



ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH IN TURKEY: A MIXED FREQUENCY VAR APPROACH



 **Dilara Berksun**¹
 **Nukhet Dogan**²
 **M. Hakan Berument**^{3*}

^{1,2}Department of Economics, Bilkent University, Ankara Turkey.

¹Email: dilara.berksun@bilkent.edu.tr Tel: ++903122901864

²Email: berument@bilkent.edu.tr Tel: +903122903247

³Department of Econometrics, Ankara Haci Bayram Veli University, Ankara Turkey.

³Email: nukhed@gazi.edu.tr Tel: +903122161308



(+ Corresponding author)

ABSTRACT

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This paper investigates the relationship between monthly electricity consumption, quarterly GDP, and quarterly components of GDP using the Mixed Frequency VAR (MF-VAR) model for Turkey for the period from 1987:2Q to 2017:3Q. When the conventional quarterly VAR model is used, any causal relationship between electricity consumption and GDP growth could not be found. However, when we used the MF-VAR specification, we found that electricity consumption does increase GDP growth; this supports to the *growth* hypothesis but not the *conservation* hypothesis. Repeating the same exercise by adding other low frequency variables, the empirical evidence still reveals that an increase in electricity consumption increases GDP. However, an increase in electricity consumption increases Private Consumption, Investment, Imports expenditures, Construction, Industrial, Manufacturing, and Service Sector outputs more than it increases GDP. In addition to this, the empirical evidence reveals that an increase in electricity consumption increases Agricultural sector output less than it increases GDP.

Contribution/ Originality: This study contributes to the existing literature in two ways. First contribution is that to determine the causal relationship between electricity consumption and economic growth using mixed frequency data. As a second contribution, we add different components of GDP relative to GDP into our model.

1. INTRODUCTION

There is a vast amount of literature on the relationship between electricity consumption and Gross Domestic Product (GDP). However, in terms of the direction of this causal relationship, the studies vary. While some authors find a unidirectional causality running from one of the variables to the other, others detect a bidirectional causality or no causality at all. The literature uncovers four possible relationships between electricity consumption and economic growth, which are synthesized into four testable hypotheses, each requiring a different policy implication for energy investment and macroeconomic policy design (Apergis & Payne, 2009; Payne, 2010). First, the *growth* hypothesis corresponds to the positive unidirectional causality running from electricity consumption to economic growth. This hypothesis is based on the idea that energy is a factor of production (Csereklyei & Humer, 2012). It implies that an increase in electricity consumption will cause an increase in GDP. Therefore, under the growth hypothesis, implementing policies that reduce electricity consumption will hinder economic growth, and putting policies into effect that result in an increase in electricity consumption will boost it. Hence, for a resource

stagnated country, an increase in electricity consumption will have a significantly positive effect on output. Authors Narayan and Singh (2007); Shiu and Lam (2004) and Altinay and Karagol (2005) find results which support the growth hypothesis for the Fiji Islands, China, and Turkey, respectively.

Second, the *conservation* hypothesis represents the positive unidirectional causality running from output to electricity consumption. This hypothesis implies that an increase in GDP causes an increase in electricity consumption. When this is the case, implementing electricity conservation policies will not have a negative affect on the growth of GDP (Narayan & Singh, 2007). Some of the empirical evidence for the conservation hypothesis are found by Ghosh (2002); Narayan and Smyth (2005) and Yoo and Kim (2006) for India, Australia, and Indonesia, respectively.

Third, the *feedback* hypothesis, describes the bidirectional relationship between electricity consumption and output. It is based on the idea that electricity consumption and GDP are two interdependent variables. For this reason, an increase (decrease) in electricity consumption causes an increase (decrease) in GDP, and an increase (decrease) in GDP causes an increase (decrease) in electricity consumption (Payne, 2010). That is to say, implementing policies that promote one of them may trigger an increase in both GDP and electricity consumption; putting policies into effect that hinder one may cause a decline in both. Based on this, putting policies into effect that are directed toward improvements in energy may not have an adverse effect on GDP; they may even have a positive effect on it (Payne, 2010). Empirical evidence that support the feedback hypothesis include Yoo (2005); Jumbe (2004) and Odhiambo (2009) articles on Korea, Malawi, and South Africa, respectively.

Fourth, the *neutrality* hypothesis depicts the absence of any causal relationship between electricity consumption and income. It is based on the idea that electricity consumption represents a very small and insignificant part of GDP (Apergis & Payne, 2009). Hence, implementing policies that promote or hinder one of the variables would not have a significant effect on the other. A cut in electricity production, for example, would not have a noteworthy adverse impact on real GDP (Payne, 2010). Studies that support the neutrality hypothesis include (Wolde-Rufael, 2006) findings for Algeria, Congo Republic, Kenya, South Africa, and Sudan. Using the Toda-Yamamoto causality, they could not find any causal relationship between electricity consumption and GDP based on the annual data from 1971 to 2001.

Researchers have investigated the relationship between electricity consumption as well as the subcomponents of GDP. This raises an interesting question as results may vary between aggregate and individual levels because of the aggregation bias problem for GDP (Tang & Shahbaz, 2013). While finding a certain type of causality at the aggregate level, it is possible to find a different type of causality at the individual level. For example, while finding a bidirectional causality between per capita electricity consumption and GDP at the aggregate level, Kouakou (2011) finds a unidirectional causality at the sectoral level. In addition to this, the electricity demand of each subcomponent of GDP is different from the other due to their difference in capital intensiveness. For this reason, the direction of causality across the subcomponents of GDP may also vary for a specific country.

The causal relationship may run from electricity consumption to certain components of GDP. For example, Mawejje and Mawejje (2016); Kouakou (2011) and Shahbaz, Uddin, Rehman, and Imran (2014) found a unidirectional causality running from electricity consumption to industrial production for Uganda, Ivory Coast, and Bangladesh, respectively. This is also important for countries' growth strategies. For example, export led growth strategy may require a different electricity generation policy than domestic lead (say healthcare) growth.

However, Lean and Smyth (2010) found that causality runs from the export sector to electricity consumption for Malaysia. Likewise, Jamil and Ahmad (2010) found that growth in output in commercial, manufacturing and agricultural sectors and growth in private expenditure increase electricity consumption in Pakistan. Similarly, Mawejje and Mawejje (2016) found a unidirectional causality running from service sector and agricultural production output to electricity consumption for Uganda.

Third, causality between electricity consumption and the subcomponents of GDP may be bidirectional. However, Maweje and Maweje (2016) could not find any causality between electricity consumption and real output in the agricultural sector in Uganda. For a more detailed summary of literature on electricity consumption and economic growth, see *A survey of the electricity consumption-growth literature* by Payne (2010).

Vector autoregressive (VAR) models are one of the most widely used models to capture the relationship between electricity consumption and output (see, for example, Borozan (2013) and references cited in). However, the common pitfall of VAR models is that they require the researcher to use the same frequency data. Hence, researchers working with annual GDP were compelled to use annual electricity consumption, even if they only had access to quarterly or monthly electricity consumption data. Similarly, researchers using quarterly GDP were compelled to use quarterly electricity consumption in their models, even if they had access to monthly electricity consumption data.

It is certainly possible to align variables either downward or upward in order to transform them to the same frequency, however, this has consequences in terms of potentially misspecifying the co-movements (Ghysels, 2016). More specifically, downward alignment discards valuable information in the high frequency data, while upward alignment by interpolating the high frequency data with heuristic rules (such as polynomial fillings) introduces noises to the data (Qian, 2013). This in turn affects the results of the analysis. For this reason, we refrained from interpolating quarterly GDP to monthly GDP, or aggregating monthly electricity consumption to quarterly electricity consumption. We were able to do this by employing the Mixed Frequency VAR model (MF-VAR), which allowed us to examine mixed frequency data. We were also able to include the subcomponents of GDP into our model without being forced to align GDP upward or downward. This is our paper's first contribution to the existing literature. The MF-VAR model also contributes to decreasing 'type II error' in the estimations.

The second contribution of this paper is that we add different components of GDP relative to GDP into our model. Hence, from the impulse response functions we analyze how a shock in monthly electricity consumptions affects the subcomponents relative to GDP, and how a shock in the subcomponents of GDP relative to GDP effect monthly electricity consumptions. In addition to this, instead of using causality in our model, we resorted to examining the causal relationship with impulse response function (IRF). The reason behind this is that using IRFs enables us to not only analyze the direction of causality, but also to observe the dynamic interaction of electricity and GDP, and electricity and the subcomponents of GDP, relative to GDP.

The purpose of this paper is to determine the causal relationship between electricity consumption and economic growth in Turkey. Like many other developing countries, Turkey's has limited natural resources that can be used to generate electricity, and relies heavily on imported primary energy resources. Thus, Turkey is a good representative in a set of resource-poor emerging markets that produces most of its resources that are used to generate electricity from imports. Second, while Turkey generated about 125 billion kWh of electricity in 2000, this increased to 295 billion kWh in 2010, an average annual increase of 7.5 percent (2018 BP Statistics). Based on these statistics, Turkey became the first in Europe and third in the world in increased electricity generation. Thus, studying Turkey itself is important for its generated capacity in the world.

Parallel to the increase in electrical energy, Turkey's GDP has also been increasing. Based on World Bank statistics, Turkey has experienced an annual GDP per capita growth rate of 3.119%, on average, between 1987 and 2017. However, the growth rate per capita of income has always been highly volatile. This is also true for our sample period, where the standard deviation is equal to 4.5. Additionally, the maximum value between 1987 and 2017 is 9.475% (2011), and the minimum is -7.356 (2001). Thus, with the high volatility of GDP growth rate per capita, we do have a lower chance of making a type II error: failing to reject a false null hypothesis. This is the third reason for using Turkish data.

Based on our empirical results, when we used the conventional quarterly VAR model we could not find any causal relationship between electricity consumption and GDP growth. However, when we used the MF-VAR

specification, we found that electricity consumption does increase GDP growth. Repeating the same exercise by adding other low frequency variables, we found that giving a shock to monthly electricity consumptions increases Private Consumption, Investment, Imports, Construction sector output, Manufacturing sector output, Industrial sector output, and Service sector output, and decreases Agricultural sector output relative to GDP lending support to the growth hypothesis.

The rest of the paper is organized as follows: We will explain MF-VAR, data source, and notations in Section 2. In Section 3, we will discuss the empirical results of the impulse response functions, and we will finish with concluding remarks in Section 4.

2. DATA AND METHODOLOGY

To examine the dynamic relationship between monthly electricity consumption, quarterly GDP, and quarterly subcomponents of GDP, we employ the MF-VAR approach analysis by using 1987:2Q-2017:3Q data. We obtained the quarterly data on GDP and its subcomponents from the Turkish Statistical Institute, and monthly data on electricity consumption from the Republic of Turkey Ministry of Energy and Natural Resources. Based on the trajectory of the impulse responses, we first use two variable MF-VAR specifications with monthly electricity consumption as the high frequency variable, and GDP as the low frequency variable. Then, by adding a quarterly measured subcomponent of GDP into our model, we will look at the three variable case.

Starting out with the two variable MF-VAR model, let $x_{t-i/m}^m$ and y_t denote the high and low frequency variables respectively for $t = 1, \dots, T$. As there are 122 quarters in our sample, T is equal to 122. For the high frequency variable, i denotes the specific month under consideration, and m denotes the high-frequency observations per low-frequency observation which is equal to 3 in our study. Based on the work of [Chauvet, Goetz, and Hecq \(2013\)](#) we use $L^{1/m}$ for the high frequency lag operator and L for the low frequency counterpart. These amount to $Ly_t = y_{t-1}$ or $Lx_t^m = x_{t-i/m}^m$ and $L^{1/m}x_{t-i/m}^m = x_{t-i/m-1/m}^m = x_{t-(i+1)/m}^m$. Apart from this we also have $L^{1/n}x_{t-(m-1)/m}^m = x_{t-1}^m$.

Following [Götz, Hecq, and Smeekes \(2016\)](#) we take the high frequency variables as $X^t = (x_t^m, x_{t-1/m}^m, \dots, x_{t-(m-1)/m}^m)$, and after ensuring their stationarity, we specify the $VAR(p)$ for $Z_t = (X_t', y_t)'$ in [Equation 1](#) as follows:

$$Z_t = \mu + \Gamma_1 Z_{t-1} + \dots + \Gamma_p Z_{t-p} + \varepsilon_t. \quad (1)$$

Using Schwarz Criteria, we took the optimal lag length to be one. Apart from adding seasonal dummies in order to account for the seasonality, we also include crises dummies into our model for 1994:Q2, 2000:Q4, 2001:Q1, 2008:Q3 time periods. The VAR model for quarterly GDP growth rate and for the monthly electricity consumption growth rate can be written in the explicit form in [Equation 2](#) as follows:

$$\begin{bmatrix} EC_{t-2/3}^3 \\ EC_{t-1/3}^3 \\ EC_t^3 \\ GDP_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \begin{bmatrix} \pi_1 & \phi_{1,1} & \phi_{1,2} & \phi_{1,3} \\ \pi_2 & \phi_{2,1} & \phi_{2,2} & \phi_{2,3} \\ \pi_3 & \phi_{3,1} & \phi_{3,2} & \phi_{3,3} \\ \pi_4 & \phi_{4,1} & \phi_{4,2} & \phi_{4,3} \end{bmatrix} \begin{bmatrix} EC_{t-1-2/3}^3 \\ EC_{t-1-1/3}^3 \\ EC_{t-1}^3 \\ GDP_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}, \quad (2)$$

where ε_t is for the error term and $\varepsilon_t \sim MVN(0_{(4 \times 1)}, \Sigma)$. In this equation, $EC_{t-2/3}^3$, $EC_{t-1/3}^3$, and EC_t^3 represent the electricity consumptions of the first, second, and third month of each quarter, respectively, and GDP_t represents the quarterly GDP.

In order to capture the relative contribution of the subcomponents of GDP following Strongin (1995) we added another low frequency variable just after GDP growth. This low frequency variable, which we will denote by ρ_t , will be Private Consumption, Government Spending, Investment, Export, Import, Construction Sector, Private Industry, Manufacturing Industry, Service and Agricultural Sector output growths by turns. Thus, the impulse responses to a given shock of ρ_t captures how ρ_t affects other variables, once one accounts for the effect of GDP growth. In other words, it captures how ρ_t affects and is affected by other variables relative to GDP growth. Based on this, Equation 2 will become Equation 3 as follows:

$$\begin{bmatrix} EC_{t-2/3}^3 \\ EC_{t-1/3}^3 \\ EC_t^3 \\ GDP_t \\ \rho_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \\ \mu_5 \end{bmatrix} + \begin{bmatrix} \pi_1 & \phi_{1,1} & \phi_{1,2} & \phi_{1,3} & \phi_{1,4} \\ \pi_2 & \phi_{2,1} & \phi_{2,2} & \phi_{2,3} & \phi_{2,4} \\ \pi_3 & \phi_{3,1} & \phi_{3,2} & \phi_{3,3} & \phi_{3,4} \\ \pi_4 & \phi_{4,1} & \phi_{4,2} & \phi_{4,3} & \phi_{4,4} \\ \pi_5 & \phi_{5,1} & \phi_{5,2} & \phi_{5,3} & \phi_{5,4} \end{bmatrix} \begin{bmatrix} EC_{t-1-2/3}^3 \\ EC_{t-1-1/3}^3 \\ EC_{t-1}^3 \\ GDP_{t-1} \\ \rho_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \\ \varepsilon_{5,t} \end{bmatrix}. \tag{3}$$

Next, we employ conventional impulse response analysis using Cholesky decomposition for inferences with order $EC_{t-2/3}^3, EC_{t-1/3}^3, EC_t^3, GDP_t$, and ρ_t . The decomposition imposes a recursive causal ordering that restricts the contemporaneous impact of each variable on the variables. That is, each variable affects the subsequent variable, and no variable affects the previous one contemporaneously; however, each variable affects each other with a lag.

3. EMPIRICAL RESULTS

We examine the dynamic interactions among a set of macro variables and electricity consumption using VAR and MF-VAR models by employing IRFs. The IRF reports the estimated effects of one standard deviation shock given to a variable, on current and future values of all variables in the VAR system (Borozan, 2013). The dotted lines in the figures show 95% confidence intervals, and the middle line between these two dotted lines gives the impulse responses. If the confidence bands include zero line, then we fail to reject the null hypothesis stating that impulse responses are statistically insignificant.

Figure 1 reports the analysis on the impulse responses of quarterly electricity consumption (EC) and GDP using the conventional VAR model. As the VAR model requires all the variables in the model to be in the same frequency, we aligned monthly electricity consumption downward to treat it as a quarterly variable. As can be seen from this figure, neither a one-standard deviation shock in quarterly electricity consumption, nor a one standard deviation shock in GDP generate statistically significant results in terms of the impulse responses of GDP and quarterly electricity consumption, respectively.

In Figure 2, however, we used the MF-VAR model to test the same relationship but with monthly electricity consumption and quarterly GDP and without doing any alignment. For notational convenience, we use EC1 instead of $EC_{t-2/3}^3$, which is the electricity consumption of the first month of each quarter. Similarly, we indicate the electricity consumption of the second month of each quarter $EC_{t-1/3}^3$, and the electricity consumption of the third month of each quarter EC_t^3 , with EC₂ and EC₃, respectively. The last column of Figure 2 suggests that a shock in GDP does not affect any of the monthly electricity consumptions in a statistically significant fashion. However, the last row of the figure reports that a shock in EC3 increases GDP growth in a statistically significant fashion at the

initial period. Hence, an increase in electricity consumption causes an increase in GDP lending support for the growth hypothesis. This result is parallel to the one found by Altinay and Karagol (2005): using data from 1950 to 2000, they also found a unidirectional causality running from electricity consumption to income for Turkey.

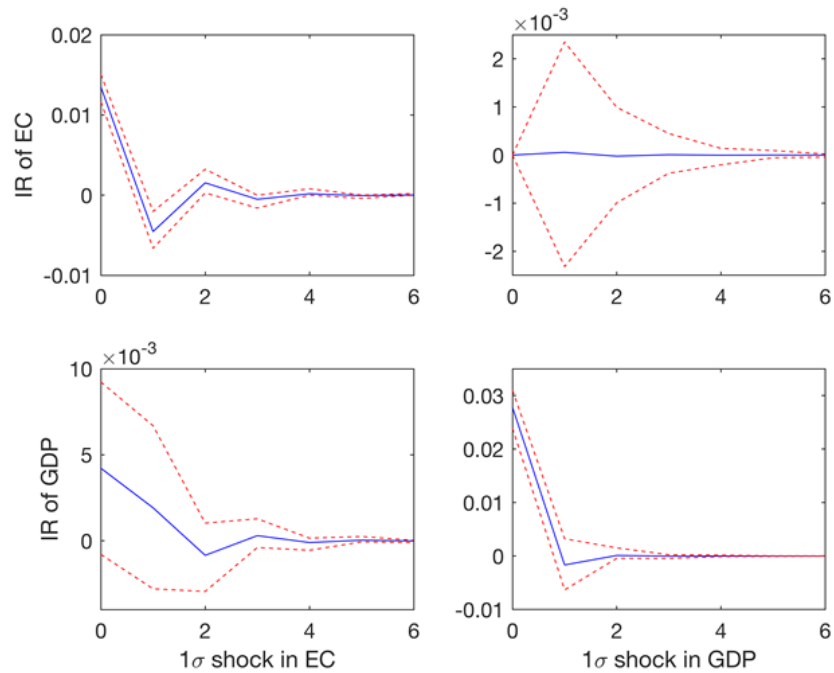


Figure-1. Impulse Response Functions based on the VAR(1) model of quarterly Electricity Consumption (EC) and quarterly GDP.

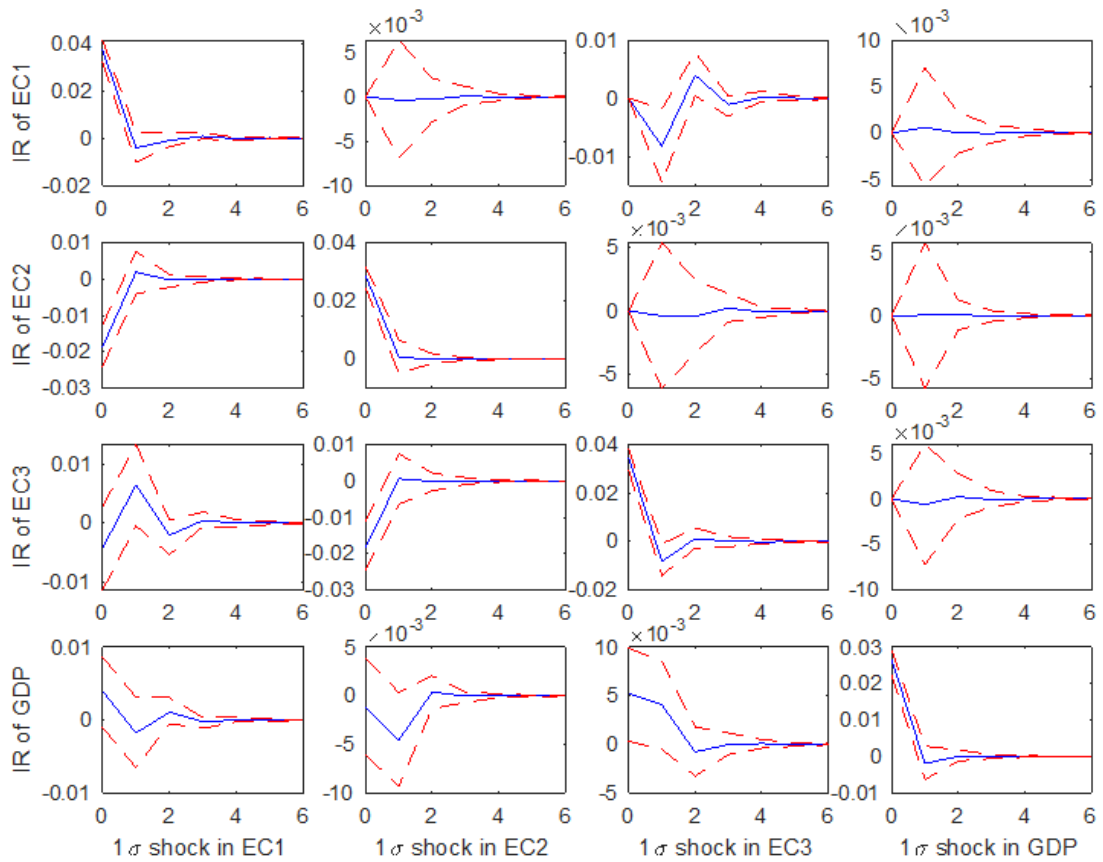


Figure-2. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$) and quarterly GDP.

Hence, based on the results from Figure 1 and Figure 2, we see that while using the same frequency data does not generate statistically significant results, the mixed frequency framework does. The reason behind the difference between the two may arise from the fact that Figure 1 suffers from the consequences of ignoring the availability of high frequency data. For this reason, the impulse responses of the MF-VAR model achieve greater explanatory power than the impulse responses of the quarterly VAR.

Next, we re-perform the analysis by adding an additional quarterly variable to the MF-VAR specification. There are two reasons for adding this second low frequency variable. First, we want to see if monthly electricity consumptions affect these added variables differently than how they affect GDP. Secondly, we want to analyze if a shock in the added variable effects electricity consumption differently when compared to a shock in GDP.

Figure 3 to 12 report the impulse responses of our MF-VAR model with added variables. However, we report the impulse response estimates that concern the added variables and monthly electricity consumptions only because the rest is almost identical to Figure 2. Based on this, the first column of Figure 3 to 12 report how a one-standard deviation shock in EC1, EC2, and EC3 affect the added variable. The second column of these figures, on the other hand, reports how a one-standard deviation shock in the added variables affects the monthly electricity consumptions. The added variables from Figures 3 to 7 are based on the expenditure approach of GDP calculation and include Private Consumption Expenditure, Government Spending, Investment, Exports, and Imports. The added variables from Figures 8 to 12, on the other hand, are based on the production approach of GDP calculation and include the Construction Sector, Industrial Sector, Manufacturing Industry, Service, and Agricultural Sector outputs.

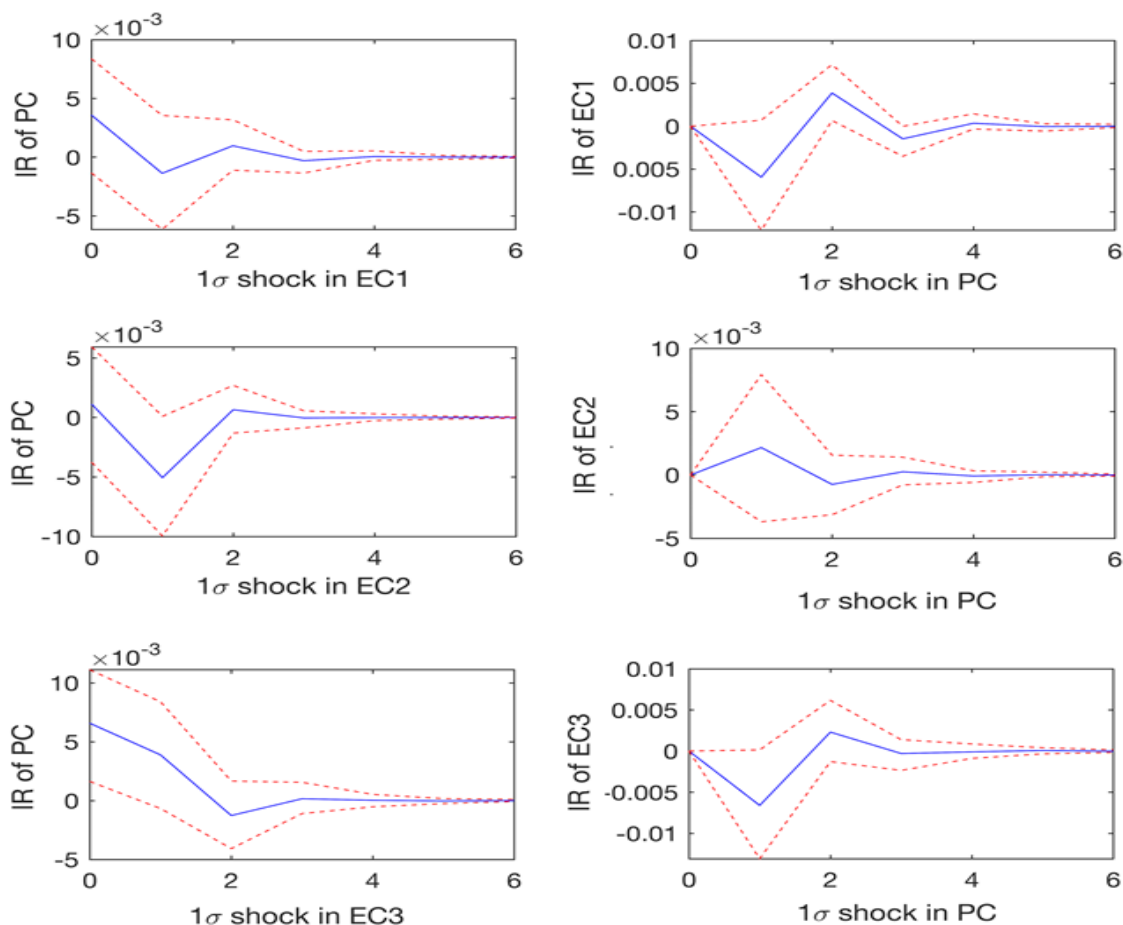


Figure-3. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Private Consumption (PC).

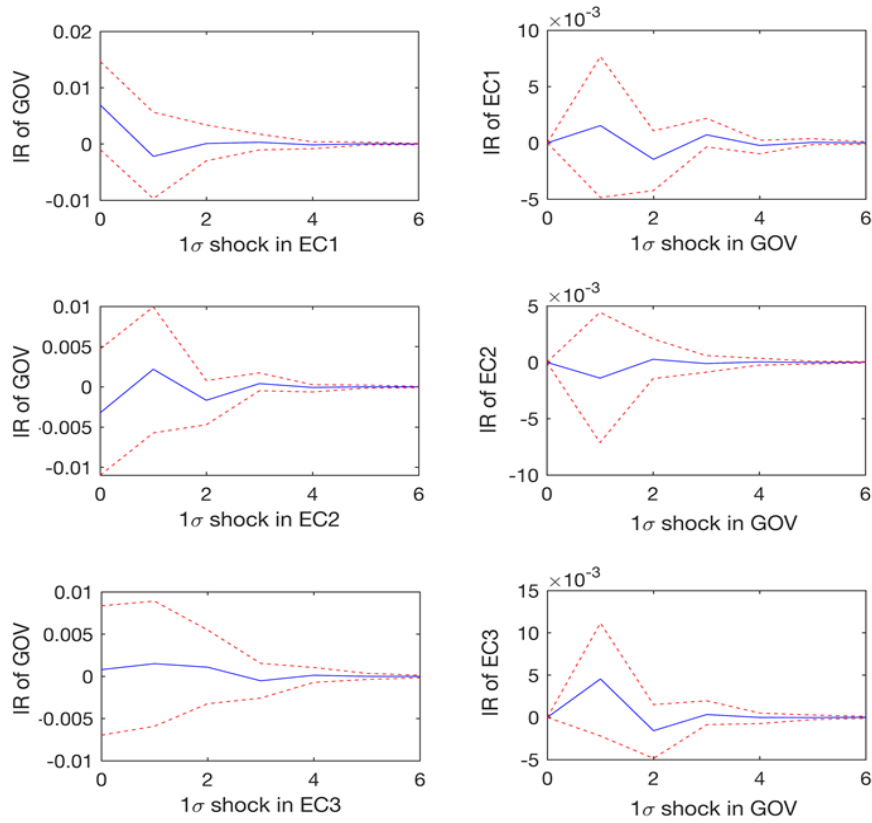


Figure-4. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Government Spending (GOV).

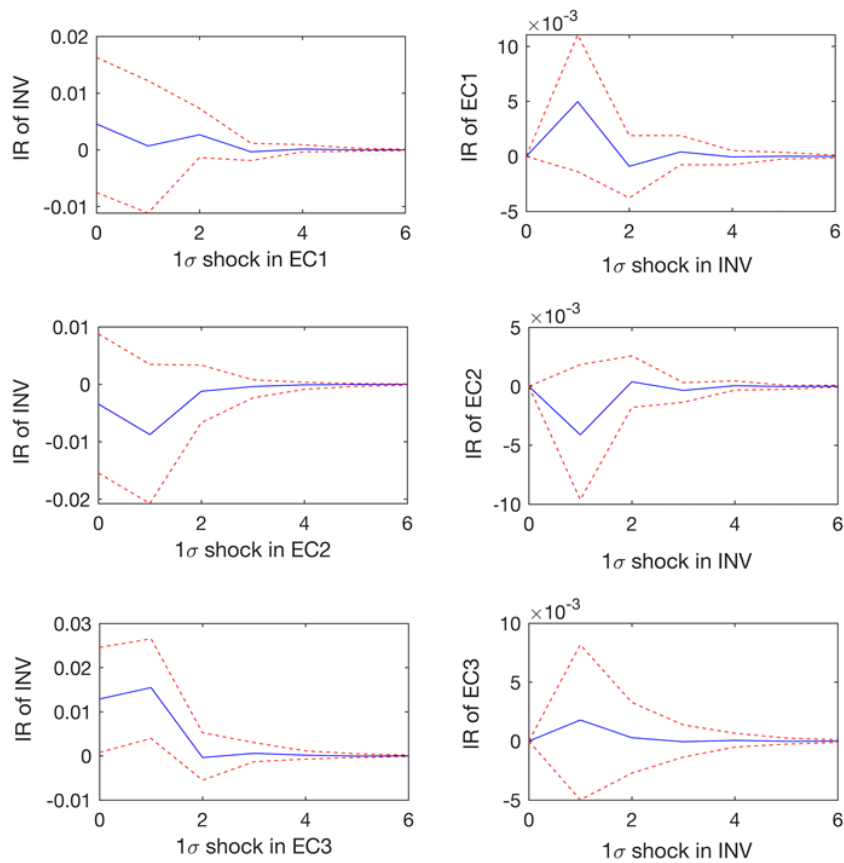


Figure-5. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity

Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Investment (INV).

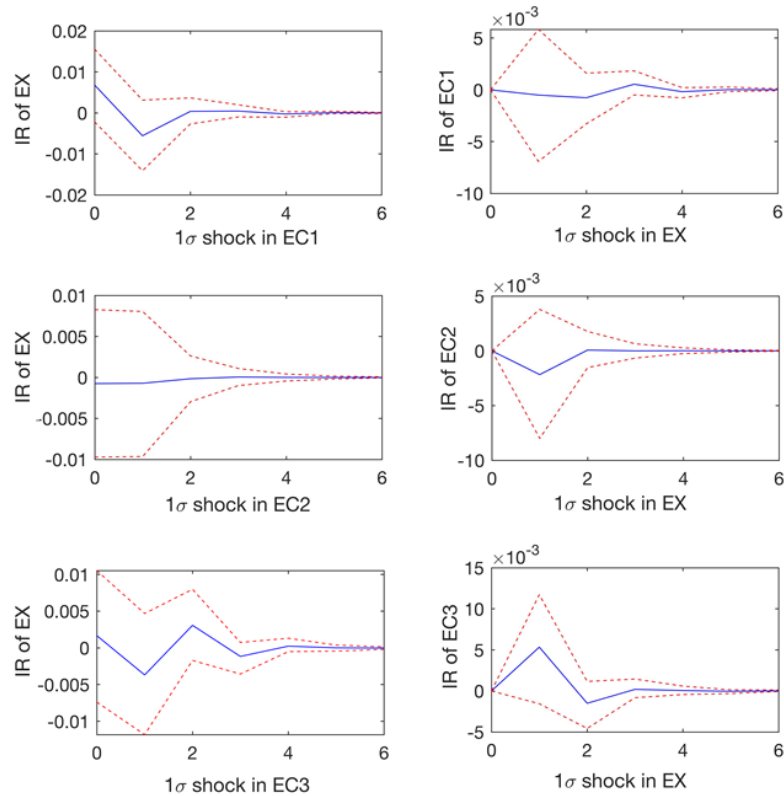


Figure-6. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Exports (EX).

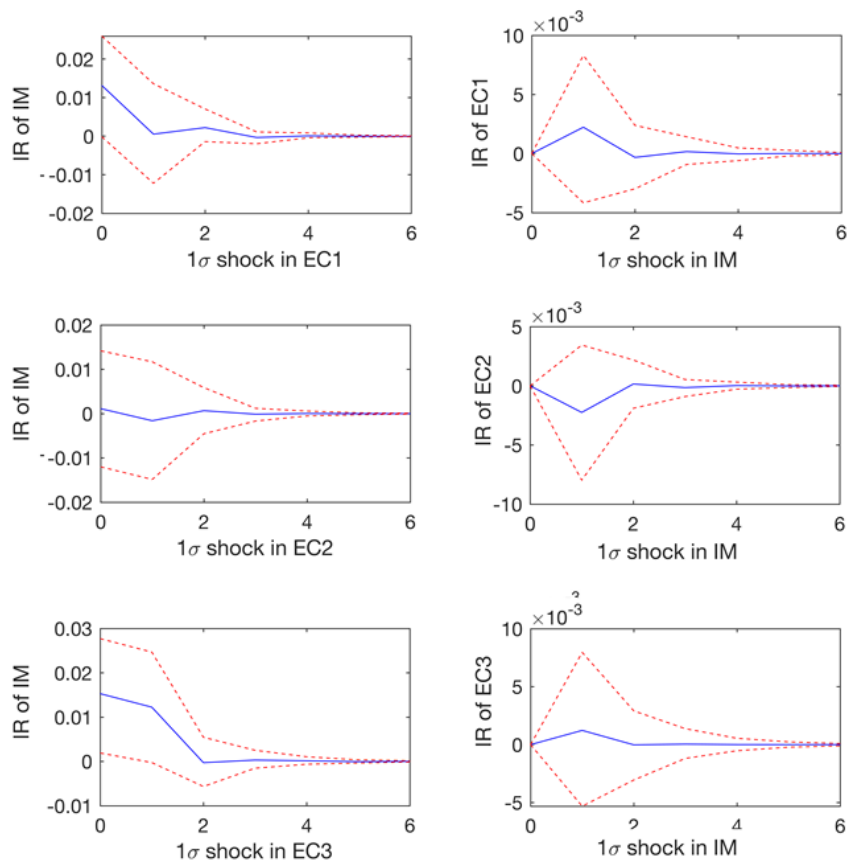


Figure-7. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Imports (IM).

Figures 3 to 7 reveal that when a shock is given to the electricity consumption of the third month of each quarter, EC3 increases Private Consumption Expenditure, Investment, and Imports more than it increases GDP contemporaneously. This means that if the government implements policies that result in an increase in the electricity consumption of these components, the output of them will increase more than GDP increases. However, we could not find any statistically significant responses of Government Spending and Exports relative to GDP growth.

In terms of the impulse responses of monthly electricity consumptions to a one-standard deviation shock in the added variable, the only statistically significant result we found was for Private Consumption Expenditure, where the second column of this third figure reports that a shock in Private Consumption relative to GDP increases EC1 at the second period. This means that a shock in Private Consumption expenditure increases electricity consumption more than a shock in GDP increases electricity consumption.

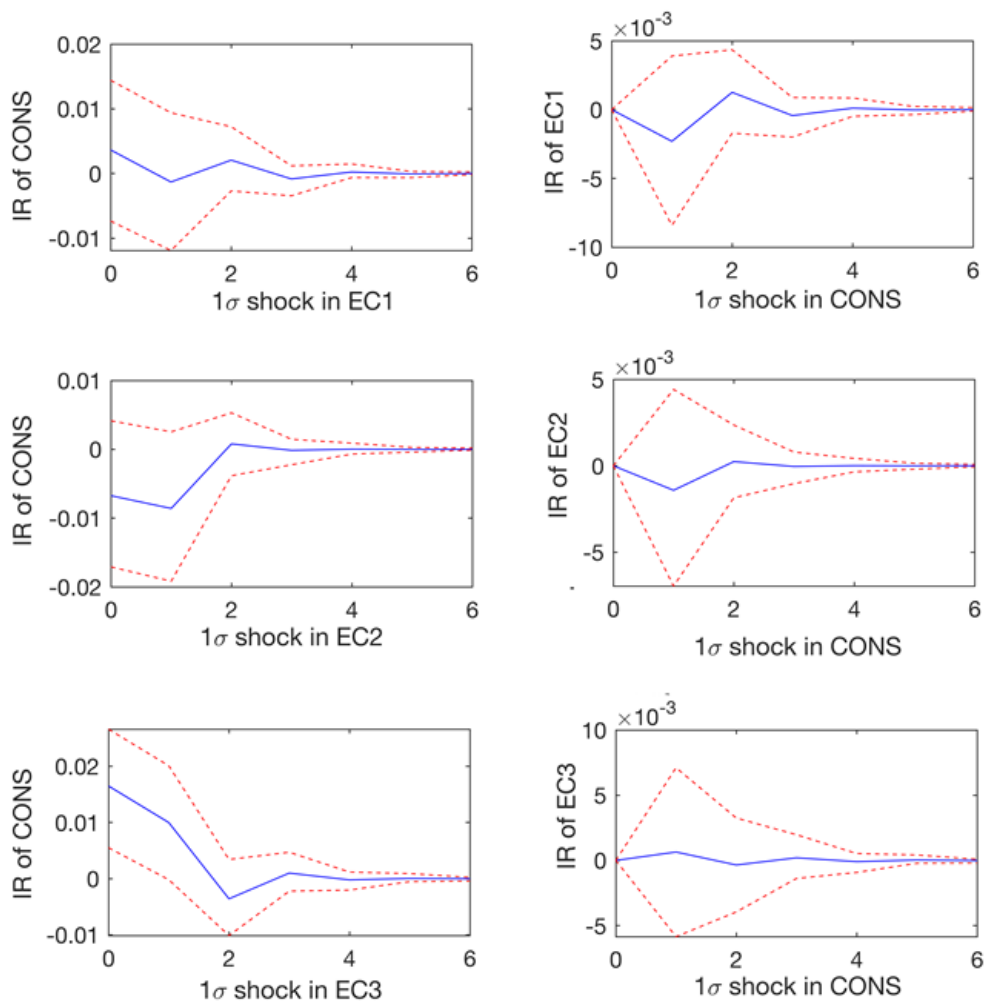


Figure-8. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions (EC1, EC2, EC3), quarterly GDP, and quarterly Construction Sector output (CONS).

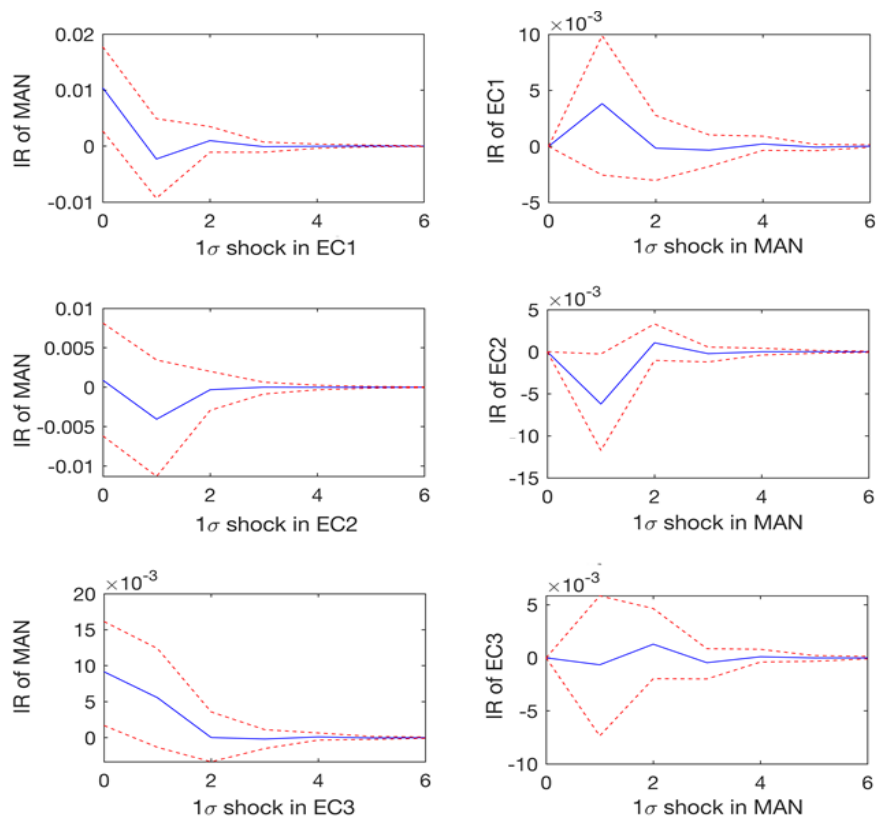


Figure-9. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Manufacturing Sector output (MAN).

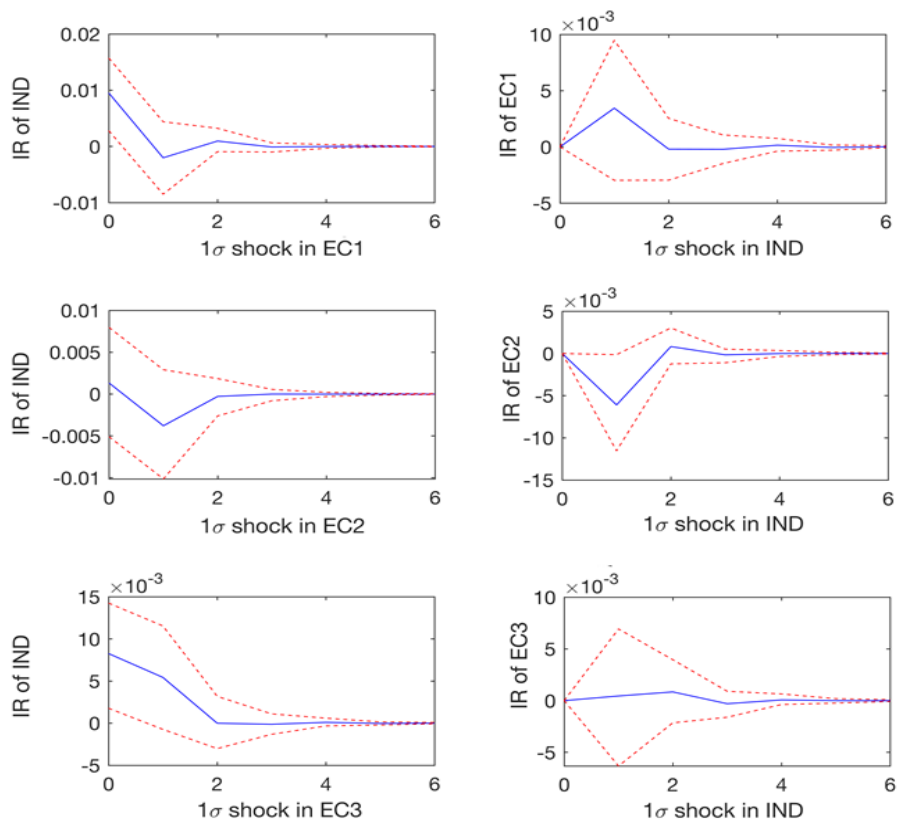


Figure-10. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Industrial Sector output (IND).

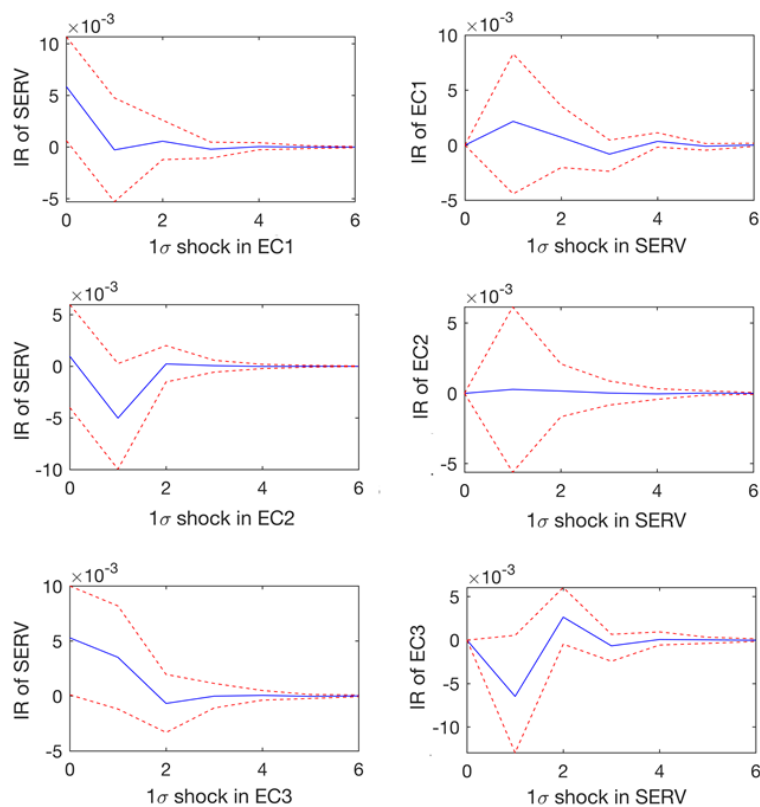


Figure-11. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Service sector output (SERV).

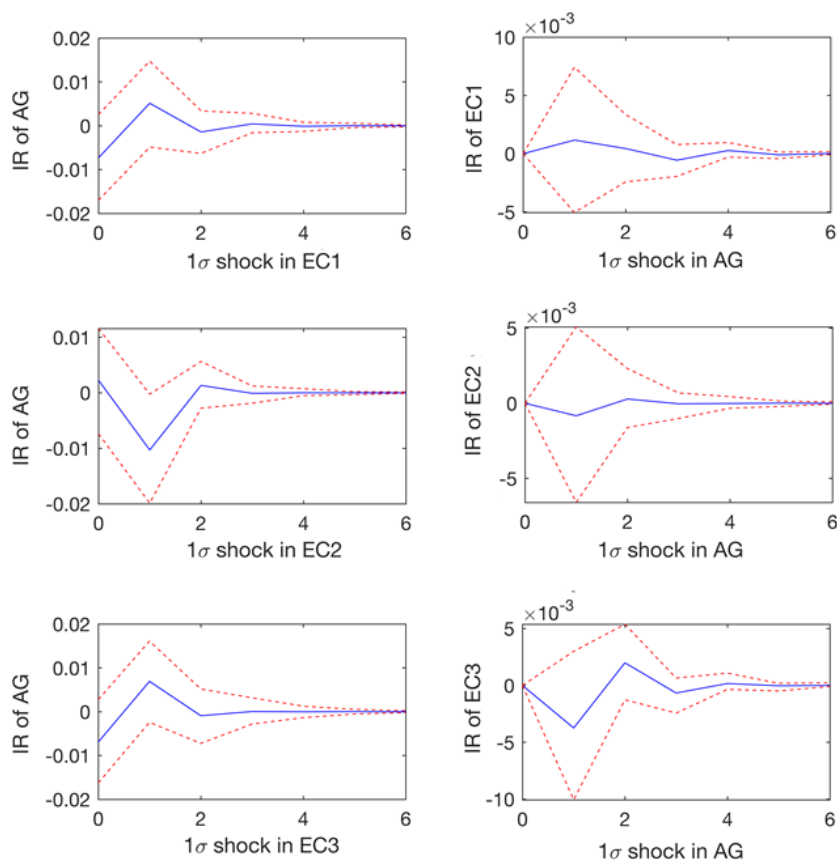


Figure-12. Impulse Response Functions based on the MF-VAR(1) model of monthly Electricity Consumptions ($EC1, EC2, EC3$), quarterly GDP, and quarterly Agricultural Sector output (AG).

Taking into consideration Figures 8 to 12, we see that a shock in monthly electricity consumption increases Construction sector, Manufacturing sector, Industrial sector, and Service sector outputs more than it increases GDP contemporaneously. As can be seen in Figures 8 to 11, these effects are due to an increase in the electricity consumption of the first or third months of each quarter. Different from these results, Figure 12 reports that in the first period an increase in EC2 increases Agricultural sector output less than it increases GDP. Even if these decreases are not statistically significant, when the level of confidence is at the 95%, then they are statistically significant for EC1; the same is true for EC3 when the confidence level is at the 90%. For the impulse responses of the electricity consumption to a one-standard deviation of the added variables, we were not able to find any statistically significant results for the last five figures.

4. CONCLUSION

In this study, we investigate the relationship between electricity consumption and GDP growth, as well as the relationship between electricity consumption and the relative growth of GDP's sub-components to GDP for the Turkish economy. When we used the conventional quarterly VAR model, we could not find a statistically significant relationship between quarterly electricity consumption and quarterly GDP growth. However, when we adopted the MF-VAR specification with monthly electricity consumption and quarterly GDP, we found that an increase in electricity consumption increases GDP growth.

Continuing to use the MF-VAR model but with an added low frequency variable, we found that an increase in electricity consumption increases Private Consumption, Investment, Imports, Construction sector output, Manufacturing sector output, Industrial sector output, and Service sector output more than a positive shock in electricity consumption increases GDP. In addition to this, we found that an increase in electricity consumption increases Agricultural sector output less than it increases GDP growth. Looking at the effect of a shock in the added variable on electricity consumption, we could not find a statistically significant result except for the effect of a shock in Private Consumption on electricity consumption. This estimation suggests that a positive shock in Private Consumption increases electricity consumption more than a positive shock in GDP increases electricity consumption.

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