gamma_{y\pi} + \gamma_{yy}\gamma_{y\pi} + \alpha_{\pi\pi}\varepsilon_{\pi,t-1}^2 + (\alpha_{\pi\pi}\alpha_{yy} + \alpha_{y\pi}\alpha_{\pi y})\varepsilon_{\pi,t-1}\varepsilon_{y,t-1} + \alpha_{yy}\alpha_{y\pi}\varepsilon_{y,t-1}^2 + \beta_{\pi\pi}\beta_{y\pi} h_{\pi,t-1} + (\beta_{\pi\pi}\beta_{yy} + \beta_{y\pi}\beta_{\pi y}) h_{\pi y,t-1} + \beta_{yy}\beta_{y\pi} h_{y,t-1}$$

In the model, γ is a 2×2 matrix consisting of 3 constant terms representing the average conditional variance values of the output gap (γ_{yy}), inflation gap ($\gamma_{\pi\pi}$) and covariance ($\gamma_{y\pi}$). Parameters in A matrix are the correlations of conditional volatility of inflation ($\alpha_{\pi\pi}$) and conditional volatility of output (α_{yy}) with lagged squared residuals. Parameters located on the off-diagonal of this matrix shows how a variable's past squared residuals affect the other's conditional variance. For instance, the term $\alpha_{y\pi}$ measures the cross effect of past inflation error on output variance while the term $\alpha_{\pi y}$ represents the cross effect of past output error on the variance of inflation. Parameters on the diagonal of B matrix ($\beta_{\pi\pi}$ and β_{yy}) quantify the persistence of conditional variances. Off-diagonals of this matrix ($\beta_{y\pi}$ and $\beta_{\pi y}$) show the degree of correlation between lagged conditional variances of variables. Since Broyden-Fletcher-Goldfarb-Shanno (BFGS) univariate methodology is used to get maximum likelihood estimates of the parameters, the relevant coefficients in the above equations ($\alpha_{y\pi}$, $\alpha_{\pi y}$, $\beta_{y\pi}$ ve $\beta_{\pi y}$) indicate the correlations between real and nominal uncertainties.

All the data, except the world oil price, used in the analysis are obtained from CBRT's electronic database in monthly frequency for the 1987:01 - 2018:12 period. Inflation is measured as the headline inflation by the monthly percentage change in the consumer price index ($\pi_t = \log(CPI_t/CPI_{t-1})$). Since monthly GDP figures are not observable, monthly output series are proxied by the industrial production index that represents the highest correlation with GDP figures. To represent the real exchange rate, we use CBRT's real effective exchange rate index based on consumer prices while the interest rate is measured as the short term interest rate in the interbank money market. Since analyzing period covers a pretty long time, some indexed variables like consumer prices and real effective exchange rate were subject to base year change. Therefore, these series were extrapolated backwards by using the old ones' monthly rate of change and re-indexed by accepting as 1987:01=100. Oil prices in dollar terms in the estimation period comes from the IMF's database. All the gap series are defined as deviations from Hodrick – Prescott filtered series. It is the statistical requirement to test the stationary of the variables that are going to be used in the estimation. For each variable and sub-sample, together with the whole sample, we used ADF and KPSS tests. Obtained stationary test results in Table 1 show that all the "gap" series are stationary in their levels.

Table 1: Unit Root Test Results

Variable	*ADF*	*Lags*	*KPSS*	*Band*	*Variable*	*ADF*	*Lags*	*KPSS*	*Band*
1987:01 – 1994:04					***2001:03 – 2018:12***				
gapy	4,847*	11	0,198*	11	*gapy*	3,935*	12	0,246*	8
gapp	4,904*	0	0,079*	0	*gapp*	9,904*	1	0,172*	6
gape	2,555**	0	0,172*	3	*gape*	9,943*	1	0,036*	7
gapi	4,133*	0	0,247*	3	*gapi*	34,831*	13	0,376**	3
gapo	6,700*	3	0,039*	0	*gapo*	9,760*	0	0,023*	1
1994:05 – 2001:2					***1987:01 – 2018:12***				
gapy	3,451*	11	0,139*	9	*gapy*	6,150*	12	0,079*	6
gapp	10,727*	1	0,069*	3	*gapp*	6,656*	13	0,024*	2
gape	13,937*	1	0,318*	2	*gape*	12,759*	1	0,021*	2
gapi	2,755a,**	1	0,369**	2	*gapi*	13,504*	3	0,084*	6
gapo	8,727*	0	0,076*	1	*gapo*	13,969*	0	0,018*	2
Notes: a refers to the inclusion of trends. * and ** refer to acceptance of stationary in the relevant series at 1% and 5% levels of significance, respectively									

As noted above, the model in our study is based on two fundamental equations: output gap and inflation that we call aggregate demand and Phillips curve equations, respectively. Estimation results of these equations are given in Table 2. Before analyzing the estimation results, some points should be clarified relevant to the estimation procedure. Principally, results in the table belong to the model producing lower autocorrelation and eliminating the ARCH effect. In the estimation procedure, however, we tried to estimate the basic equations with statistically significant variables. However, we were confronted with autocorrelation and ARCH problems in the GARCH model. To overcome these problems, we estimated the fundamental equations for different lags and predicted a 24-month lag as the optimal.

Table 2: Estimation Results of Fundamental Equations for Various Samples

Variable	1987:01-1994:04		1994:05-2001:02		2001:03-2018:12		1987:01-2018:12	
	Coefficient	t - ratio	Coefficient	t - ratio	Coefficient	t - ratio	Coefficient	t - ratio
Output Gap Equation								
$gapy_{t-i}$	13,295	4,744*	-6,192	2,883**	-8,778	6,437*	-8,026	7,836*
$gapp_{t-i}$	-10,656	2,020**	-2,068	0,456	-3,408	0,964	-3,015	1,486**
$gape_{t-i}$	17,184	2,131**	2,956	0,527	-0,492	0,277	0,048	0,035
$gapi_{t-i}$	9,984	1,796**	0,289	0,241	-1,761	1,302***	-0,708	1,828**
$gapo_{t-i}$	1,735	1,283***	0,791	0,945	0,902	1,508**	0,856	2,100*
Phillips Curve Equation								
gay_{-i}	-3,571	1,242***	1,719	1,361***	0,301	0,822	0,694	1,608**
$gapp_{t-i}$	-4,773	2,026*	-2,201	2,663*	-0,860	1,935**	-1,555	3,643*
$gape_{t-i}$	0,194	0,106	-3,007	4,689*	-1,033	3,945*	-1,326	4,184*
gap_{-i}	-0,887	1,187	-0,253	1,381***	0,109	0,972	-0,117	1,122***
Note: *, **, and *** refer that the coefficient is statistically significant at 1%, 5% and %10 levels of significance, respectively.								

As Table 2 indicates, all the statistically significant coefficients have theoretically expected signs. However, in the context of the aggregate demand equation for the 1994:05-2001:02 period and in the context of the Phillips curve equation for the 1987:01-1994:04 period, estimated coefficients are statistically insignificant although they carry expected signs theoretically. Therefore, these sub-periods are excluded from the analysis and the rest of the paper focused on the 2001:03-2018:12 sub-period and 1987:01-2018:12 whole period. The sub-period can also be called the inflation-targeting era for the Turkish economy. Under these restrictions, Table 3 presents the results of the variance equation, which is based on the statistically significant estimates mentioned above.

The first remarkable result in Table 3 is that there is no difference in signs of estimated coefficients for two periods while there are only little differences for coefficient magnitudes. We can say that estimated coefficients get smaller in the full sample period compared to the sub-sample. Parameters of volatility tradeoff ($\beta_{y\pi}$ ve $\beta_{\pi y}$) show the degree of correlation between the conditional variance of one variable and the past conditional variance of the other. Obtained results show that the effect of the lagged output gap on inflation volatility is statistically significant. Diagonal elements of A matrix ($\beta_{\pi\pi}$ ve β_{yy}), on the other hand, measure the persistence of conditional variances. According to the table, volatility of output gap tends to be higher than inflation volatility, indicating that the former has a higher level of persistency than the latter. This situation is more distinct in the 2001:03-2018:12 sub-sample period. Volatility transmission between inflation and output gap is checked by the tests on off-diagonal elements of matrix B. We calculated Ljung-Box Q and Lagrange Multiplier statistics for the 12th and 24th months for levels and squares of the residuals obtained from the BEKK methodology. Calculations of this process which are presented in Table 4, indicate no sign of serial correlation in the distribution of residuals. Performed Wald test results demonstrate that the null hypothesis of no cross effect is rejected and, therefore, the existence of volatility transfer from output gap to inflation (and vice versa) should be accepted.

Table 3: Results of Variance Equations

Parameter	2001:03 – 2018:12		1987:01 – 2018:12	
	Coefficient	Marginal Significance	Coefficient	Marginal Significance
Constant Terms				
γ_{yy}	0,436	0,258	-0,311	0,091
$\gamma_{y\pi}$	0,623	0,000	-0,685	0,000
$\gamma_{\pi\pi}$	0,001	0,814	0,003	0,912
Transmission				
α_{yy}	0,335	0,312	0,299	0,101
$\alpha_{y\pi}$	-0,355	0,038	-0,392	0,000
$\alpha_{\pi y}$	0,188	0,421	0,082	0,333
$\alpha_{\pi\pi}$	0,247	0,091	0,219	0,100
Tradeoff				
$\beta_{y\pi}$	0,155	0,314	0,169	0,088
$\beta_{\pi y}$	-0,909	0,033	-0,951	0,000
Wald Test				
$\pi \rightarrow y$ $(H_0= \alpha_{y\pi}= \beta_{y\pi}=0)$	2,791	0,075	13,361	0,000
$Y \rightarrow \pi$ $(H_0= \alpha_{\pi y}= \beta_{\pi y}=0)$	4,818	0,038	9,712	0,000
Persistence				
β_{yy}	0,819	0,000	0,744	0,000
$\beta_{\pi\pi}$	0,487	0,000	0,409	0,000

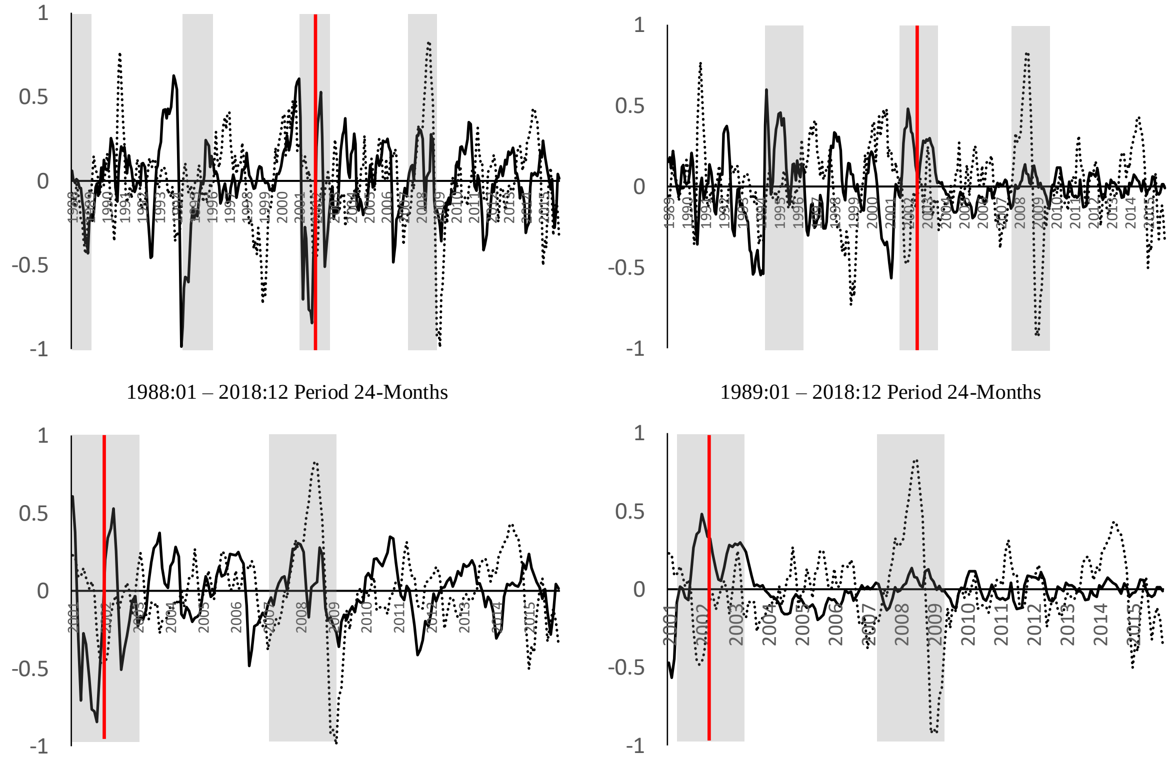
Table 4: Residual Diagnostics for Variance Equations

Test	2001:03 – 2018:12		1987:01 – 2018:12		2001:03 – 2018:12		1987:01 – 2018:12	
	Test Statistic	Marginal Significance	Test Statistic	Marginal Significance	Test Statistic	Marginal Significance	Test Statistic	Marginal Significance
Aggregate Demand Equation					***Phillips Curve Equation***			
Q(12)	8,143	0,423	6,125	0,385	5,241	0,311	4,222	0,356
Q(24)	12,458	0,675	10,005	0,523	10,412	0,558	9,998	0,575
$Q^2(12)$	4,369	0,314	4,218	0,298	3,111	0,212	2,119	0,112
$Q^2(24)$	10,877	0,415	8,441	0,388	9,455	0,401	8,413	0,366
LM(12)	4,725	0,199	5,144	0,177	3,252	0,128	2,988	0,115
LM(24)	18,555	0,061	12,123	0,085	6,419	0,148	5,887	0,162
$LM^2(12)$	0,714	0,877	1,145	0,745	1,223	0,742	1,665	0,676
$LM^2(24)$	12,244	0,557	10,857	0,433	8,456	0,453	7,453	0,558

Notes: Q and Q^2 are the Ljung-Box serial correlation tests for residuals and squared residuals, respectively, while LM and LM^2 show the Lagrange Multiplier serial correlation tests for residuals and squared residuals, respectively

A. Empirical Evidence for Taylor Curve Relationship

In this part of the paper, we are going to explore the relationship between the Taylor curve and economic growth performance. Our main objective is to investigate the structure of the correlation between the output gap and inflation at various stages of the business cycle and in inflation targeting and to examine the causes of structural change if it exists. To analyze whether there are positive correlation periods (that is, whether monetary policy cares about output or inflation) constitutes the other objective of this section. We use 12 and 24 months rolling correlations which seems reliable for forward-looking monetary policy since, as it is generally accepted, interest rate changes influence the economy within 1 ½ to 2 years. Figure 1 presents calculated rolling correlations on a 12 and 24-month basis. Before going further, we should notice that the tendency pictured in the figure is not a causality analysis; it just depicts to help understand the structure of the Taylor curve.



1988:01 – 2018:12 Period 24-Months

1989:01 – 2018:12 Period 24-Months

2001:03 – 2018:12 Period 12-Months

2001:03 – 2018:12 Period 24-Months

Notes: Shaded areas show recession periods while the red vertical line indicates inflation-targeting monetary policy. The solid black line represents 12 or 24 months rolling correlations between output and inflation volatilities, while the dashed line shows the change rate of real GDP.

Fig. 1 Rolling Correlations between Inflation and Output Growth

At first glance, our findings show that the relationship discussed above is negative most of the time during the analyzing period. The presence of an adverse relationship between conditional variances of inflation and production supports theoretical expectation. According to the results obtained, there is a slowdown in economic growth after periods of positive tradeoff. This finding can be considered as an indicator that the output growth rate of the economy might be adversely affected in these inefficient monetary policy periods. Estimation for the whole sample period shows that the evidence for this tradeoff gains strength during the last years of the 90s (the last years before the inflation targeting regime). This confirms the view that the tradeoff between inflation and output gap volatilities has already begun before the inflation targeting. Considering the fundamental result obtained from the above graphics, we can reach some interesting conclusions when we analyze the average conditional variances of inflation and output gap in terms of three sub-samples (1987:01-1994:04, 1994:05-2001:02 and 2001:03-2018:12). Results on the basis of these periods are visualized to draw Figure 2 while we present scatter plots of conditional variances for the same periods in Figure 3. To calculate volatilities, we used the whole sample period (1987:01-2018:12). As can be seen in the examination of the related figures, the average variances calculated for the period 1987: 01 - 1994: 04 show an opposite performance compared to the period 2001: 03-2018: 12. This improvement can be said to be the result of a more consistent monetary policy. In fact, the use of inflation expectations as an anchor in the second period created a significant decrease in inflation volatility. The beginning of the inflation targeting regime in Turkey, unlike in other countries, does not coincide with a long period of economic stability. However, with the beginning of the inflation targeting regime (including the implicit inflation targeting period in 2002-2005), there was no economic instability resulting from the internal dynamics of the country. In other words, the Taylor curve has shifted towards the axes (i.e., inward) since lower inflation volatility was realized for a given output gap volatility in the economy.

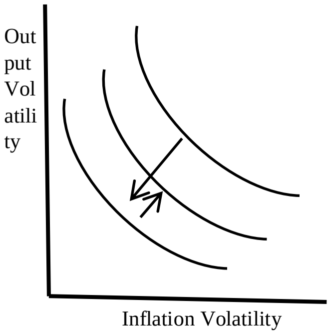
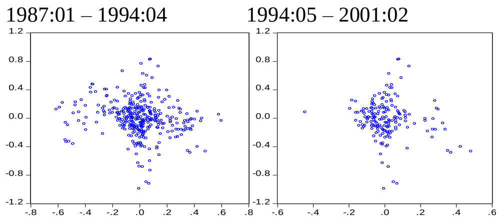
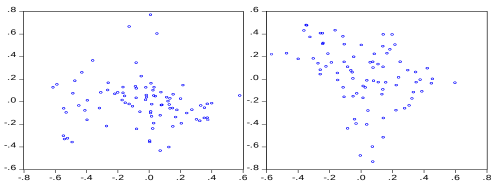


Fig. 2 Shifts in Taylor Curve



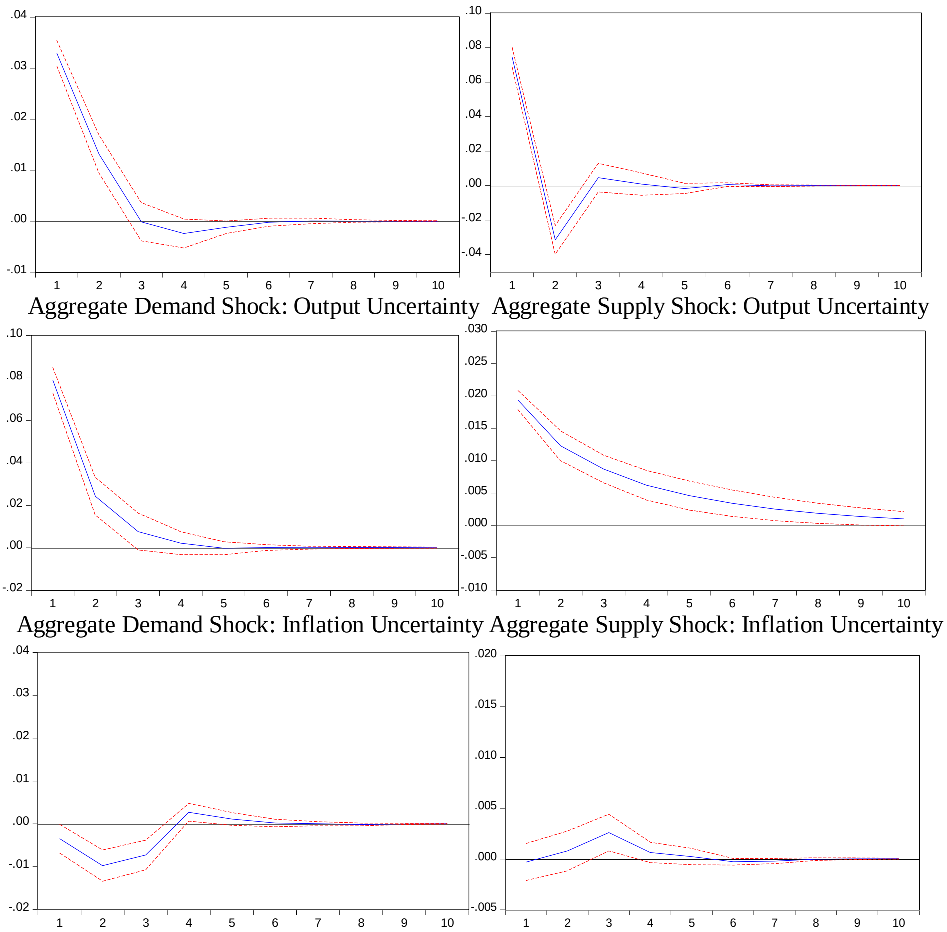


2001:03 – 2018:12 1987:01 – 2018:12

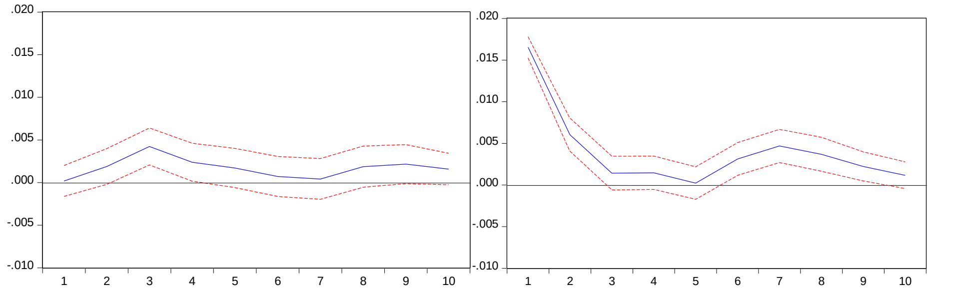
Fig. 3 Scatter Plot Diagrams of Inflation and Output Gap Volatilities by Periods

B. Persistency of Volatility against Economic Shocks

How aggregate demand ($\varepsilon_{y,t}$) and aggregate supply ($\varepsilon_{\pi,t}$) shocks obtained from fundamental equations affect the conditional variances of inflation and output gap is the other important issue to analyze. By using the methodology suggested by Olson et al. (2012), we estimate Equation (4) in a VAR form. The effects of these shocks and the reactions of production and inflation uncertainties can be examined in Figure 4 below. It is worth noting that in this process, generalized impulse-response functions are used to avoid possible bias caused by the problem of ordering variables.



Response of Output Uncertainty to AD Shock | Response of Output Uncertainty to AS Shock



Response of Inflation Uncertainty to AD Shock | Response of Inflation Uncertainty to AS Shock

Fig. 4 Effects of Aggregate Demand and Supply Shocks on Conditional Variances

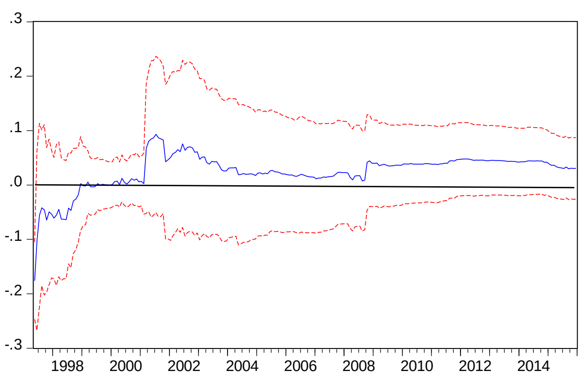
The first reality revealed by the results is that there is evidence that supply and demand shocks are not permanent. Second, shocks on conditional variances of related variables influence the economy only in the short term. Because of the non-persistency in variances, results show the fact that divergences from the Taylor relationship will only be apparent in the short term provided that a central bank conducts an efficient monetary policy (Olson et al., 2012). As clearly seen in the lower part of Figure 4, the effects of aggregate demand-supply shocks are transitory. These temporary effects are more distinct and short-lived (about 6 months) in the case of output uncertainty, while they are more substantial and long-lived (about 10 months) in the case of inflation uncertainty.

C. Taylor Curve and Taylor Rule in Conducting Monetary Policy

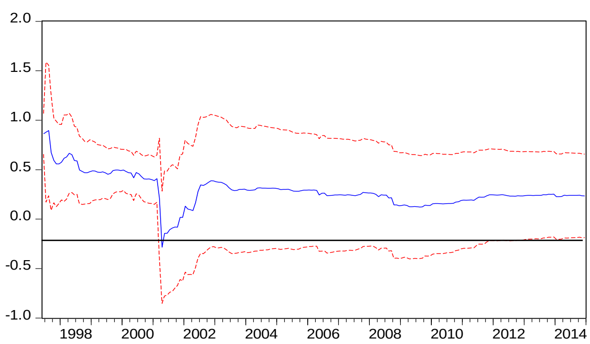
If the response of a central bank is in accordance with the Taylor rule, investigating the correlations among variables can present additional evidence for the Taylor curve relationship. If we consider the loss function in Equation (1), the optimal response for a central bank is the Taylor rule. As stated above in the discussion of the results, there are greater negative tradeoffs during the inflation-targeting era. Here, we investigate whether these tradeoffs match the period in which monetary policy was conducted with respect to the Taylor rule. In order to test whether positive reactions of the CBRT are suitable to the structure of the economy and the Taylor rule, we are going to use different methods. Analyzing the appropriateness to Taylor principle makes it possible to evaluate the monetary policy optimality more accurately. As noted in Olson et al. (2012), we should test whether the backwards-looking coefficients of Equation (5) below (θ_1 and θ_2) are big enough to make inflation and output stable. Equation (5) is estimated as rolling regressions for ten-year (120 months) periods.

$$i_t = \theta_0 + \theta_1\pi_t + \theta_2 y_t + \theta_3 i_{t-1} + \theta_4 i_{t-2} + \varepsilon_t \qquad (5)$$

The reason to prefer a ten-year period for rolling coefficients of all variables is to involve entirely the time elapsed from the introduction of the inflation targeting regime in Turkey. Estimated rolling coefficients are given in Figure 5 below. Equation (5) was initially estimated for 12 lags ($t = 1 \ldots 12$), insignificant lags were removed from the equation, and as a result, the equation was reduced to two lags. In fact, what interests us in this equation is the parameters of inflation and output gaps(θ_1 and θ_2). The inflation coefficient (θ_1) is mostly negative in the pre-2002 period, and again mostly, it is not statistically significant. Nevertheless, the coefficient becomes positive during the targeting term and becomes statistically significant. The output gap coefficient is mostly positive and statistically significant in certain periods.



Rolling Coefficients for Inflation



Rolling Coefficients for Output Gap

Fig. 5 Coefficients of Inflation and Output Gap for Rolling Regression Equation

Another point that should be questioned at this point is what the results of the Taylor rule show us about the implementation of monetary policy. According to the Taylor rule, the value of $\frac{\theta_1}{(1-\theta_3-\theta_4)}$ The term should be greater than the unity for well-regulated anti-inflationary policies. If this value is less than 1, it is understood that policymakers allow the interest rate to decrease when there is an inflationary shock and the interest rate to increase when there is a disinflationary or deflationary shock. Taylor proposes two basic policy rules for evaluating monetary policy. For this purpose, Figure 6 is prepared; however, some explanations are needed to read this figure. The dashed straight line in the Figure shows the value 1, which is a critical value for the evaluation of the optimality of monetary policy. The solid line indicates the calculated monetary policy stance for the Turkish economy. Each point over the dashed line states the robustness of the Taylor rule and points out monetary policy optimality. The points under the dashed line indicate that there is a lack of optimality in the conduct of monetary policy. According to Figure 6, the null hypothesis (θ_1 = 0) cannot be rejected for most of the pre-2002 period. It is possible to say that the Taylor principle was realized in the post-2001 period (excluding the temporary break in 2010 following the 2009 recession). This situation indicates that the monetary policy carried out during the inflation targeting period is closer to the optimality compared to the period before inflation targeting. This finding of the Taylor rule supports the evidence for "the existence of a negative tradeoff between volatilities in inflation targeting period" obtained through the Taylor curve and rolling regression estimates.

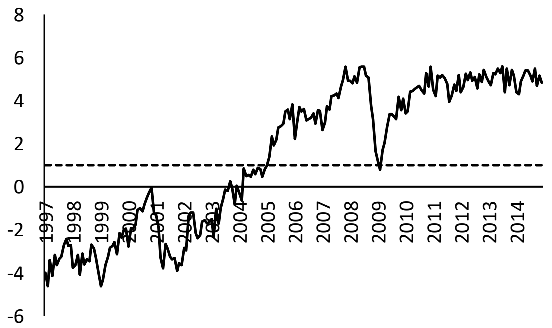


Fig 6: Taylor Rule and Monetary Policy Stance in Turkey

VI. CONCLUSION

In this study, the relationship between output and inflation volatilities is empirically examined. In order to determine the interaction between inflation and output volatilities, the GARCH model was estimated using the BEKK algorithm. In order to obtain the time-varying Taylor curve relationship rolling correlation, the technique has been used while impulse-response functions have been used to evaluate the effect of aggregate demand and supply shocks on conditional variances of output and inflation. Under the assumption of the constant Taylor curve, the optimality of monetary policy in the inflation targeting regime was evaluated by applying the Taylor rule and by questioning the extent to which the monetary policy fulfils its function.

According to the results obtained, the Taylor curve shifted during the sampling period and moved inward in the inflation-targeting era. In addition, the growth record of the economy is stronger in terms during which the relationship expressed by the Taylor curve exists. Evidence has been reached showing that the economic slowdown was experienced during the periods when the tradeoff between the output gap and inflation volatilities was positive and strong, but this was short-term. Another result of this study is that aggregate supply and demand shocks do not have a lasting effect on the output gap and inflation volatilities. Evidence from the Taylor rule shows that monetary policy is optimal in the period of inflation targeting compared to previous monetary policy strategies. Outcomes of examining the extent to which distant policy strategies have succeeded in stabilizing inflation, and the output gap have varied considerably over the years. According to these results, it can be said that as a result of the monetary policies carried out prior to inflation targeting, the economy is located in the upper regions of the Taylor curve. Estimations related to the inflation targeting era in Turkey indicate that monetary policy is sufficiently flexible in directing the regime. As a result, considering that price stability is a legal duty and this has a negative effect on output, it is possible to say that the Central Bank performs its policy decisions in an appropriate and balanced manner against two types of gaps (inflation gap when inflation deviates from the target and output gap when actual output deviates from potential).

The transition to inflation targeting regime minimized the volatility in inflation and directed the economy towards price stability. In this context, the implementation of monetary policy is aimed at minimizing the expected and unexpected inflation deviations. Movements of the Taylor curve since the global financial crisis of 2007 indicate that decision-makers should focus on reducing inflation and outputvolatilities. Let us emphasize once again that the deviation criteria developed in this study include expected and unexpected deviations. While the expected volatility deviations can be eliminated by economic agents (i.e. they can protect themselves against the expected volatility deviations), the unexpected volatility deviations affect the investment and consumption decisions of economic units. Therefore, policymakers should strive to minimize unexpected volatility deviations that adversely affect the economic growth performance of the economy. This conclusion is consistent with Friedman (1977)'s view that inflation uncertainty slows down economic growth. One of the remarkable results obtained in this study is the deceleration tendency observed in economic growth after periods of positive tradeoff. In other words, when inflation and output volatilities change positively, the growth performance of the economy weakens for a period of time. This positive tradeoff indicates that there is no movement on the efficiency frontier. On the contrary, it is shifted. As a result, it is possible to say that monetary policy deteriorated from optimality during the periods of positive tradeoff, and this negatively affected the economic growth performance of the Turkish economy. It is also possible to say that the outward shifts from the origin bear a cost of welfare since outward shifting means increasing inflation volatility which causes a decrease in purchasing power of economic units. Such a period will also be a period in which the purchasing and investment plans are negatively affected. As the Taylor curve moves away from the origin, policymakers confront the problem of not being able to minimize inflation and output volatilities. Such a situation is not an ideal one because of the weakening of tradeoffs and the slowdown in economic growth compared to periods in which volatilities are minimized.

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