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The Origins and Dynamics of Inflation in Turkey: An SVAR Approach

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Abstract

This study aims to present empirical evidence on the relative importance of supply and demand-side factors in determining the fluctuations in the general level of prices in the Turkish economy. The employed strategy uses the view that supply and demand pressures can be distinguished from each other depending on the direction of their effects on price and quantity. After classifying the related economic variables as supply, demand, and common factors, the main determinants of domestic supply and demand were estimated econometrically using sample data from 2003:1–2021:4, and their relative contribution to inflation was calculated. By using these basic determinants, the estimated structural vector autoregressive (SVAR) model shows that the pressures arising from the supply side are more dominant than the pressures of the demand side on the inflationary process in Turkey. The results indicate that the methodology suggested in this study will be useful in separating the factors that contribute to inflation, which has recently gotten out of control in Turkey and is gradually moving away from the targeted inflation. Policymakers considering these findings can reach optimal decisions in conducting the monetary policy toward the targeted level of inflation.

Keywords: Inflation, Monetary policy, SVAR, Turkey.
JEL Classification: C32; E17; E31; E50.

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Contribution of this paper to the literature
This paper presents empirical evidence of the sources of the recent inflationary pressures in the Turkish economy. The methodology used (SVAR) differs from the previous studies, and the results show that inflation is basically driven by supply-side factors contrary to the widespread belief that it is a demand-pull process.

1. Introduction

Empirical studies on inflation, sometimes due to the uncertainty in its measurement, and sometimes the difficulty in determining the factors underlying its change, are a focus for monetary policymakers. Both reasons are closely related to better conduct of monetary policy. On the one hand, if inflation is not measured correctly, it will not be possible to distinguish the permanent factors that create inflationary pressure from the factors that create temporary fluctuations in the inflation rate. On the other hand, if the source of inflationary pressure is indistinguishable (i.e., whether supply-side factors or demand-side factors are dominant in the inflationary process), it will be very difficult to determine the right path for monetary policy. Although both reasons are important, this study focuses on the second reason, that is, a method that makes it possible to distinguish between inflationary pressures caused by shifts in domestic demand and those caused by shifts in supply.

In this study, empirical evidence on the relative importance of demand and supply factors in determining the causes of fluctuations in the general price level as measured by the Consumer Price Index (CPI) in the Turkish economy is investigated. The method developed to determine the source of these pressures is discussed and the contributions of structural shocks and macroeconomic factors to the observed inflation rate are analyzed. Determinations of structural shocks and analysis of the impulse response and variance decomposition are performed using the vector auto regression (VAR) methodology.

The proposed method starts with the classification of the factors that shift domestic supply and domestic demand. The selection of the variables is carried out by considering their effects on price and quantity in the domestic market. Specifically, if the shock observed in a variable has an adverse effect on inflation (price level) and domestic demand (quantity), this variable is classified as a factor that shifts supply. For example, if a shock in a variable causes a positive reaction in inflation and a negative reaction in output, it should be considered as a factor that creates a shift that represents the decrease in supply. If the shock in a variable has the same effect on price and quantity, this variable is considered a demand-shifting factor. If a variable increases prices but its effect on quantity cannot be clearly determined (for example, the effect of wages on quantity), this variable is classified as a *control variable* that affects both supply and demand. After determining the variables that shift the supply or the demand according to the net effects they create, the multivariate reduced VAR model is estimated. This model includes domestic demand and inflation rate in addition to supply and demand shifting factors. In this process, variables that can affect both supply and demand are included in the VAR model as control variables. In the next step, structural shocks are identified by diagonalizing the variance-covariance matrix of the reduced VAR residuals, and thus uncorrelated structural shocks are obtained so that the effects of identified supply-side and demand-side shocks can be analyzed. In other words, it can be determined whether the variation in inflation is caused by the factors that shift the supply or the demand. The practical advantage of this method is that, instead of describing supply and demand shocks as "anonymous" or "intuitive", it allows the empirical determination of the contribution of these shocks to the variations in inflation by obtaining the shocks in the observed variables. Thus, since the contribution of structural shocks to past inflation can be determined, the effect of observed variables on inflation dynamics can be accurately evaluated. In this case, policymakers can make decisions by considering the contribution of structural shocks in the observed variables to inflation. This makes a positive contribution to understanding and explaining the results of the decisions.

Within the framework of this method, the inflation and real domestic demand series (representing the price level and quantity of output, respectively) were subjected to a preliminary examination through quarterly data for the 2003:1–2021:4 period in Turkey (see Figure 1). In the sample period, inflation was subject to shocks from different sources and fluctuated around 11% annually on average. When the period after the change in the administrative structure of the country (transition from the parliamentary system to the presidential system) was carried out, with the referendum in 2018 excluded, this value was around 8% closer to the target set by the Central Bank of the Republic of Turkey (point target ∓ 2%). The highest inflation rate during the sample period was 26% in 2021:4. As of the end of 2019, it is seen that inflation has gotten out of control. This period corresponds to the term during which the effects of excessively expanding monetary aggregates as a result of the Covid-19 pandemic that emerged at the beginning of 2020 began to show. When fluctuations in international energy prices, increases in agricultural product prices, especially wheat, and mistakes made in monetary policy (reducing the policy rate despite increasing inflationary pressure) were added to this process, the link between the inflation target and the actual inflation was broken (see Figure 1). The lowest annual change in prices is the 4.4% increase in the 2011:1 quarter. This corresponds with the period when the decrease in oil prices was at its highest level. While the average change observed in domestic output over the sample period was an increase of 5.5%, the deepest economic contraction was the -14.4% decrease in production experienced in 2009:1 as a result of the 2008 global crisis. The fastest economic expansion is the approximate 21% increase in output in 2021:2 after the contraction observed due to the Covid-19 pandemic.

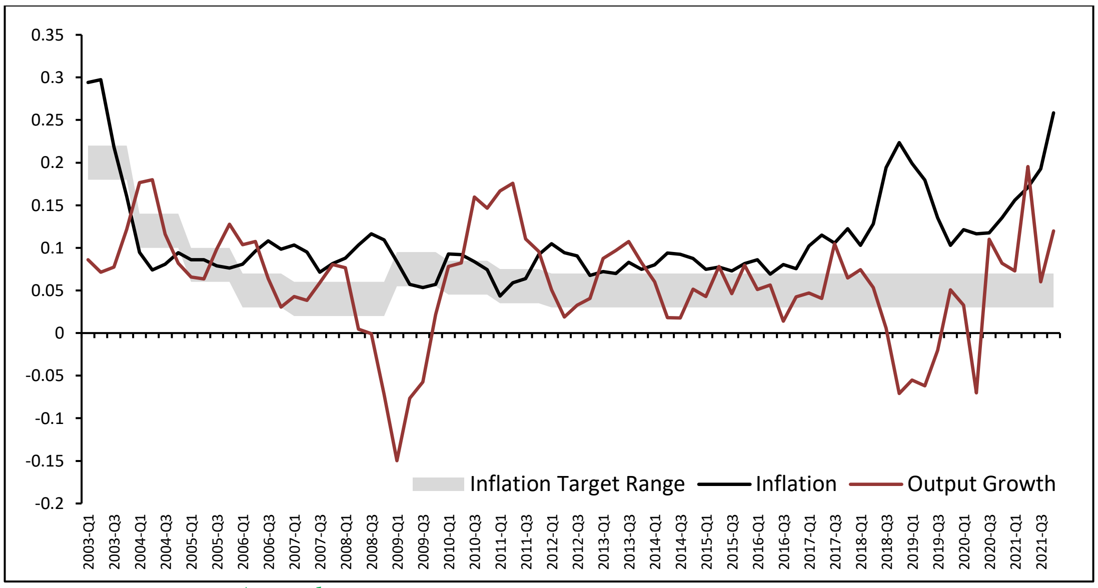


Figure 1. Annual percentage change in price level and real domestic demand.

The remainder of the study is organized as follows: Chapter 2 gives a summary of the literature, Chapter 3 discusses the methodological issues, Chapter 4 deals with the VAR model estimation, Chapter 5 discusses the estimation results, and finally, Chapter 6 highlights the conclusions reached.

2. A Short Literature Review

Many studies deal with the identification of unobservable shocks and the effect of these shocks on observed data. The basis of this approach is based on the study by Blanchard and Quah (1989), in which the bivariate SVAR model consisting of the production growth rate and the unemployment rate is used to determine the temporary and permanent components of production in the US economy. In this seminal study, the authors use two basic identification assumptions: Demand shocks have no effect on output in the long run, and the variance-covariance matrix for structural shocks is diagonal (i.e., structural shocks are not correlated). According to the empirical evidence obtained, more than 80% of the observed variation in production in the short run is explained by demand shocks. It should be noted that there are many studies in which the proposed method was used in the aforementioned study [for an extensive review of the literature on this subject, see Lutkepohl (2017), and for a short review of the recent empirical literature, see Siklar and Siklar (2022)]. In most of the applied studies, various identification constraints and parametric restrictions are used in the covariance matrix of structural shocks.

Cover, Enders, and Hueng (2006) propose an alternative to the Blanchard and Quah methodology through an equation system in which aggregate demand - aggregate supply is used. They use the inflation series instead of the unemployment series and apply a decomposition method where the covariance of supply-demand shocks is non-zero (thus allowing for some correlation between structural shocks). The basic argument for enabling this correlation is that economic policymakers can take into account the past consequences of these shocks when they make policy decisions. Using these criteria, a 54% correlation in the long term and a 70% correlation in the short term is determined between supply and demand shocks. The authors use these values to verify their assumptions. Using a similar model to the aforementioned, Enders and Hurn (2007) estimate for Australia with the addition of an aggregate supply equation and examine the effects of an external supply shock under the assumption that Australia is a small open economy. In their study, the authors identified a 73% correlation between aggregate supply and aggregate demand shocks.

Another method in the estimation of the SVAR models is to impose sign restrictions on the impulse-response functions for the identification of structural shocks. For example, Fry and Pagan (2011) estimate two SVAR models with sign restrictions, the first of which is a supply-demand model in a market with partial equilibrium, and the second is a small-scale macroeconomic model. In both models, "given" sign matrices are used for creating orthogonal matrices to identify and distinguish supply and demand shocks. The authors use impulse-response functions consistent with the signs describing the demand shock (shocks with an adverse effect on price and quantity). The macroeconomic model includes the policy interest rate in addition to the price and output series. Sign restrictions, according to the authors, are a useful strategy for identifying multiple shocks in an empirical analysis. Similarly, Ouliaris and Pagan (2015) estimate the same model with two different methods. In the first of these, a large number of uncorrelated shocks are created, thus obtaining an equal number of impulse-response functions satisfying the sign restrictions. In the second method, some elements of the variance-covariance matrix are constrained and the model is simulated randomly to obtain a large number of impulse-response functions. The results obtained are quite close to each other, independent of the method.

Another advancement in evaluating the results of SVAR models is the use of historical variance decompositions. Pagliacci (2016) estimates a sign-restricted SVAR model using data from the USA and some Latin American countries and calculates the historical decomposition of output growth in response to supply and demand shocks. Thus, depending on the dynamic effects of structural shocks on prices and output, two new indicators are presented to those who make monetary policy decisions. The findings show that more than half of the variation in output in five of the eight countries in the sample is due to supply shocks. On the other hand, it is also among the findings that a significant part of the variation in inflation in the short and long terms is explained by supply shocks.

Since there is a large amount of applied literature on the sources of inflation for both developed and developing countries, we only review the recent prominent studies which consider the subject from a point of view similar to ours. For instance, Benkovskis, Kulikov, Paula, and Ruud (2009), by using the backward-looking Phillips curve model and VAR method for estimation, reach the conclusion that the output gap (cyclical demand) explains a large part of the long-run inflation in Baltic countries. They also point out that supply shocks affect core inflation through expectations. Barnett, Bersch, and Ojima (2012) use Mongolian data for the 2002–2011 period and state that inflation is largely due to food prices and domestic demand pressures. By estimating a VAR model and forward-looking Phillips curve, the authors found that changes in food prices as a result of agricultural supply shocks, high-level fiscal spending as a result of wage increases, and excess demand are the main determinants of the inflationary process in Mongolia. Mohanty and John (2015) studied inflation in India through a time-varying parameter (TVP) SVAR model and concluded that the price of crude oil and exchange rate from the supply side and the output gap from the demand side are predominant factors in the inflationary process. Szafranek and Hałka (2019) analyze Polish inflation through an SVAR model estimated using Bayesian techniques. They conclude that global demand and oil prices are the main factors affecting inflationary pressures in Poland depending on both aggregated and disaggregated analyses. Sharma and Padhi (2021) employ the Bayesian dynamic factor model to obtain a measure of demand-supply using sectoral outputs and input-output linkages in India. They conclude that supply is more persistent than demand while demand creates more volatility than supply in the inflationary process. They also find that the estimated demand-supply measure has more predictive power than conventional measures. Depending on an estimated Bayesian SVAR model, Alonso, Kataryniuk, and Martínez-Martín (2021) find that the recent increase in prices in the Euro area basically stems from demand shocks, while negative supply shocks contribute to gradually increasing prices. They also state that the response of prices to demand shocks persists longer than that of supply shocks. Yilmazkuday (2022) analyzes Turkish inflation through an SVAR model estimated with monthly data for the 2005–2021 period. His results show that the volatility in inflation is explained to a great extent by oil prices and exchange rate movements in the long run. He also points out that conventional monetary policy, which contains policy rate increases following positive inflation and depreciation shocks, would be optimal to reach price stability in Turkey. Lopez and Sepulveda (2022) use the two-stage least squares (2SLS) and generalized method of moments (GMM) methods and find that domestic demand plays a very limited role in creating inflationary pressure in Chile during the 2000–2021 period. Based on a simulated VAR model, the study concludes that a large part of the domestic inflation in Chile is due to foreign inflation. By using the Phillips curve decomposition model, Shapiro (2022a) and Shapiro (2022b) show that recent inflation in the United States essentially stems from the supply-side factors reflecting labor shortages and global supply disruptions. He also states that this brings the possibility of a period of low economic growth and a high level of inflation.

3. Methodology

This section provides details on the methodology used to determine the sources of inflationary pressures in the Turkish economy. The steps related to the method applied can be listed as follows: (i) identifying the variables that can be classified as supply shifting or demand shifting, (ii) estimating the multivariate VAR model and obtaining uncorrelated structural shocks, (iii) calculating the moving average vector (VMA) for the SVAR model, (iv) determining the contribution of the structural shock for each variable classified as supply shifting and demand shifting, and (v) estimating the impulse-response functions and variance decompositions.

3.1. Determination of Variables Shifting Supply or Demand

3.1.1. Partial Equilibrium

The idea of variables shifting the domestic supply and demand curves arose from a partial equilibrium analysis. Suppose there are K time-isolated markets and they are indexed by $\kappa = 1, 2, \ldots, K$. For each market κ, p_κ is the price of a basket of goods that brings together the goods and services in the economy, y_κ is the quantity of these goods and services, and x_κ is the vector of variables that reflect the characteristics of the market. The domestic demand function, $d_\kappa^d(.)$, for each κ market defines the quantity of goods and services that consumers are willing to buy, while the domestic supply function, $s_\kappa^d(.)$, defines the quantity of goods and services that firms want to sell in the market. Both consumers and firms have price-taker identities in the market. On the other hand, both supply and demand are functions of the price (p_κ).

When domestic markets are in equilibrium, the realized transaction volume (y_κ) is assumed as the equilibrium quantity. In other words, for all markets, price (p_κ) is set to equalize domestic demand and supply:

$$d_\kappa^d(p_\kappa; x_\kappa) = s_\kappa^d(p_\kappa; x_\kappa) = y_\kappa \quad (1)$$

For each κ market, the observable variables (for which the data is available) are equilibrium price (p_κ) and equilibrium quantity (y_κ). It is not possible to directly observe the demand $[d_\kappa^d(p_\kappa; x_\kappa)]$ or supply $[s_\kappa^d(p_\kappa; x_\kappa)]$ functions; it is only possible to observe equilibrium transactions and the other variables (x_κ) that contribute to characterizing the market. When we try to identify these functions from the equilibrium transactions, the problem of simultaneity arises since the price and quantity are endogenously determined within the supply-demand system.

The structural description of this simple supply-demand model is:

Domestic Demand: $d_\kappa^d(p_\kappa; x_\kappa) = \alpha_p^d p_\kappa + \alpha_x^d x'_\kappa + \varepsilon_\kappa^d$

Domestic Supply: $s_\kappa^d(p_\kappa; x_\kappa) = \alpha_p^s p_\kappa + \alpha_x^s x'_\kappa + \varepsilon_\kappa^s$

Equilibrium: $d_\kappa^d(p_\kappa; x_\kappa) = s_\kappa^d(p_\kappa; x_\kappa) = y_\kappa$

This system of equations can be simplified as:

$$\text{Demand: } y_\kappa = \alpha_p^d p_\kappa + \alpha_x^d x'_\kappa + \varepsilon_\kappa^d \quad (2)$$

$$\text{Supply: } y_\kappa = \alpha_p^s p_\kappa + \alpha_x^s x'_\kappa + \varepsilon_\kappa^s \quad (3)$$

If we solve the structural equations given by Equations 2 and 3 for p_κ and y_κ, we get the reduced form of the equation system as follows:

$$p_\kappa = \gamma_x^p x'_\kappa + \xi_\kappa^p \quad (4)$$

$$y_\kappa = \gamma_x^y x'_\kappa + \xi_\kappa^y \quad (5)$$

Where:

$$\gamma_x^p = \frac{\alpha_x^s - \alpha_x^d}{\alpha_p^d - \alpha_p^s}$$
$$\gamma_x^y = \alpha_p^s \gamma_x^p$$
$$\xi_\kappa^p = \frac{\varepsilon_\kappa^s - \varepsilon_\kappa^d}{\alpha_p^d - \alpha_p^s}$$
$$\xi_\kappa^y = \alpha_p^s \varepsilon_\kappa^p$$

If Equations 4 and 5 are estimated separately, it will not be possible to obtain an efficient and consistent estimator of the structural parameters due to the identification problem arising from the simultaneous determination of equilibrium price and equilibrium quantity. However, it is not a strict requirement to obtain structural parameters to distinguish inflationary pressures arising from supply-side and demand-side factors. It will be sufficient to accurately estimate the contribution of each factor to the variation in inflation, depending on which of them affects supply and demand.

If we assume that the vector of explanatory variables (x_κ) can be split into three components, we have:

$$x'_\kappa = [x_\kappa^d \ \ x_\kappa^s \ \ x_\kappa^c]$$

where x_κ^d denotes the variables that shift the domestic demand curve but do not affect the supply curve, x_κ^s denotes the variables that shift the domestic supply curve but do not affect the domestic demand curve, and x_κ^c denotes the control variables that can affect both the supply and demand curves. In the system given by the Equations 4 and 5, if x_κ is expanded according to the above definition, we have:

$$p_\kappa = \gamma_{x,d}^p (x_\kappa^d)' + \gamma_{x,s}^p (x_\kappa^s)' + \gamma_{c,\kappa}^p (x_\kappa^c)' + \xi_\kappa^p \quad (6)$$
$$y_\kappa = \gamma_{x,d}^y (x_\kappa^d)' + \gamma_{x,s}^y (x_\kappa^s)' + \gamma_{c,\kappa}^y (x_\kappa^c)' + \xi_\kappa^y \quad (7)$$

The above equations can be estimated individually using ordinary least squares. However, the residual terms ξ_κ^p and ξ_κ^y are correlated and ignoring this may affect the marginal effects to be estimated. On the other hand, most of the consequences resulting from a shift in supply and/or demand will have lagging effects over time. However, we aim to analyze the dynamic effects of the variables that cause shifts in the supply and demand. Therefore, we are not concerned with the estimation of a static model defined in Equations 6 and 7 since only the average effects can be determined. The VAR approach is preferred as it controls the possible correlation between residual terms and allows dynamic analysis. However, the partial market equilibrium outlined above is useful because it clarifies what is to be understood from the variables that cause a shift in the supply and demand curves:

i. Variables that shift domestic demand: Variables that cause price and quantity to move in the same direction.
ii. Variables that shift domestic supply: Variables that cause opposite movements in price and quantity.

3.1.2. Definitions of Domestic Demand and Domestic Supply

The domestic demand and supply aggregates used in this study are obtained from the national accounting:

$$Y_t = C_t + G_t + I_t + X_t - M_t$$

Depending on this basic relationship, we can define the domestic demand and domestic supply as follows:

$$DD_t = C_t + G_t + I_t$$
$$DS_t = Y_t + M_t - X_t$$

Where DD and DS stand for domestic demand and domestic supply, respectively. In the equilibrium, we observe that:

$$Y_t = DS_t = DD_t$$

Instead of real gross domestic product (GDP), the reason for using domestic demand to represent quantity is that domestic demand, like inflation, is more affected by import prices and less affected by export prices when compared with real GDP.

3.1.3. Selection of Variables Shifting Supply and Demand

To determine the variables that shift the supply or/and demand curves a series of unrestricted VAR models, three variables are estimated (price, quantity, and the variable considered to be shifting). In these models, the variable that is thought to be shifting is the most exogenous in the recursive causality ordering (Wold, 1951), and the responses of domestic demand and inflation are analyzed in face of a shock in this most exogenous variable. It is concluded that if the average response of inflation and output is positive in the face of a positive shock in the candidate variable, this variable can be accepted as the variable that shifts the demand curve and can be used in the VAR model to obtain structural shocks. For example, international oil prices (*oil*) can intuitively be thought of as a variable that shifts the supply curve. In other words, an increase in oil prices (as it will increase costs) may cause a contraction in domestic supply and thus an increase in inflation (π) and a decrease in output (y). It is expected that these dynamics will be determined from impulse-response functions obtained from unrestricted VAR models. The specification required for this example is as follows:

$$oil_t = \psi_{1,1} oil_{t-1} + \psi_{1,2} y_{t-1} + \psi_{1,3} \pi_{t-1} + \xi_{oil,t}$$
$$y_t = \psi_{2,1} oil_{t-1} + \psi_{2,2} y_{t-1} + \psi_{2,3} \pi_{t-1} + \xi_{y,t}$$
$$\pi_t = \psi_{3,1} oil_{t-1} + \psi_{3,2} y_{t-1} + \psi_{3,3} \pi_{t-1} + \xi_{\pi,t}$$

The impulse-response functions obtained using the annual rate of change in each variable and the Wold (1951) ordering are given in Figure 2.

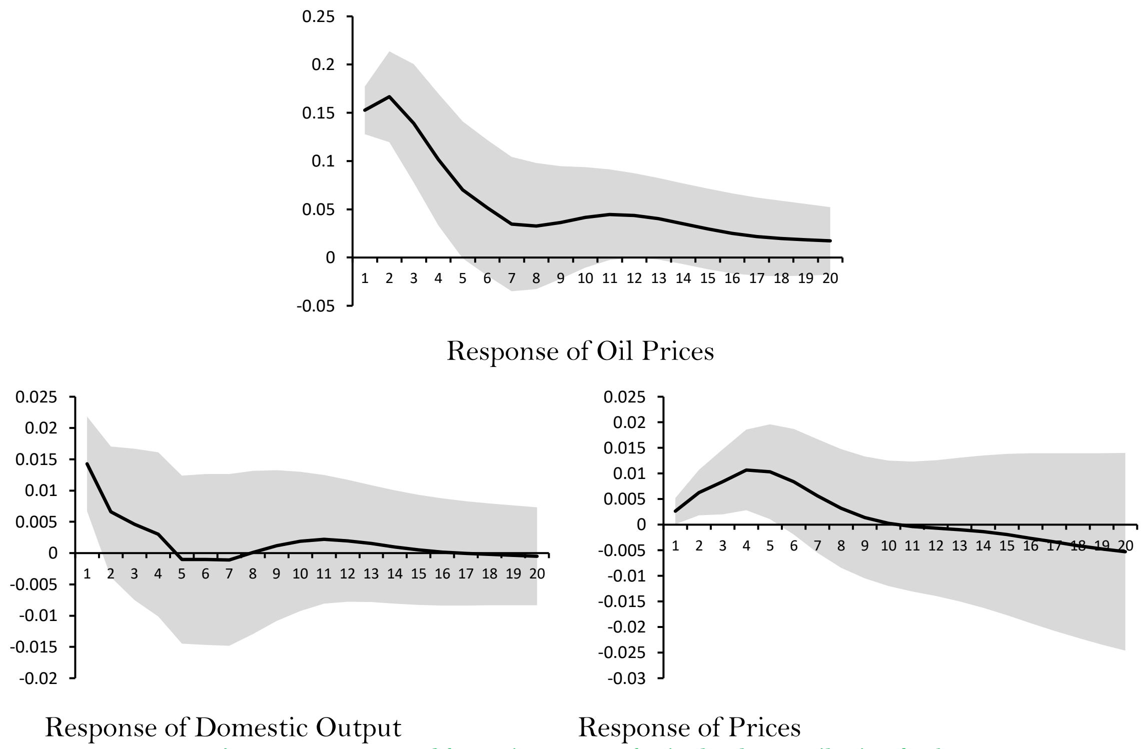


Figure 2. Responses of domestic output and price level to an oil price shock.

As Figure 2 clearly indicates, the average response of domestic output is negative, while inflation is positive. In other words, a positive shock in oil prices creates an adverse reaction in price and quantity, representing an inward shift in the supply curve. Therefore, we can classify oil prices as a variable that shifts the supply curve. On the other hand, if the dynamic structure summarized above had created a reaction in the same direction on price and quantity, we would have to classify this variable as demand-shifting.

This process was carried out for a wide set of variables, and 16 of them were selected and classified as supply and demand shifting variables as follows:

Demand-Shifting Variables: Autonomous consumption expenditures (aco_t), government consumption expenditures (gov_t), total investment expenditures (inv_t), loans to the private sector (pcr_t), foreign credits (fcr_t), and money supply ($ms1_t$).

Supply-Shifting Variables: Import prices (ipi_t), international oil prices (oil_t), international natural gas prices (gas_t), international energy prices (enr_t), domestic energy prices (den_t), and productivity (pro_t).

Control Variables (that shift both supply and demand): Short-term interest rate (int_t), nominal USD/TL exchange rate (nfx_t), real foreign exchange rate (rfx_t), and wages (wag_t).

Among these, nine variables that meet the criteria in the impulse-response analysis summarized above are as follows: Government consumption expenditures (gov_t), loans to the private sector (pcr_t), and money supply ($ms1_t$) as demand shifting variables; import prices (ipi_t), international oil prices (oil_t), international natural gas prices (gas_t), and productivity (pro_t) as supply shifting variables; nominal foreign exchange rate (nfx_t) and wages (wag_t) as control variables. As noted earlier, domestic demand is used to represent output, and the consumer price index is used to represent prices. Thus, there are 11 variables to be used in the VAR model.

3.2. Multivariate VAR Model

3.2.1. VAR Model in Reduced Form

The multivariate VAR model, which includes the variables that are likely to shift supply and demand and measures related to quantity (domestic demand) and prices will be estimated in reduced form. It is necessary to obtain sufficient results in terms of having the statistical properties (including stable, normal, homoscedastic, and unautocorrelated residuals) required for decision-making. Following Hamilton (1994), if the general specification of a *pth*-order VAR is denoted as VAR(1), we have:

$$\zeta_t = \Gamma \zeta_{t-1} + \xi_t \quad (8)$$

Where:

$$E(\xi_t \xi_\tau') = \begin{cases} \Omega \; for \; t = \tau \\ 0 \; other \; wise \end{cases}$$

and

$$\Omega = \begin{bmatrix} \omega & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 \\ \vdots & \vdots & \dots & \vdots \\ 0 & 0 & \dots & 0 \end{bmatrix}$$

In this notation, ζ_t denotes the vector of matrices containing the data without mean, Γ denotes the coefficients matrix, and Ω denotes the variance-covariance matrix of the residual terms. According to general usage, the data series included in ζ_t is the deviation from the steady-state value. According to Hamilton (1994), this is equivalent to subtracting the unconditional expected value from the data: $\mu = \left(I_n - \Phi_1 - \Phi_2 - \cdots - \Phi_p\right)^{-1} c$. If the data studied is relatively short, subtracting the sample mean is a reasonable approach. Thus, the system given in Equation 8 can be estimated with ordinary least squares, and the residual term series (ξ_t) and Ω matrix can be obtained.

3.2.2. Structural Innovations: The SVAR Model

The only constraint to be imposed on the innovations that will be considered structural is that they are not correlated with each other. To impose this property to the residual terms obtained by the estimation of the reduced form VAR model, we need to obtain the matrix H to diagonalize the Ω matrix:

$$H\Omega H' = D$$

where D is a diagonal matrix. Therefore, using the residual terms and the H matrix, we obtain the structural shocks ς_t:

$$\varsigma_t = H\xi_t \qquad (9)$$

satisfying the orthogonality condition:

$$E(\varsigma_t\varsigma_t') = E(H\xi_t\xi_t'H') = D$$

3.2.3. Moving Average (VMA) Representation of SVAR Model

The vector moving average representation is calculated for structural innovations since structural shocks are not observable and are difficult to interpret. The purpose of this calculation is to see the contribution of each structural shock in the formation of variations in inflation. By recursively iterating the stationary VAR model, it is possible to obtain the moving average representation:

$$\begin{aligned} y_{t+s} = \mu + \xi_{t+s} + \psi_1\xi_{t+s-1} + \psi_2\xi_{t+s-2} + \cdots + \psi_{s-1}\xi_{t+1} + \\ \Gamma_{11}^{(s)}(y_t-\mu) + \Gamma_{12}^{(s)}(y_t-\mu) + \cdots + \Gamma_{1p}^{(s)}(y_{t-p+1}-\mu) \end{aligned} \qquad (10)$$

where $\psi_j = \Gamma_{11}^{(j)}$ is the upper left block of Γ^j. The moving average representation of innovations is obtained through (9), which defines the structural shocks, and (10):

$$\begin{aligned} y_{t+s} = \mu + \varsigma_{t+s} + J_1\varsigma_{t+s-1} + J_2\varsigma_{t\pm s-2} + \cdots + J_{s-1}\varsigma_{t-1} + \\ \Gamma_{11}^{(s)}(y_t-\mu) + \Gamma_{12}^{(s)}(y_t-\mu) + \cdots + \Gamma_{1p}^{(s)}(y_{t-p+1}-\mu) \end{aligned} \qquad (11)$$

where $J_s \equiv \psi_s H^{-1}$ and includes the contribution (or weight) of each structural innovation to create the level of series in the y_t matrix. This method transforms structural shocks that are difficult to observe and understand into their contributions to the observable variable, thus simplifying the understanding and interpretation of structural shocks. This is a great advantage when examining results or making policy recommendations.

4. Estimation of the VAR Model

Using the method outlined in the previous section, a VAR model is estimated with eleven variables and with a two-period lag determined according to traditional information criteria (see Appendix 3). Quarterly data covering the period from 2003:1–2021:4 was used for the estimation. All variables are included in the VAR model with the annual rate of change and, according to unit root tests, all of them satisfy the stationarity conditions (see Appendix 2). These variables are as follows: Import price index (*ipi*), Brent oil price index (*oil*), natural gas price index (*gas*), nominal USD/TL exchange rate (*nfx*), government consumption expenditures (*gov*), wage index (*wag*), productivity index (*pro*), loans to the private sector (*pcr*), narrowly defined money supply (*ms1*), domestic output (*dmd*), and inflation (*cpi*). Detailed definitions and sources of the data regarding these listed variables and other previously covered variables are given in Appendix 1.

The estimated model is defined in Equation 8 where:

$$\zeta_t = \begin{bmatrix} y_{t-1}-\mu \\ y_{t-2}-\mu \end{bmatrix};\ y_t = \begin{bmatrix} ipi_t-\mu_{ipi} \\ oil_t-\mu_{oil} \\ gas_t-\mu_{gas} \\ nfx_t-\mu_{nfx} \\ gov_t-\mu_{gov} \\ wag_t-\mu_{wag} \\ pro_t-\mu_{pro} \\ pcr_t-\mu_{pcr} \\ ms1_t-\mu_{ms1} \\ dmd_t-\mu_{dmd} \\ cpi_t-\mu_{cpi} \end{bmatrix};\ \xi_t = \begin{bmatrix} \xi_t^{ipi} \\ \xi_t^{oil} \\ \xi_t^{gas} \\ \xi_t^{nfx} \\ \xi_t^{gov} \\ \xi_t^{wag} \\ \xi_t^{pro} \\ \xi_t^{pcr} \\ \xi_t^{ms1} \\ \xi_t^{dmd} \\ \xi_t^{cpi} \end{bmatrix}$$

This model meets the statistical properties necessary for inference: stability, normality, homoscedasticity, and no correlation in error terms (see Appendix 4).

Structural shocks (ς_t) are obtained using the residual terms vector (ξ_t) based on the reduced form estimation of this model, and the diagonalization is described in section 3.2. For the diagonalization, the recursive ordering is: ipi_t, oil_t, gas_t, nfx_t, gov_t, wag_t, pro_t, pcr_t, $ms1_t$, dmd_t and cpi_t, where the most exogenous variable comes first, and the most endogenous variable (inflation in this case) comes last. The structural shocks obtained for each of the 11 series that make up the VAR are given in Figure 3.

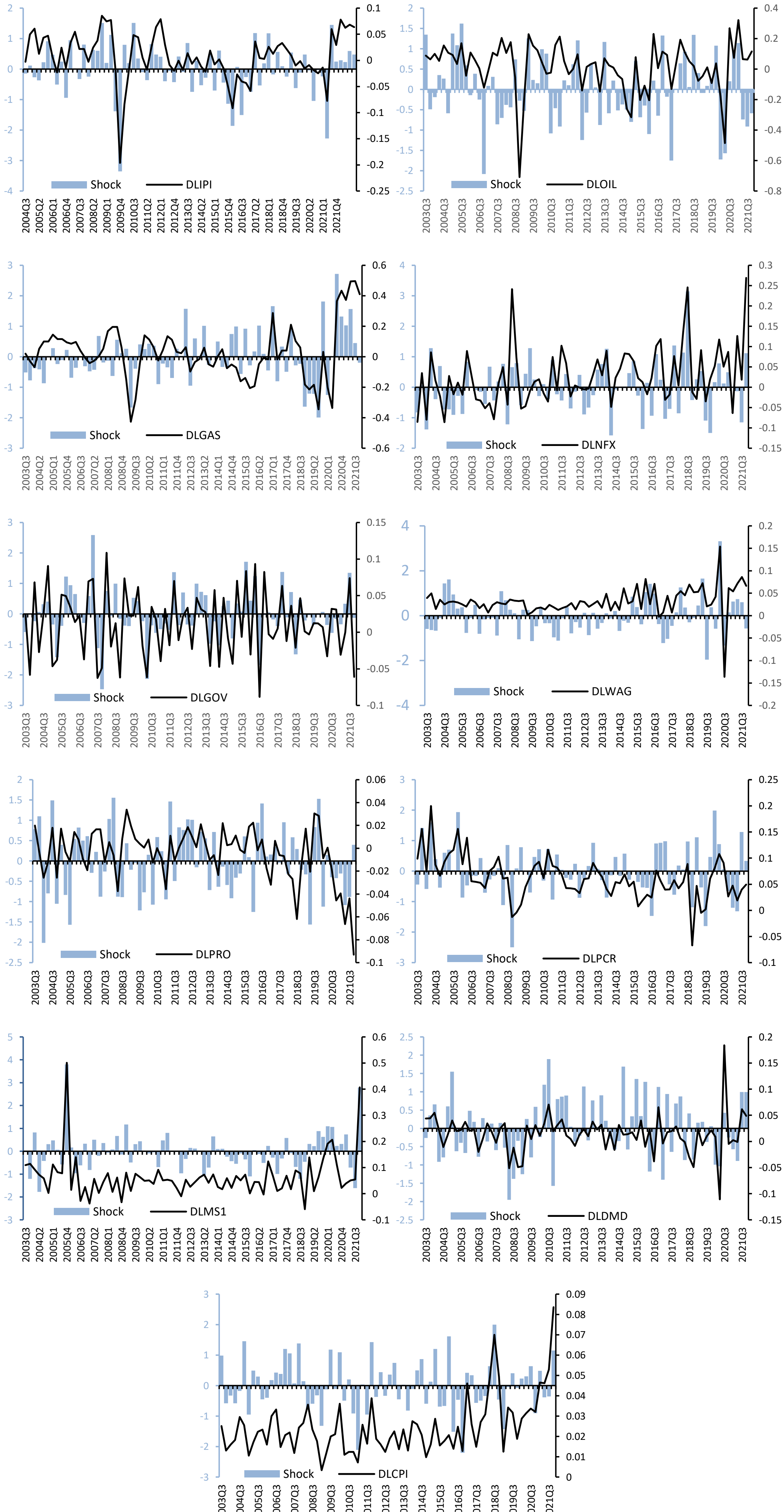


Figure 3. Structural shocks of the model variables.

To better understand their effects on inflation, the contribution of structural shocks belonging to all observable variables in the VAR model has been calculated in the context of price dynamics and aggregated as supply, demand,

and other factors. Figure 4 shows the absolute contribution of structural shocks to inflation (formation of the inflation series), while Figure 5 displays the relative contribution of these shocks to inflation.

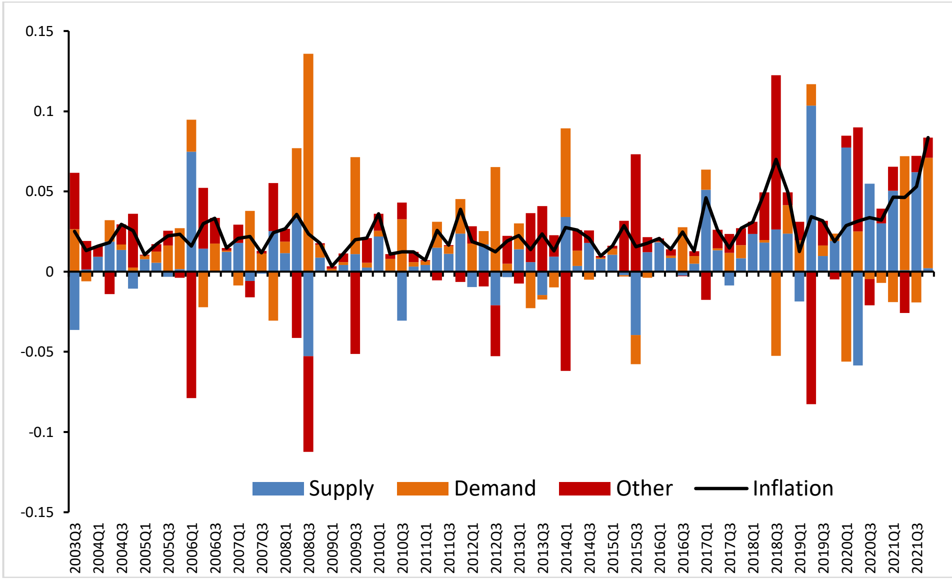


Figure 4. Aggregated contribution of structural shocks to inflation.

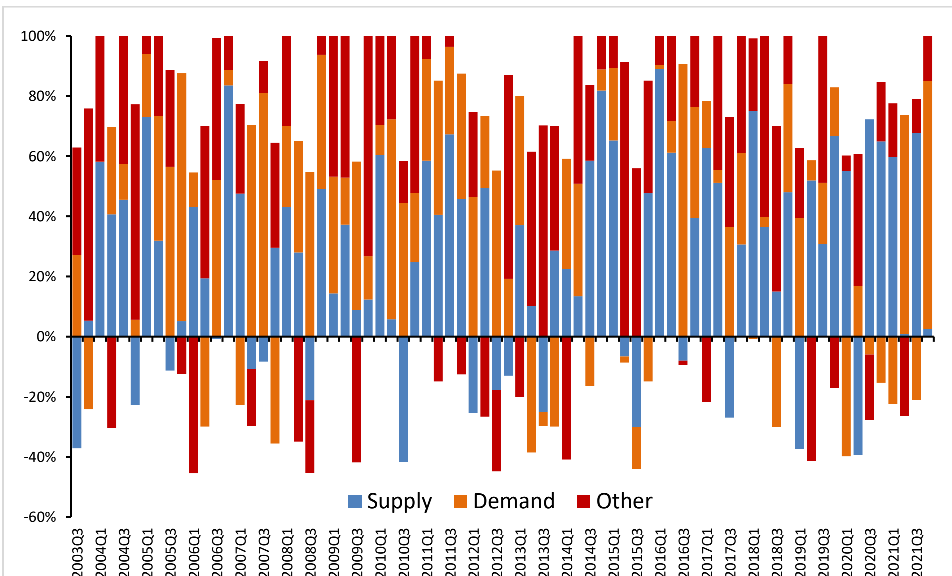


Figure 5. Relative contributions of structural shocks to inflation.

This reconstruction of inflation data allows us to interpret structural shocks in the context of determining their contribution to inflation dynamics. In other words, it becomes possible to identify the sources of variation in inflation as part of observable variables. Since this reconstruction allows for comparison of the sources of variation identified by the model, it will aid in making recommendations to monetary policymakers.

Approximately 1% of the inflation shock, which had an average of 2.5% in the sample period, is caused by shocks in supply-side factors, 1% by shocks in demand-side factors, and approximately 0.5% by shocks in control variables. In relative terms, approximately 42% of the inflation shocks in the sample period are caused by shocks in supply-side factors, 40% by shocks in demand-side factors, and 18% by shocks in control variables. The import price index, oil prices, and gas prices from the supply-side factors, money supply from the demand-side factors, and the nominal exchange rate from the control variables stand out as the determining variables in this process. When the inflation shocks in the last part of the sample period (2019–2021) are analyzed, supply-side factors come to the fore, while the contribution of demand-side factors and control variables to inflation remains limited or in the opposite (reducing) direction. Undoubtedly, the most important factor in this process is the increase in international oil and gas prices since 2017. The oil price index, which was approximately 104 at the end of 2016, and the natural gas price index, which was 105 at the end of 2016, increased to 177 and 724, respectively, at the end of 2021. This process also includes the effect of restrictions during the pandemic period. The contribution of demand-side factors to inflation shocks was negative in the five quarters of this sub-period.

Although the benefits of the analysis with such a separation are quite high, it should be noted that the identification of shocks always depends on a good specification of the model. For this reason, these findings should be supported by other indicators to be obtained from the VAR model. These VAR model outputs are discussed in the next section.

5. Estimation Results

It can be said that the model estimated in the previous section does not have a serious statistical problem with the specification because the errors pass the statistical tests successfully (see Appendix 4) and because Figure 6 below shows that the model fits well with the data. The parameter estimates (Γ matrix) and the variance-covariance matrix (Ω) for the model are given in Appendix 5 at the end of the study. In this section, the results of the two most used outputs of the models, impulse-response functions and variance decompositions, are evaluated.

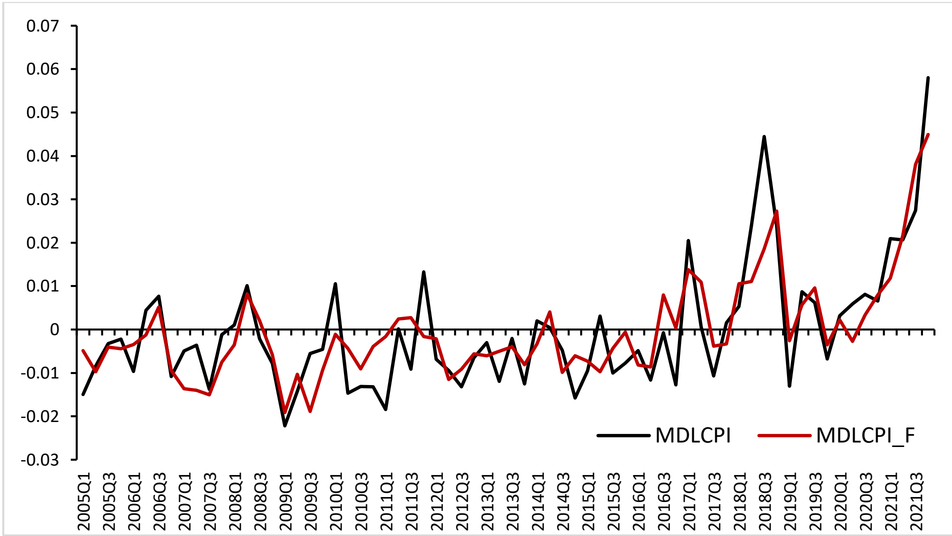
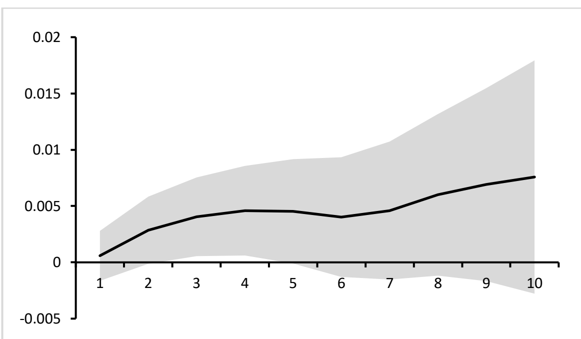
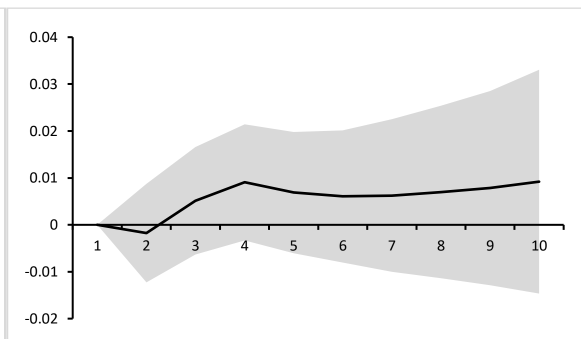


Figure 6. Actual and estimated inflation shocks.

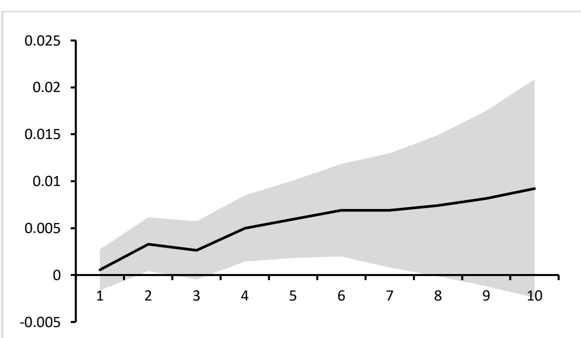
Among the impulse-response functions obtained by the estimation of the model, the functions that show the response of inflation in the face of a positive shock in the variables included in the model are given in Figure 7.



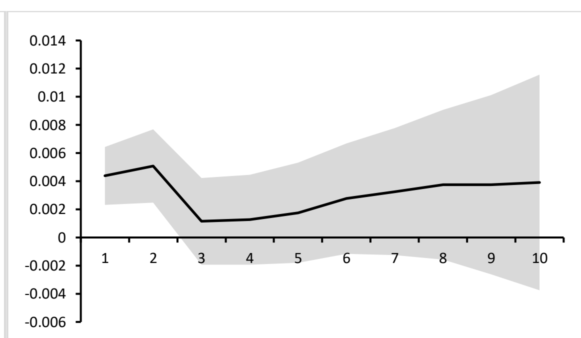
Response to an Import Price Shock



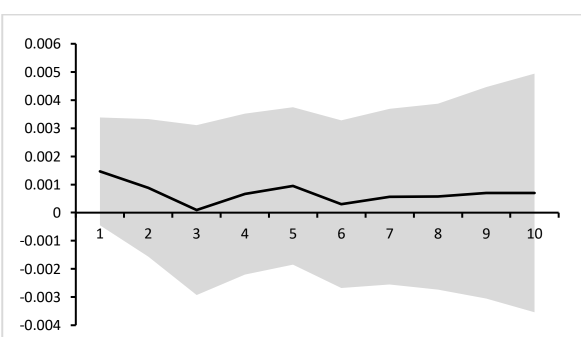
Response to an Oil Price Shock



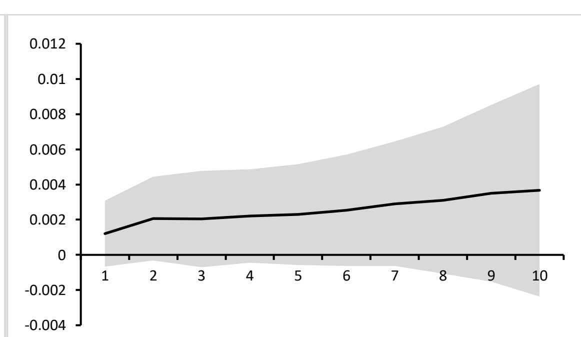
Response to a Gas Price Shock



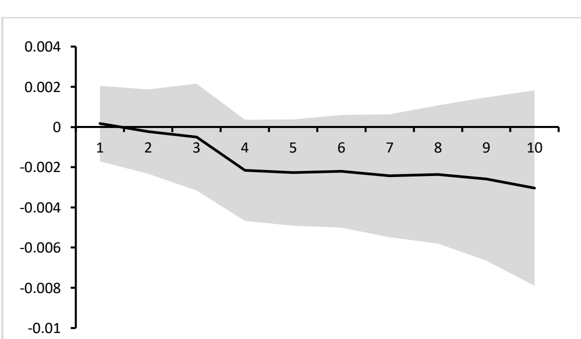
Response to a Nominal FX Shock



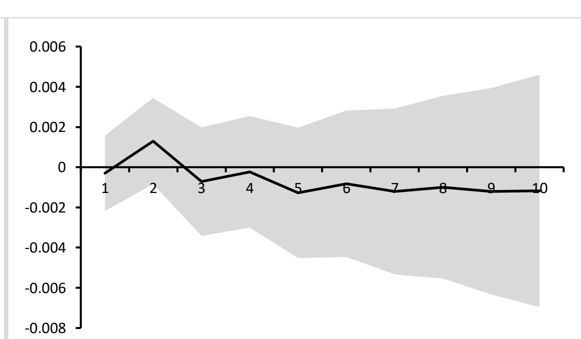
Response to a Government Expenditure Shock



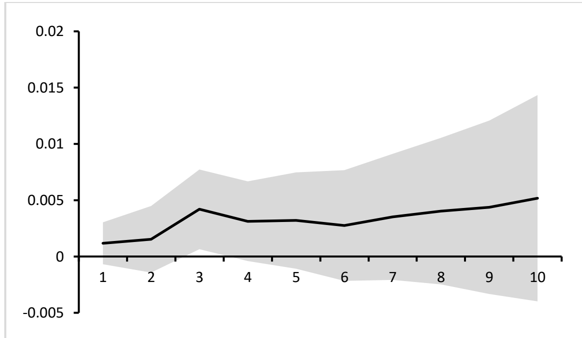
Response to a Wage Shock



Response to a Productivity Shock



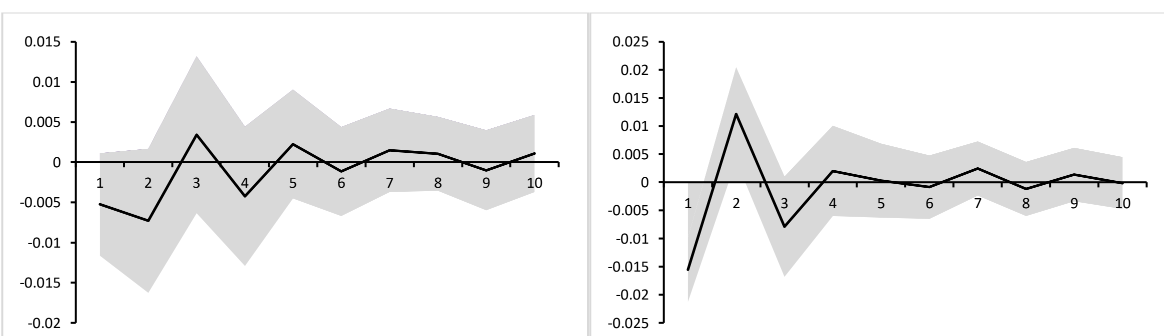
Response to a Private Credit Shock



Response to a Money Supply Shock

Figure 7. Response of inflation to the positive shocks in the model's variables.

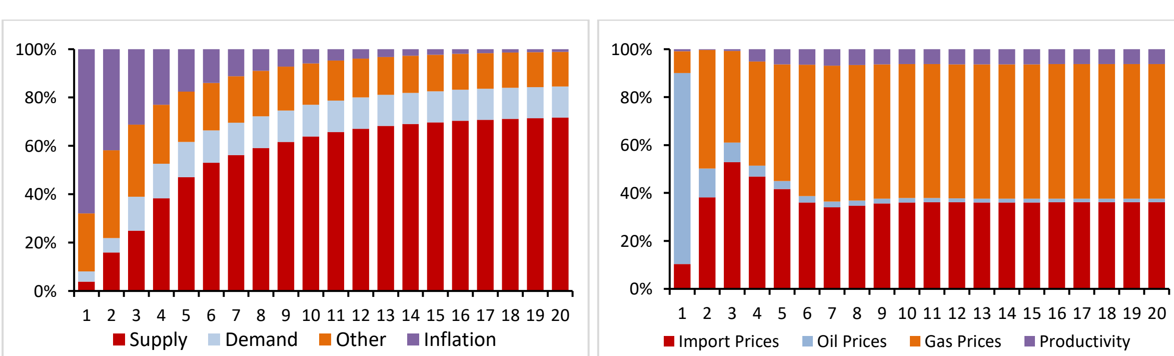
First of all, the response of inflation to a positive shock in the model variables is in line with our theoretical expectations for all variables. Except for the shocks in private sector loans, public expenditures, and oil prices, the responses of inflation to shocks in all other variables are statistically significant. Therefore, the results related to the variables whose statistical validity will be questioned should be considered instructive. Positive shocks in import prices and gas prices, which are determined as the factors that cause the supply curve to shift in this study, create a permanent increase in inflation, and this effect spreads over the long term. This situation is considered an indicator of the dependence of domestic production on imports and as a result of the use of natural gas as the main energy source in production. While oil prices have a similar effect, it gradually decreases in the long run. The effect of positive productivity shocks, another factor that shifts supply, on prices is negative but limited. The response of inflation to a positive shock in public expenditures and loans to the private sector, which are included in the model as factors shifting the demand curve, are positive and in line with theoretical expectations, although they are not statistically significant. Considering that the money supply may also reflect the reaction of the loans to the private sector, it can be stated that it is the most important variable in the model that causes the demand curve to shift. A positive shock in the money supply creates a permanent and long-term effect on inflation. When evaluated in terms of the shifting of the demand curve, money supply shocks emerge as the most important factor that creates statistically significant effect on inflation. The positive shocks in the nominal exchange rate and wages, which are included as control variables in the model because they affect both supply and demand, put upward pressure on inflation. The impact of shocks in these variables on inflation is long-lasting and permanent. When we check the response of domestic demand (used to represent quantity) to the shocks in these two control variables, both factors decrease supply in the short run (cost effect), but demand increases due to the wealth effect (exchange rate increase) and the income effect (wage increase) in the long run (see Figure 8). However, the magnitude of this response cannot be evaluated due to its statistical insignificance. Considering that the result obtained is instructive, it is revealed that monetary policy will undertake an extremely important function in tempering inflationary pressure.



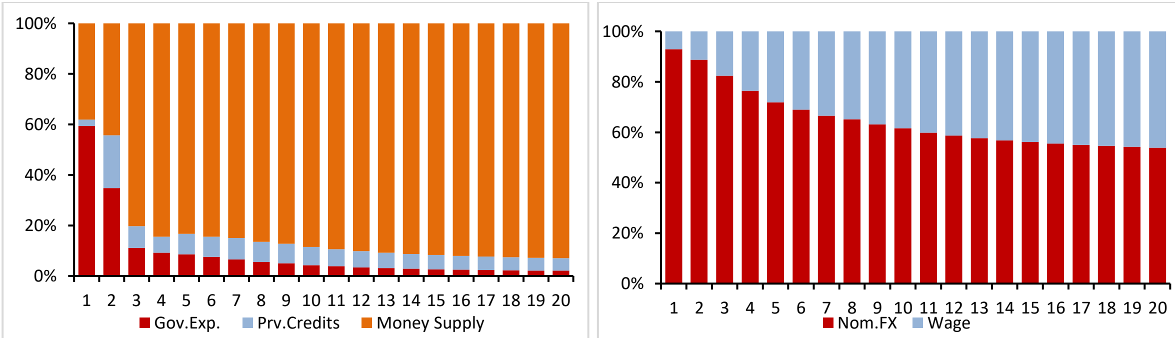
Response of Quantity to an FX Shock	Response of Quantity to a Wage Shock

Figure 8. Response of domestic demand to shocks in exchange rate and wages.

Combined with the situation shown by the decomposition in structural shocks, this result shows that inflation in Turkey changes in the short run with the determinant of supply-side factors. A similar result is obtained from the variance decomposition functions (see Figure 9 Panel A). Accordingly, on average, 53% of the variation in inflation is due to supply factors, 13% is due to demand factors, 20% is due to control variables, and 14% is due to inflation itself. A long horizon of 20 quarters was preferred in this decomposition and the same aggregation criteria were used in the analysis of structural shocks.



A. Decomposition of Inflation	B. Contributions of Supply-Side Variables



C. Contributions of Demand-Side Variables D. Contributions of Control Variables

Figure 9. Variance decomposition of inflation.

When the B, C, and D panels of Figure 9, which show the individual contributions of the variables included in the model, are examined, it is clearly seen that the main variables that determine the contribution of supply to the variation in inflation are import prices and gas prices, the main variable that determines the contribution of demand is money supply, and the main variable that determines the contribution of control variables is the exchange rate.

6. Conclusion

Knowing whether inflationary pressures are caused by supply or demand is key information for successful monetary policy implementation. However, determining the source of these pressures is not so easy in practice as the data on inflation and output are equilibrium observations, and these values are determined simultaneously with the supply and demand interaction, and their functional forms are not known directly.

To explain the inflation series in the context of the forces determining the dynamics, a method based on the SVAR model and its moving average presentation is proposed in this study. This method allows us to identify the sources of variability in the inflationary process and interpret them directly in the context of observable variables.

The method used produces statistically significant and economically consistent results for the 2003–2021 inflationary period in Turkey. Positive shocks in import and gas prices, which are determined in this study as the factors that cause the supply curve to shift, create a permanent increase in inflation, and this effect spreads over the long term. This situation is considered an indicator of the dependence of domestic production on imports and as a result of the use of natural gas as the main energy source in production. When evaluated in terms of the shifting of the demand curve, money supply shocks emerge as the most important factor that creates a statistically significant effect on inflation. The positive shocks in the nominal exchange rate and wages, which are included as control variables in the model because they affect both supply and demand, put upward pressure on inflation. The impact of shocks in these variables on inflation is long-lasting and permanent. When we check the response of domestic demand (used to represent quantity) to the shocks in these two control variables, both factors decrease supply in the short run (cost effect), but demand increases due to the wealth effect (exchange rate increase) and income effect (wage increase) in the long run. Considering that the result obtained is instructive, it is revealed that monetary policy will undertake an extremely important function in tempering the inflationary pressure in Turkey.

Combined with the situation shown by the decomposition in structural shocks, this result shows that inflation in Turkey changes in the short run with the determinant of supply-side factors. Variance decompositions of inflation also produce evidence supporting this conclusion. The results show that the method used will be useful in separating the factors that create pressure in the inflationary process, which has recently gotten out of control in Turkey and is gradually moving away from the targeted inflation.

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Appendix

The sample covers the 2003:I–2021:IV period, and all the data are quarterly. All the data are seasonally adjusted (except the short-term interest rate, nominal exchange rate, and real exchange rate) by using the X12 methodology and then transformed into logarithms (except the short-term interest rate).

Since the autonomous consumption expenditures are not observable, the time series is obtained by estimating the consumption function of $c_t = c_0 + \beta_1 y_t + \beta_2 y_{t-1} + \varepsilon_t$ with rolling regressions for the 1987:1–2021:4 period, where c, c_0, and y indicate logs of real private consumption expenditures, real autonomous consumption expenditures, and real GDP, respectively.

There is no productivity index data in Turkey for the entire period examined. Therefore, the productivity index was calculated using the method used by Moura, Lima, and Mendonca (2008). Accordingly, productivity in tradable sectors was calculated as the inverse of the producer price index (*ppi*), and productivity in non-tradable sectors was calculated as the inverse of the consumer price index (*cpi*). Productivity ratios were then obtained by dividing the productivity into the tradable sectors by the productivity in the non-tradable sectors. These ratios were converted into an index by taking the initial value of 100.

Appendix 1. Definition and sources of the data.

Symbol	Explanation	Source
y	Real gross domestic product	TURKSTAT[1]
con	Real private consumption expenditures	TURKSTAT
aco	Autonomous consumption expenditures	Our Estimation
gov	Real Government consumption expenditures	TURKSTAT
inv	Real total investment expenditures	TURKSTAT
exp	Real export volume	TURKSTAT
imp	Real import volume	TURKSTAT
pcr	Private sector credits	CBRT - EDDS[2]
fcr	International credit volume	CBRT - EDDS
ms1	Narrowly defined money stock	CBRT - EDDS
ipi	Import price index	CBRT - EDDS
oil	International Brent petroleum price index	FRED[3]
gas	The international natural gas price index	FRED
enr	The international energy price index	FRED
den	The domestic energy price index	CBRT - EDDS
pro	Productivity	Own Calculation
int	Short-term interest rate	CBRT - EDDS
nfx	Nominal USD/TL exchange rate	CBRT - EDDS
rfx	Real effective exchange rate (CPI-based)	CBRT - EDDS
wag	Manufacturing industry average wage cost index	TURKSTAT
dmd	Domestic demand	Own Calculation
cpi	Consumer price index	TURKSTAT
ppi	Producer price index	TURKSTAT

Notes: 1 refers to the Turkish Statistical Institution.
2 refers to the electronic data delivery system of the Central Bank of The Republic of Turkey.
3 refers to the digital database of the Federal Reserve Bank of St. Louis.

Appendix 2. Unit root tests.

Variable	Traditional Unit Root Tests					Break Point Unit Root Test		
	Augmented Dickey–Fuller Test			Phillips–Perron Test		Dickey–Fuller min t-Test		
	Lag**	t-statistic	Prob.	t-statistic	Prob.	Lag	t-statistic	Prob.
Demand Side Variables								
aco	9	0.22	0.92	1.35	0.59	6	3.41*	0.99
Δaco	8	3.11	0.02	5.03	0.00	0	5.82	0.00
gov	3	0.52	0.88	0.94	0.76	3	1.58	0.99
Δgov	2	8.24	0.00	24.33	0.00	0	14.81	0.00
inv	3	2.91*	0.16	2.39*	0.37	4	3.88*	0.59
Δinv	0	7.60	0.00	7.76	0.00	0	8,97	0.00
pcr	4	2.08*	0.54	1.29	0.88	6	3.92*	0.57
Δpcr	5	3.62*	0.03	6.43	0.00	0	7.27*	0.00
fcr	2	2.01	0.27	0.04	0.66	1	1.69	0.97
Δfcr	8	5.12	0.00	21.80	0.00	0	12.61	0.00
ms1	0	0.03	0.95	0.00	0.95	4	2.55	0.88
Δms1	6	3.66	0.02	7.63	0.00	0	7.83	0.00

Supply Side Variables								
ipi	1	2.48*	0.33	2.30*	0.42	1	3.54*	0.79
Δipi	2	4.75	0.00	4.60	0.00	0	6.34	0.00
oil	1	2.50*	0.32	2.41*	0.36	1	4.13*	0.43
Δoil	0	7.25	0.00	7.14	0.00	0	8.77	0.00
gas	1	2.94*	0.15	2.08*	0.54	3	3.83*	0.62
Δgas	0	3.53	0.00	3.69	0.00	0	6.57	0.00
enr	1	2.55*	0.30	2.48*	0.33	2	3.79*	0.65
Δenr	0	6.12	0.00	6.15	0.00	0	7.58	0.00
den	1	1.12	0.99	1.40	0.99	0	0.92	0.99
Δden	0	6.86	0.00	6.87	0.00	0	7.72	0.00
pro	4	1.47	0.99	2.12	0.99	3	1.96	0.98
Δpro	3	1.86	0.05	4.84	0.00	0	7.25	0.00
Control Variables								
int	4	2.05*	0.59	2.06*	0.55	4	3.70*	0.60
Δint	0	6.18	0.00	5.93	0.00	0	7.53	0.00
nfx	10	0.12*	0.99	1.08*	0.99	0	3.21*	0.92
Δnfx	0	7.50	0.00	7.49	0.00	0	8.67	0.00
rfx	6	0.50*	0.99	1.14*	0.91	0	4.13*	0.43
Δrfx	0	10.18	0.00	10.18	0.00	0	10.79	0.00
wag	1	1.87	0.99	1.52	0.99	1	1.19	0.99
Δwag	0	10.89	0.00	10.69	0.00	0	12.26	0.00
Quantity Variable								
dmd	1	1.15	0.69	1.19	0.674	1	2.67	0.84
Δdmd	0	10.39	0.00	10.35	0.000	0	12.16	0.00
Price Variable								
cpi	1	1.12	0.99	0.60	0.98	1	1.35	0.99
Δcpi	0	3.71	0.00	3.54	0.00	0	5.39	0.00

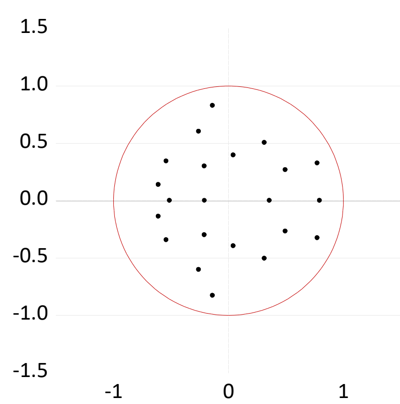
Notes: (*) refers to trend inclusion.
(**) based on Akaike Information Criterion.

Appendix 3. Lag order selection.

Lag	Log-Likelihood	Likelihood Ratio	Final Prediction Error	Akaike Information Criterion	Schwarz Information Criterion	Hannan–Quinn Information Criterion
0	195.83	---	4.52E-08	-5.56	-5.43	-5.50
1	464.70	498.78	2.97E-11	-12.89	-12.24	-12.63
2	484.38	34.22*	2.68E-11*	-12.99*	-12.83*	-12.93*
3	496.52	19.70	3.04E-11	-12.88	-11.20	-12.21
4	505.43	13.42	3.82E-11	-12.67	-10.47	-11.80
5	523.38	24.98	3.75E-11	-12.73	-10.01	-11.65
6	531.07	9.80	5.05E-11	-12.49	-9.25	-11.21

Note: * indicates lag order selected by the relevant criterion.

Appendix 4. Diagnostic tests for VAR residuals.
Appendix 4.1. Model stability condition.



Appendix 4.2. LM test for serial correlation.

Lag	LR Stat.	DF	Prob.	Rao F Stat.	DF	Prob.
Null Hypothesis: No serial correlation at lag order h						
1	129.41	121	0.28	1.07	121, 266.6	0.31
2	120.98	121	0.43	0.98	121, 266.6	0.51
Null Hypothesis: No serial correlation at lags 1 to h						
1	129.41	121	0.28	1.07	121, 266.6	0.31
2	180.02	242	0.45	1.06	242, 235.7	0.16

Appendix 4.3. White heteroscedasticity test.

Residuals from the equation for:	R^2	F (44, 31)*	Prob.	χ^2 (44)	Prob.
ipi_t	0.81	3.02	0.00	61.64	0.04
oil_t	0.84	3.75	0.00	63.98	0.02
gas_t	0.68	1.56	0.09	52.37	0.18
nfx_t	0.67	1.46	0.13	51.27	0.20
gov_t	0.56	0.92	0.59	43.20	0.50
wag_t	0.58	0.98	0.52	44.38	0.45
pro_t	0.86	4.40	0.00	65.52	0.01
pcr_t	0.38	0.44	0.99	29.44	0.95
$ms1_t$	0.72	1.82	0.04	54.79	0.12
dmd_t	0.67	1.44	0.14	51.05	0.21
cpi_t	0.46	0.61	0.93	35.34	0.82
Joint	--	---	---	2952.76 (2904)	0.25

Note: * Numbers in parentheses show the degrees of freedom for the relevant distribution.

Appendix 4.4. Normality test.

	Skewness	χ^2	Prob.	Kurtosis	χ^2	Prob.	Jarque–Bera Stat	Prob.
ipi	-0.16	0.32 (1)*	0.56	2.80	0.11 (1)	0.73	0.44 (2)	0.80
oil	-0.21	0.56 (1)	0.45	3.57	0.98 (1)	0.32	1.54 (2)	0.46
gas	-0.07	0.06 (1)	0.79	3.08	0.02 (1)	0.88	0.08 (2)	0.95
nfx	0.11	0.15 (1)	0.69	2.97	0.00 (1)	0.96	0.15 (2)	0.92
gov	-0.20	0.50 (1)	0.47	3.33	0.34 (1)	0.55	0.84 (2)	0.65
wag	-0.05	0.03 (1)	0.85	4.61	7.81 (1)	0.00	7.85 (2)	0.01
pro	0.30	1.11 (1)	0.29	4.66	8.30 (1)	0.00	9.42 (2)	0.00
pcr	-0.05	0.03 (1)	0.84	3.07	0.01 (1)	0.90	0.05 (2)	0.97
ms1	-0.21	0.54 (1)	0.45	2.68	0.29 (1)	0.59	0.83 (2)	0.65
dmd	0.14	0.24 (1)	0.62	2.63	0.40 (1)	0.52	0.65 (2)	0.72
cpi	-0.34	1.43 (1)	0.23	3.53	0.86 (1)	0.35	2.29 (2)	0.31
Joint	---	5.03 (11)	0.92	---	19.15 (11)	0.61	24.19 (22)	0.33

Note: * Numbers in parentheses show the degrees of freedom for the χ^2 distribution.

Appendix 5. Estimates of the Γ and Ω matrices.

$$\Gamma = \begin{bmatrix} 0.02 & 0.01 & -0.04 & -0.03 & -0.01 & -0.02 & 0.01 & 0.02 & -0.01 & -0.01 & 0.01 \\ 0.12 & 0.06 & -0.05 & -0.05 & -0.01 & -0.03 & 0.01 & 0.04 & -0.02 & 0.01 & 0.01 \\ 0.05 & 0.07 & -0.02 & -0.15 & -0.06 & -0.09 & 0.03 & 0.14 & -0.04 & -0.10 & 0.02 \\ -0.11 & 0.01 & -0.08 & 0.01 & -0.01 & -0.03 & 0.03 & 0.01 & -0.04 & -0.03 & -0.03 \\ 0.01 & 0.00 & 0.01 & 0.01 & 0.02 & 0.01 & -0.01 & -0.01 & 0.01 & 0.01 & -0.00 \\ -0.04 & 0.00 & -0.05 & -0.01 & 0.01 & -0.01 & 0.01 & -0.00 & -0.02 & -0.01 & -0.01 \\ 0.03 & -0.01 & 0.04 & 0.01 & 0.01 & 0.02 & -0.01 & -0.01 & 0.02 & 0.02 & 0.01 \\ 0.05 & 0.01 & 0.05 & -0.01 & -0.01 & 0.01 & -0.02 & 0.05 & 0.04 & 0.03 & 0.03 \\ -0.05 & 0.03 & -0.03 & -0.03 & 0.01 & -0.01 & 0.01 & 0.06 & 0.03 & -0.01 & 0.01 \\ 0.01 & 0.01 & 0.00 & -0.01 & -0.01 & -0.01 & -0.01 & 0.01 & 0.01 & 0.01 & 0.01 \\ -0.03 & 0.01 & -0.04 & -0.01 & -0.00 & -0.01 & 0.01 & 0.01 & -0.02 & -0.02 & 0.01 \end{bmatrix}$$

$$\Omega = \begin{bmatrix} 0.04 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.08 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.12 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.06 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.04 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.02 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.01 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.03 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.06 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.02 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.01 \end{bmatrix}$$