Which has Higher Real Effects on an US Unincorporated Territory,

The Price of Crude Oil or the Monetary Policy? Evidence Fron the Case of Puerto Rico

Braulio A. Quintero and Carlos A. Rodriguez

Abstract

Puerto Rico is an unincorporated territory of the United States of America. As part of the political-economic arrangement between both political entities, Puerto Rico does not control the local price of oil because it does not have domestic sources of oil, and it does not control its monetary policy, as that is a right reserved by the U.S. Federal Reserve System. This paper investigates the impacts of exogenous shocks of oil price and monetary policy on the Economic Activity Index, Puerto Rico Consumer Price Index, total non-farm employment, electricity consumption, gasoline consumption, and cement sales. Impulse response functions are used to study the oil price and monetary policy shocks. The oil price shock had a more significant effect on gasoline consumption than on electricity consumption. Monetary policy shocks had a higher magnitude on electricity consumption than on gasoline consumption. The monetary policy and oil price shock had minimal effect on the aggregated endogenous variables, Economic Activity Index, and Puerto Rico Consumer Price Index. This study suggests that individuals in Puerto Rico are vulnerable to a volatile oil market. Also, both exogenous variable shocks had minimal impact on employment. As for future steps, it would be prudent to investigate the effect of both exogenous variables on individual employment sectors, not aggregated. Besides, the government of Puerto Rico should develop policies to minimize the effect of oil price shocks.

Key Words: Oil Price Shocks, Monetary Policy Shocks, Structural Decomposition, Time Series Analysis, US and Puerto Rico Economic Relations

JEL Codes: C32, C51, C57, E43, E52, Q41, Q43

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1. INTRODUCTION

Oil price and monetary policy shocks can affect economies in different ways and magnitudes. Oil price shocks can affect financial markets (Demirer et al., 2020), global agricultural commodities trading (Wang et al., 2014) and gasoline (Wensheng et al., 2018) and electricity prices (Amin, 2015). Oil price shocks can affect oil exporting and oil importing countries in different ways (Wang et al., 2013). Researchers have studied the effects of monetary policies and oil price shocks on the U.S. economy (Hamilton, 2003; Hamilton, 2004; Kim, 2001; Surico, 2007; Vargas-Silva, 2008). Barsky and Kilian (2002) studied how global shifts in monetary policy in the 1970s affected real economic growth and inflation. Some have argued that the Great Stagflation (Blinder, 1979) was not necessarily caused by the oil price shocks of the 1970s, as had been argued by Hall and Klitgaard. (2017). However, others have shown that it was the oil crisis in the early 1970s that caused the Great Stagflation.

Hooker (2002) suggested that oil shocks affected inflation rates before 1981 in the U.S., but since then, the pass-through has been negligible, and oil price shocks have not as heavily impacted monetary policy. Bodenstein et al. (2012) developed a model for the U.S. monetary policy that determined that causality runs both ways from oil price to monetary policy as well as from changes in monetary policy to the supply and demand in global markets. Cuñado and Pérez de Gracia (2003) concluded that oil price shocks affected the European economies differently depending on the national oil price index used in the analysis. Also, there is no long-run relation in Europe between economic activity and oil price shocks. Oil price is limited to the short-run equilibrium. Cologni and Manera (2008) studied the impulse response of oil prices, inflation, and interest rates of G7 countries and among their results, they determined that there is a temporary effect of oil price shocks on consumer prices and inflation rates in all G7 countries, except in the UK, US, and Japan. Hence the results are mixed for countries and specific global regions.

Puerto Rico, an unincorporated territory of the U.S., has a dollarized economy. The government of Puerto Rico does not control its monetary policy, which limits the policy options the government must stabilize economic recessions. Therefore, monetary policy and oil prices affect Puerto Rico exogenously because neither of the indicators is part of Puerto Rico data (Rodirguez-Ramos, 2002; Rodriguez and Toledo, 2007). The integration of the economy of Puerto Rico into the U.S. banking industry links it directly to the Federal Reserve System. The monetary policies implemented by the Federal Reserve Bank affects the economy of Puerto Rico in three main ways: (1) maintaining open market operations of commerce between firms and individuals, (2) determination of interbank lending interest rates, and (3) establishing the rates of liquidity reserves required by banks.

In addition to the monetary policy challenges inherited by the political-economic relation between the US and Puerto Rico, the island population is dependent on imported oil. The dependence on imported oil and the volatility of its price affects the production and consumption of goods and services in Puerto Rico. The oil price volatility in international markets affects the operation costs of business directly on the island. The electricity industry is especially vulnerable to sudden changes in oil prices as 70 % of the power generation on the island depends on residual fuel oil, and the other 30 % is dependent on coal and liquid natural gas. The dependence of Puerto Rico on imported fossil fuels, especially oil, represents a vulnerability that has adverse effects on the economy.

Hence, the main objective of this paper is to determine the impact of monetary policy and oil price shocks on several economic indicators: (1) Economic Activity Index (2), Puerto Rico Consumer Price Index (3) total non-farm employment, (4) electricity consumption, (5) gasoline consumption, and (6) cement sales. These data are selected because they represented major indices of economic activity and were readily available. The main research questions are: (1) what is the period that it takes for an economic indicator in Puerto Rico to reach a new equilibrium after oil price and monetary policy shocks, and (2) how the magnitude of the oil price and monetary price shocks affects each indicator.

This paper has four additional sections. Section 2 discusses the background information on the monetary policy, which frames the methods used in this paper. Section 3 presents the methods implemented to answer both research questions. Section 4 presents and discusses the results of this research, and section 5, uses the result of this research in the light of previous research.

Specifically, we undertook a time series analysis of the components of the Economic Activity Index (EAI) and analyze the responses of the EAI, the local price index, and the EAI components to external shocks (monetary policy and oil prices). The Economic Activity Index is a composite metric estimated by the government of Puerto Rico to evaluate the monthly economic activity. The time-series analysis of the EAI and its components is performed to understand the basic structure of the economy of Puerto Rico, and the impulse response analysis determines how external shocks affect the economy of Puerto Rico. The time series and impulse response analysis are essential tools for policy decisions.

2. METHODS

2.1. Econometric model assumptions

The following monetary scheme appears when the particularities of the economy of Puerto Rico are examined *vis-à-vis* the influence exercised by the Federal Reserve Bank over the money flow on the island. The following set of general assumptions describes the monetary relation in which a currency is importing **by Economy A** and exporting **by Economy B**. Both economies maintain a specific political and economic relation. We assume that **Economies A and B** have a relation described by three main characteristics:

- **Economy A**, imports, and depends on the currency of **Economy B**
- his banking system integrates into the banking system of **Economy B.**
- **Economy B** unilaterally establishes the monetary policy of **Economy A**.

A significant implication of the characteristics that describe the relation between **Economy A and B** is that **Economy A** cannot establish its monetary policy to stabilize its fiscal issues. Hence, this study assumes that the policymakers of **Economy A**:

- Form their local decisions according to the hypothesis of rational expectations
- Have complete knowledge of the effects of the monetary policy on **Economy A**
- Know the structure of the economy at the beginning of every period t
- Know that any deviation from an inflation rate of 0 % and full employment is a loss of social welfare
- Know that the government institution has the policy tools to fulfill their political objectives.

According to the point previously discussed, the following equations describe the **Economy A**.

$$L_{It} = \omega \dot{p}_{It}^{2} + \left(y_{It} - \lambda \bar{y}\right)^{2} \tag{1}$$

$$y_{It} = \bar{y} + \gamma_1 \left(\dot{p}_{It} - p_{t-1} \dot{p}_{It} \right) + \gamma_{\boldsymbol{m}-1} \boldsymbol{Z}_{\boldsymbol{It}} + \boldsymbol{e}_{\mathbf{I,st}} \tag{2}$$

$$\dot{m}_{It} + \dot{v}_{It} = \dot{p}_{It} + \dot{y}_{It} \tag{3}$$

$$\dot{m}_{It} = \tau \dot{m}_{Xt} \tag{4}$$

Equation (1) is the government revenue loss function with ω >0. Where L_{It} is the government metric to minimize revenue loss, and ω is the weight that the government gives to inflation relative to the weight given to the economic activity $\bar{y}$ when there is full employment, $\dot{p}$ is the estimated growth on prices, $\dot{m}$ is the estimated money supply growth, $\dot{v}$ is the estimated velocity of money. Lambda (λ) is a weight parameter that varies between 0 and 1, which implies that the government imposes a transitory reduction of $\bar{y}$ economic activity. The implication of this equation is that fiscal policies will generate a level of economic activity higher than the optimum $\lambda \bar{y}$, which is the desired level of economic activity.

Equation (2) is the Lucas Supply Function (Bull and Frydman, 1983) that assumes that economic activity y_{It} is maintained with full employment unless there is a sudden change in prices $\left(\dot{p}_{It} - p_{t-1} \dot{p}_{It} \right)$. Where $\dot{p}_{It}$ is the level of prices as measured by the Puerto Rico Consumer Price Index (PRCPI) and $p_{t-1} \dot{p}_{It}$ is the rational expectation of the changes in prices according to the information available at the time of expectation formation. Matrix $\boldsymbol{Z}_{\boldsymbol{It}}$, with n × n dimensions, contains a group of economic variables relevant to this study. The γ_1 parameter represents the response of the real economic activity relative to a price shock. An increase in the price of oil, and hence mostly everything, will be reflected in a proportional decrease in economic activity and hence, employment. The vector $\gamma_{\boldsymbol{m}-1}$ represents the body of parameters, excluding γ_1, that measures the response of the economic activity upon changes on the $\boldsymbol{Z}_{\boldsymbol{It}}$ matrix. In other words, γ_1 is the same as the partial elasticities of the system. A stochastic component is added $\boldsymbol{e}_{\mathbf{I,\,st}}$ due to the random effects generated from a deviation of full employment. This error term has a normal distribution, an independent mean, and constant variance.

Equation (3) is a simplified version of the quantitative equation of money, where: $\dot{m}_{It}$ represents the monetary growth, $\dot{v}_{It}$ represents the change velocity of money and $\dot{y}_{It}$ the real growth rate of the economy. Equation (4) indicates the money supply of the currency importing economy A is a portion τ of money supply exporting economy B. Concerning the currency exporting economy; it assumed that:

$$r_{Xt} = r\left(u_{Xt}, \dot{p}_{xt}\right) \tag{5}$$

$$\dot{p}_{Xt} = g\left(\dot{m}_{Xt}, e_{Xsdt}\right) \tag{6}$$

The interest rate r is the monetary policy instrument, and according to Equation (5) has a feedback rule for **Economy B** (Rodriguez and Toledo, 2007). The monetary authorities of **Economy B** determine the interest rate according to the behavior of the economic activity function and inflation. However, the rule exposed in Equation (5) (the Okun Law) (Prachowny, 1993) is included to replace the production gap for the unemployment rate (Stock and Watson, 2001). Equation (7) describes the dynamic behavior of prices in economy B, which depend mainly on monetary growth, but unexpected changes in aggregate demand and supply (which can be monetary impulses) can add white noise to its evolution (Rodriguez and Toledo, 2007).

Economic agents will, in theory, form their expectations according to the rational expectations hypothesis. Hence, the anticipated value for a variable Z is expressed in a conditioned fashion according to information grouping $E(Z_t \mid \mathrm{I}_t)$. The government desires to maximize the social welfare function, given the restrictions imposed by the relation between inflation and full employment.

$$L_{It} = \omega \dot{p}_{It}^2 + \left[\bar{y} + \gamma_1 \left(\dot{p}_{It} - p_{t-1} \, \dot{p}_{It} \right) + \gamma_{m-1} \boldsymbol{Z}_{It} + \boldsymbol{e}_{\mathbf{I,st}} - \lambda \bar{y} \right]^2 \tag{7}$$

Given the maximums and minimums for L_{It}, the derivative demands to be null relative to the inflation. Then the following equation is obtained:

$$\frac{\partial L_t}{\partial \dot{p}_{It}} = \omega \dot{p}_{It} - \left[\bar{y} + \gamma_1 \left(\dot{p}_{It} - p_{t-1} \, \dot{p}_{It} \right) + \gamma_{m-1} \boldsymbol{Z}_{It} + \boldsymbol{e}_{\mathbf{I,st}} - \lambda \bar{y} \right] \gamma_1 = 0 \tag{8}$$

Reordering Equation (8) the following equation is:

$$\dot{p}_{It} = \varphi_1 \bar{y} + \varphi_2 p_{t-1} \, \dot{p}_{It} + \varphi_3 \boldsymbol{Z}_{It} + \boldsymbol{e}_{\mathbf{I,st}} \tag{9}$$

Where:

$$\varphi_1 = \frac{\left(\lambda \gamma_1 - \gamma_1\right)}{\gamma_1^2 - \omega}$$

$$\varphi_2 = \frac{1}{\gamma_1^2 - \omega}$$

$$\varphi_3 = \frac{\gamma_0}{\gamma_1^2 - \omega}$$

Assuming the velocity of money is constant, and that the growth of production depends on the change of the factors of production expressed in Equation (3) in neutral terms of money are the stochastic form:

$$\dot{m}_{It} = \dot{p}_{It} + \boldsymbol{e}_{\mathbf{I,dt}} \tag{10}$$

Any deviation in Equation (10) generates the stochastic component $\boldsymbol{e}_{\mathbf{I,dt}}$ that includes the random effects. To relate the monetary policy of the economy of country B with the economy of country A, Equation (5) is substituted in Equation (6) and the following equations are:

$$\dot{m}_{Xt} = r^{-1}\left(u_{Xt}, r_{Xt}, e_{Xsdt}\right) \tag{11}$$

$$\dot{p}_{It} = \tau\left[r^{-1}\left(u_{Xt}, r_{Xt}, e_{Xsdt}\right)\right] \tag{12}$$

Equations (5), (9), and (12) describe the system that will be studied. Given that Equations (9) and (12) include the price expectations, it is necessary to include them in the rational expectation hypothesis because it uses the systems information to predict this variable. The assumption is that the system is under full employment when Equation (9) sets into Equation (12), and a Vector Autoregressive model will be in its primitive form.

$$y_{It} = a_{10} + \sum a_{11}(i)\, y_{Xt-i} + \sum a_{12}(i)\, \dot{p}_{\boldsymbol{It}-i} + \sum c_{13}(i)\, r_{xt-i} + B_0 \boldsymbol{Z}_{\boldsymbol{It}} + B_1 \boldsymbol{Z}_{\boldsymbol{It}-1} + \cdots + B_q \boldsymbol{Z}_{\boldsymbol{It-q}} + e_{1t} \tag{13}$$

$$\dot{p}_{It} = a_{20} + \sum a_{21}(i)\, y_{Xt-i} + \sum a_{22}(i)\, \dot{p}_{It-i} + \sum c_{23}(i)\, r_{xt-i} + B_0 \boldsymbol{Z}_{\boldsymbol{It}} + B_1 \boldsymbol{Z}_{\boldsymbol{It}-1} + \cdots + B_q \boldsymbol{Z}_{\boldsymbol{It-q}} + e_{2t} \tag{14}$$

The variables a_{ij} represent the systems parameters, c_{ij} the parameters of the exogenous variable r_{xt-i} , and

B_q the matrices of the variables according to the lags q and e_{1t} .

e_{2t} are the error terms with a mean of zero and constant variance for Equation (13) and Equation (14), respectively.

Under the assumption of rational expectations, the impulses of aggregate demand would have only transitory effects on aggregate production, while they would permanently influence the price level. On the other hand, the innovations of the aggregate supply would be expected to affect both the prices and the production permanently. In the next two sub-sections, we'll discuss the data source and the strategy used to identify those two types of disturbances empirically (Blanchard and Quah, 1989).

Due to these restrictions, the reduced form of this model implies that production and prices depend on the impulses of aggregate supply and demand, of the monetary policy of the United States, as well as an additional set of variables presented in the next section (Blanchard and Quah, 1989).

$$y_{It} = \theta_1(\varepsilon_{IS,t}, \varepsilon_{ID,t}, \varepsilon_{r,t}, \ldots) \tag{15}$$

$$p_{It} = \theta_2(\varepsilon_{IS,t}, \varepsilon_{ID,t}, \varepsilon_{r,t}, \ldots) \tag{16}$$

1.1. Data sources and analysis

I used oil price (OP) from the West Texas Intermediate benchmark index and the Federal Fund Interest Rates (FF) as proxy variables, which served as the exogenous shocks. The exogenous variables data are from the Federal Reserve Economic Research electronic data portal. This study considered the following six endogenous variables: the Puerto Rico Consumer Price Index (PRCPI), the Economic Activity Index (EAI), total non-farm employment, electricity consumption, gasoline consumption, and cement sales. The Puerto Rico Consumer Price Index measures the relative value of the basic basket of foodstuff in Puerto Rico, and the Puerto Rico Planning Board estimates it, and the data values are from the Puerto Rico GBD data portal. The Economic Activity Index is a composite metric based upon the methods developed by The Conference Board. The EAI has four components: total non-farm employment (TNFE) (Figure 23e), electricity consumption (EC), gasoline consumption (GC), and cement sales (CS) (Figure 23h). Data constraints set the study period from January 1984 to December 2015. Monthly gasoline consumption data reported by the GDB data portal begins in 1984, in contrast to the other three EAI components, for which reporting began in January 1980. We chose this data because government agencies have continuously collected them since the early 1980s. We chose the PRCPI because it is a relative measure of the average prices for commodities in Puerto Rico.

1.1. Empirical Model Identification

By rewriting equations (7) and (8), both the supply and demand impulses shocks are[1]:

$$y_{It} = \theta_1(\varepsilon_{OP,t}, \varepsilon_{FF,t}, \varepsilon_{TNFE,t}, \varepsilon_{CS,t}, \varepsilon_{GC,t}, \varepsilon_{EC,t}, \varepsilon_{si,t}, , \varepsilon_{di,t}) \tag{17}$$

$$p_{It} = \theta_2(\varepsilon_{OP,t}, \varepsilon_{FF,t}, \varepsilon_{TNFE,t}, \varepsilon_{CS,t}, \varepsilon_{GC,t}, \varepsilon_{EC,t}, \varepsilon_{si,t}, , \varepsilon_{di,t}) \tag{18}$$

In this case, a dynamic version of the relationship is:

$$\begin{bmatrix} \Delta OP_t \\ \Delta FF_{X,t} \\ \Delta TNFE_{I,t} \\ \Delta CS_{I,t} \\ \Delta GC_{I,t} \\ \Delta EC_{I,t} \\ \Delta EAI_{I,t} \\ \Delta PRCPI_{I,t} \end{bmatrix} = \begin{bmatrix} \theta_{11} & \theta_{12} & \theta_{13} & \theta_{14} & \theta_{15} & \theta_{16} & \theta_{17} & \theta_{18} \\ \theta_{21} & \theta_{22} & \theta_{23} & \theta_{24} & \theta_{25} & \theta_{26} & \theta_{27} & \theta_{28} \\ \theta_{31} & \theta_{32} & \theta_{33} & \theta_{34} & \theta_{35} & \theta_{36} & \theta_{37} & \theta_{38} \\ \theta_{41} & \theta_{42} & \theta_{43} & \theta_{44} & \theta_{45} & \theta_{46} & \theta_{47} & \theta_{48} \\ \theta_{51} & \theta_{52} & \theta_{53} & \theta_{54} & \theta_{55} & \theta_{56} & \theta_{57} & \theta_{58} \\ \theta_{61} & \theta_{62} & \theta_{63} & \theta_{64} & \theta_{65} & \theta_{66} & \theta_{67} & \theta_{68} \\ \theta_{71} & \theta_{72} & \theta_{73} & \theta_{74} & \theta_{75} & \theta_{76} & \theta_{77} & \theta_{78} \\ \theta_{81} & \theta_{82} & \theta_{83} & \theta_{84} & \theta_{85} & \theta_{86} & \theta_{87} & \theta_{88} \end{bmatrix} \begin{bmatrix} \Delta OP_t \\ \Delta FF_{X,t} \\ \Delta TNFE_{I,t} \\ \Delta CS_{I,t} \\ \Delta GC_{I,t} \\ \Delta EC_{I,t} \\ \Delta EAI_{I,t} \\ \Delta PRCPI_{I,t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{OP,t} \\ \varepsilon_{r,t} \\ \varepsilon_{TNFE,t} \\ \varepsilon_{CS,t} \\ \varepsilon_{GC,t} \\ \varepsilon_{EC,t} \\ \varepsilon_{si,t} \\ \varepsilon_{di,t} \end{bmatrix} \tag{19}$$

[1] Variables: TFE, GC, GE, EC, can also be considered as supply shocks.

Where "Δ" represents the first difference of the variables under study, $\theta_{ij}(L)=\theta_{j1}(L)+\theta_{j2}(L)+\cdots+\theta_{1p}(L)$ are elements that describe the lags operator of "L," where "P" is the order of lags. From this system, the "Vector Moving Average" (VMA) representation can be obtained

$$\begin{bmatrix} \Delta OP_t \\ \Delta FF_{X,t} \\ \Delta TNFE_{I,t} \\ \Delta CS_{I,t} \\ \Delta GC_{I,t} \\ \Delta EC_{I,t} \\ \Delta EAC_{I,t} \\ \Delta p_{I,t} \end{bmatrix} = \varphi(L) \begin{bmatrix} \varepsilon_{op,t} \\ \varepsilon_{ff,t} \\ \varepsilon_{tnfe,t} \\ \varepsilon_{cs,t} \\ \varepsilon_{si,t} \\ \varepsilon_{gc,t} \\ \varepsilon_{si,t} \\ \varepsilon_{di,t} \end{bmatrix} \tag{20}$$

The matrix $\varphi(L)$ has the lag operator polynomials. For exposure purpose evaluating $\varphi(L)$ for one lag, the long-run multipliers matrix, when restricting that all the elements of the main diagonal are equal to zero, is represented as:

$$\varphi(1) = \begin{bmatrix} \varphi_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \varphi_{21} & \varphi_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ \varphi_{31} & \varphi_{32} & \varphi_{33} & 0 & 0 & 0 & 0 & 0 \\ \varphi_{41} & \varphi_{42} & \varphi_{43} & \varphi_{44} & 0 & 0 & 0 & 0 \\ \varphi_{51} & \varphi_{52} & \varphi_{53} & \varphi_{54} & \varphi_{55} & 0 & 0 & 0 \\ \varphi_{61} & \varphi_{62} & \varphi_{63} & \varphi_{64} & \varphi_{65} & \varphi_{66} & 0 & 0 \\ \varphi_{71} & \varphi_{72} & \varphi_{73} & \varphi_{74} & \varphi_{75} & \varphi_{76} & \varphi_{77} & 0 \\ \varphi_{81} & \varphi_{82} & \varphi_{83} & \varphi_{84} & \varphi_{85} & \varphi_{86} & \varphi_{87} & \varphi_{88} \end{bmatrix} \tag{21}$$

This identification scheme, initially proposed by Blanchard and Quah (1989), points out that demand impulses affect prices, but not economic activity in the long run. In this paper, the restrictions imply that none of the unexpected changes in Puerto Rico's variables affect the United States monetary policy and the oil price. Also, these two variables have short and long-run effects on EAI, PRCPI and EAI components. On the other hand, PRCPI is also affected, in the short and long run, by local supply and demand impulses. For robustness purposes, the identification is based on contemporary relations and must be carried out according to the following matrix:

$$\varphi(0)=\begin{bmatrix} \varphi'_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \varphi'_{21} & \varphi'_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ \varphi'_{31} & \varphi'_{32} & \varphi'_{33} & 0 & 0 & 0 & 0 & 0 \\ \varphi'_{41} & \varphi'_{42} & \varphi'_{43} & \varphi'_{44} & 0 & 0 & 0 & 0 \\ \varphi'_{51} & \varphi'_{52} & \varphi'_{53} & \varphi'_{54} & \varphi'_{55} & 0 & 0 & 0 \\ \varphi'_{61} & \varphi'_{62} & \varphi'_{63} & \varphi'_{64} & \varphi'_{65} & \varphi'_{66} & 0 & 0 \\ \varphi'_{71} & \varphi'_{72} & \varphi'_{73} & \varphi'_{74} & \varphi'_{75} & \varphi'_{76} & \varphi'_{77} & 0 \\ \varphi'_{81} & \varphi'_{82} & \varphi'_{83} & \varphi'_{84} & \varphi'_{85} & \varphi'_{86} & \varphi'_{87} & \varphi'_{88} \end{bmatrix} \quad (22)$$

According to this matrix, " OP_t " is the most exogenous variable, so it is not contemporaneously affected by the other variables. The Blanchard-Quah (BQ) methods allow investigating the impulse response function of the model variables when shocked with the exogenous variables (Rossi, n.d.). Changes in the EAI and in TNFE, CS, GC and EC, provide the aggregate supply shock, and the sudden change in oil price conveys the aggregate demand shock. This Blanchard-Quah (1989) decomposition is also useful to forecast the effects of the oil price and monetary policy shock on the endogenous variables

2.1.1. Impulse response function (IRF) and forecast error variance decomposition (VD)

I used the IRF to study the oil price and monetary policy shocks on the six endogenous variables. Also, I used the VD metric to assess the accuracy of the impulse response function.

I shocked the endogenous variables with a ± 1 standard deviation. The impulse response function (IRF) forecasts the behavior of the error term of each equation in the SVAR model with a 95 % confidence interval.

3. RESULTS

3.1. EAI and components time series analysis

In 1984 Puerto Rico was coming out of a local economic recession partially caused by the 1979 international energy shock price increase that led the Commonwealth Oil Refining Company (CORCO) to file a bankruptcy case at the San Juan District Federal Court. The CORCO was the leading industrial project of the Economic Development Administration from the early 1960s to the early 1980s. From 1984 to approximately 2005, the oil price (Figure 1) ranged from $15 to $ 40, and the federal fund interest rates had a negative trend until it reached 0 % at around 2007-2008 (Figure 1). The PRCPI (Figure 1) increased continuously throughout the study period, which differs from all other variables considered in this study. The EAI and its components (total non-farm employment, gasoline consumption, electricity consumption, and cement sales) had similar growth trends from the mid-1980s to the mid-2000. The EAI did not show a very marked month-to-month variation as the TNFE, EC, GC, and CS. GC showed the most variability among the EAI components (Figure 3). However, the data showed the presence of an evident impact during the mid-2000s as electricity and gasoline consumption start to decrease, and the employment numbers began to contract. The behavior of the cement sales time series was fascinating, as it started to stagnate at the beginning of the 2000s, six years before the other variables. Those economic variables started contracting between 2005 and 2006, which coincided with the rise in oil prices and with the 10-year phase out program of the income tax exemption regulation in section 936 of the IRS tax code.

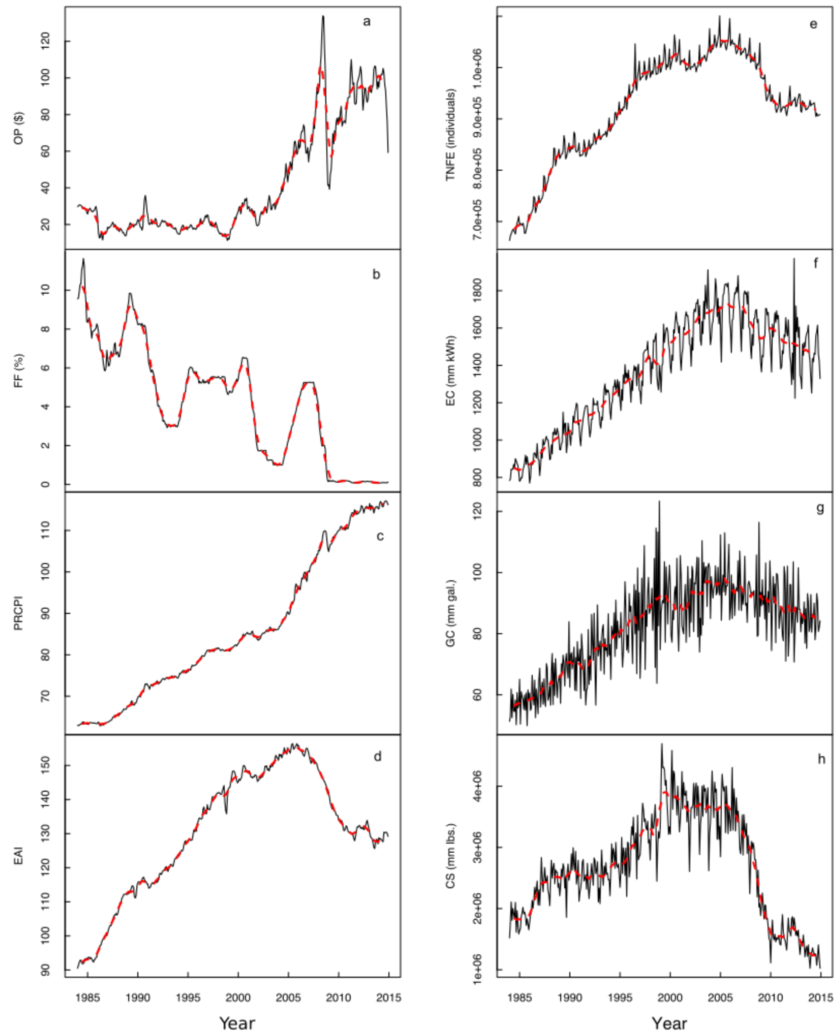

Figure 1 Trends (red lines) of series. The meanings of the graphs are: (a) OP ($) = Oil price in dollar represents the West Texas Intermediate benchmark, (b) FF is the interest rates set by the Federal Reserve Bank, (c) is the Puerto Rico Consumer Price Index and (d) is the Economic Activity Index estimated by the Puerto Rico GDB. Panel graphs e to h are the components of the EAI: TNFE (total non-farm employment in thousands of individuals), EC, GC, and CS.

Examination of the Year-to-Year (YtY) percent change shows an entirely different behavior. The YtY behaviors of all variables have similar patterns and are relatively similar (Figure 2). The EAI showed a sharp and continuous decrease from 2005 to 2010. Further examinations of the YtY results for TNFE (Figure 2), EC (Figure 24f), and CS (Figure 24h) have a similar pattern as the EAI had during the same period. However, GC did not have the dip that EAI, TNFE, EC, and CS did. Federal Funds interest rates had the highest YtY variability, followed by OP and GC (Figure 3).

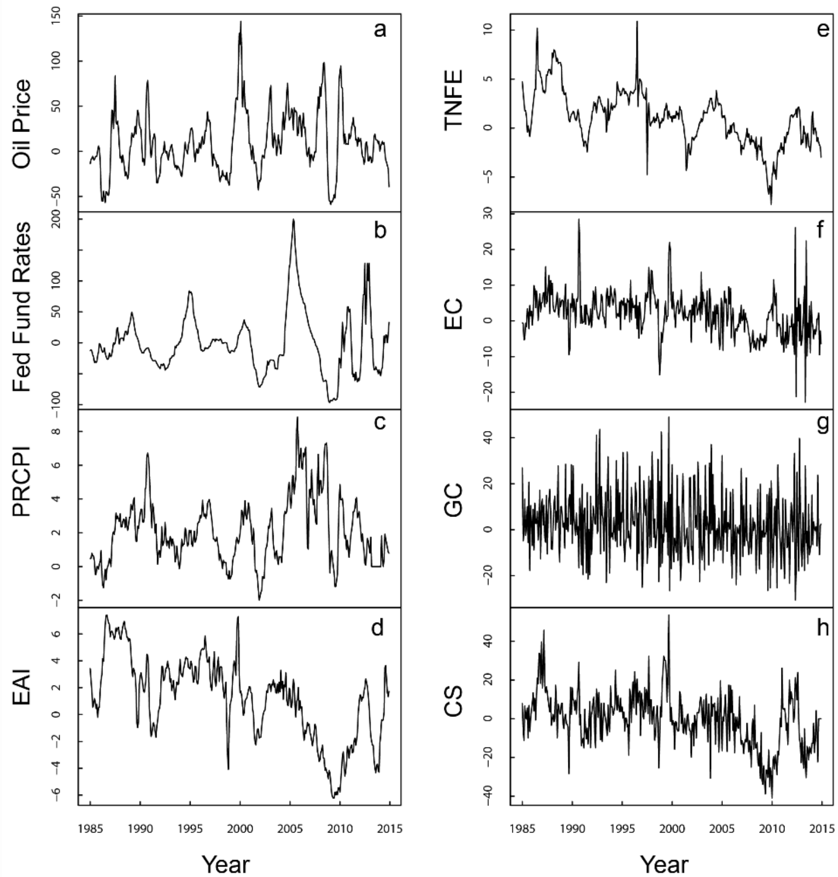

Figure 2. Estimated year-to-year percent change for the model variables; (a) OP (Oil Price, represents the values of the West Texas Intermediate benchmark index, (b) FF (Fed fund rates is the interest rates set by the Federal Reserve Bank, (c) PRCPI (Puerto Rico Consumer Index), (d) EAI (Economic Activity Index), (e) TNFE (total non-farm employment), (f) EC (electricity consumption in million kilowatt-hours), (g) GC (gasoline consumption in millions of gallons), and (h) CS (cement sales in millions of pounds).

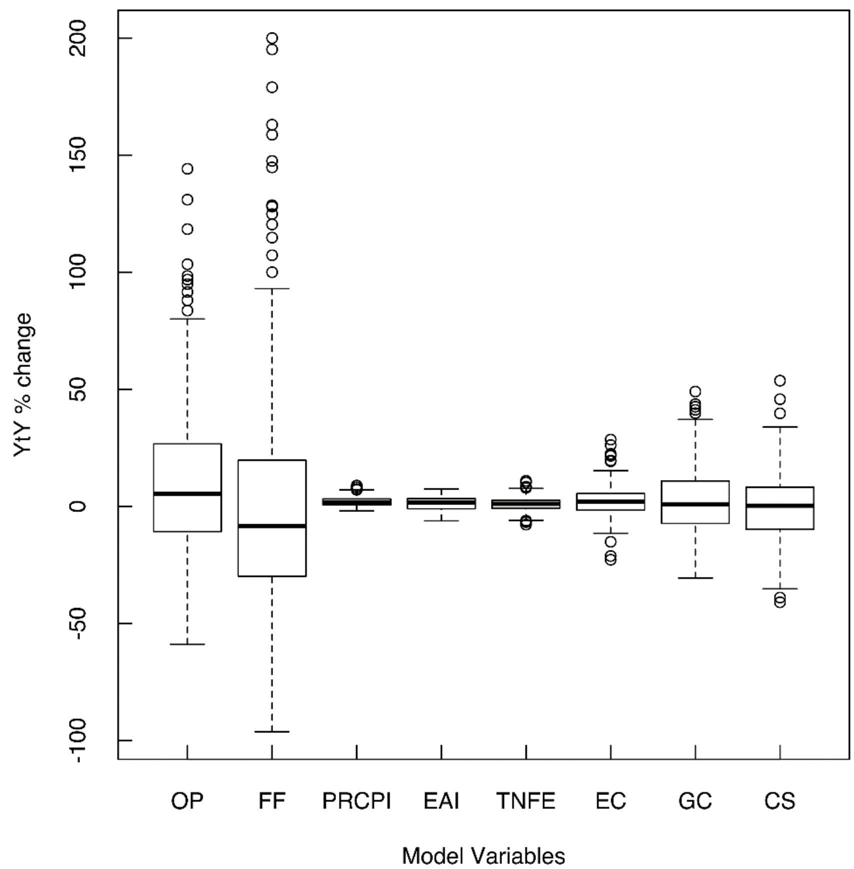

Figure 3. The boxplot for the VAR model variable presents the YtY variability. The dark line in the box represents the median YtY value and the values above and below the error bars represent the outlier's values outside the minimum and maximum value. OP= oil price; FF= federal funds interest rate; PRCPI= Puerto Rico Consumer Price Index; EAI= Economic Activity Index; TNFE= total non-farm employment; EC= electricity consumption; GC= gasoline consumption; CS= cement sales

Electricity consumption had the most predictable seasonal pattern, where the time series showed a repeated pattern of consumption growth during summers and contraction during winters within 12 months (Figures 4a-4h). Gasoline and electricity consumption peaked during the summer months (June and July), and consumption reached its lowest levels during winter months (February). Peak consumption for both variables corresponds with the hottest times of the year when most workers take vacations, and most students are in summer recess. Cement sales peaked in May and decreased by November. Labor force peaked and contracted in the short span of the winter months, which corresponds to the holiday season when labor demand temporally increases.

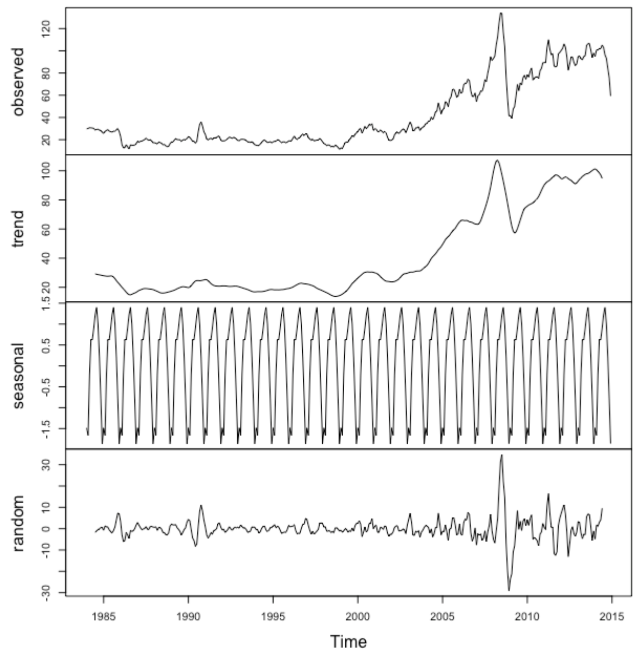

Figure 4a. Data decomposition of oil price data (OP). Oil price data was obtained from the West Texas Intermediate benchmark

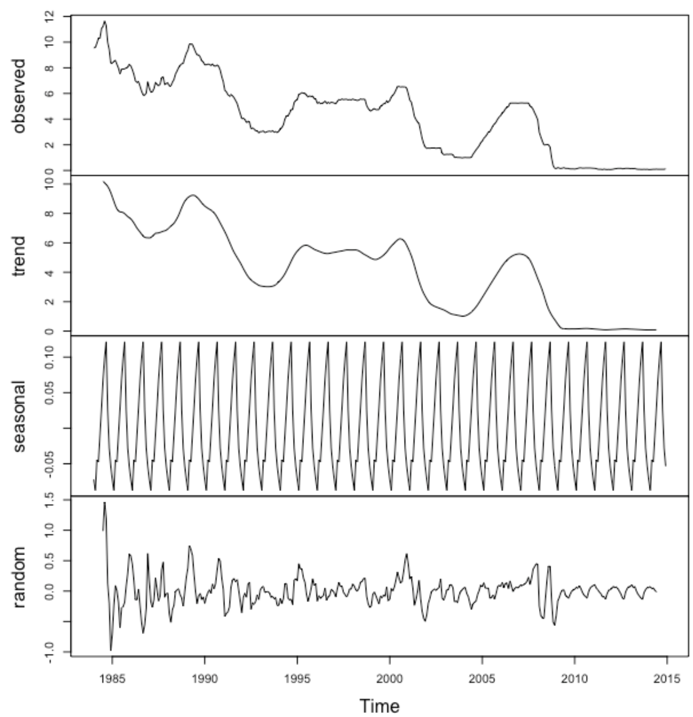

Figure 4b. Data decomposition for Federal Reserve interest rates (FF).

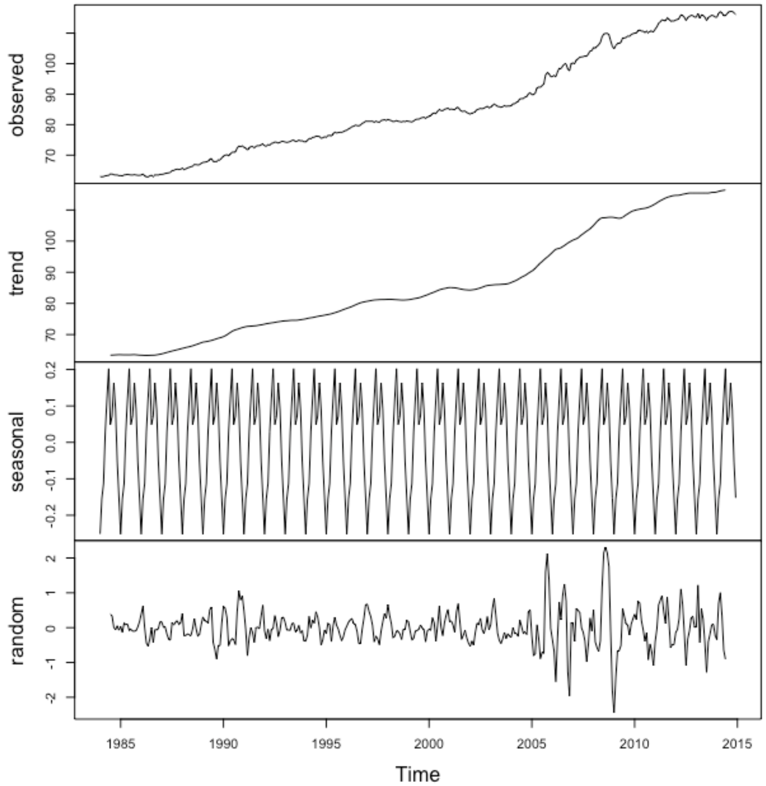

Figure 4c. Data decomposition for the Puerto Rico Consumer Price Index (PRCPI)

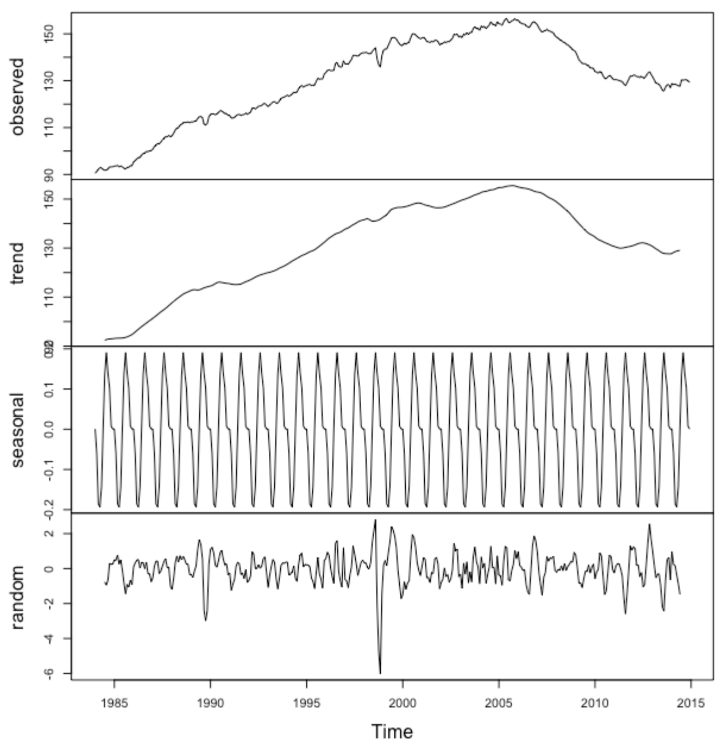

Figure 4d. Data decomposition for Economic Activity Index (EAI)

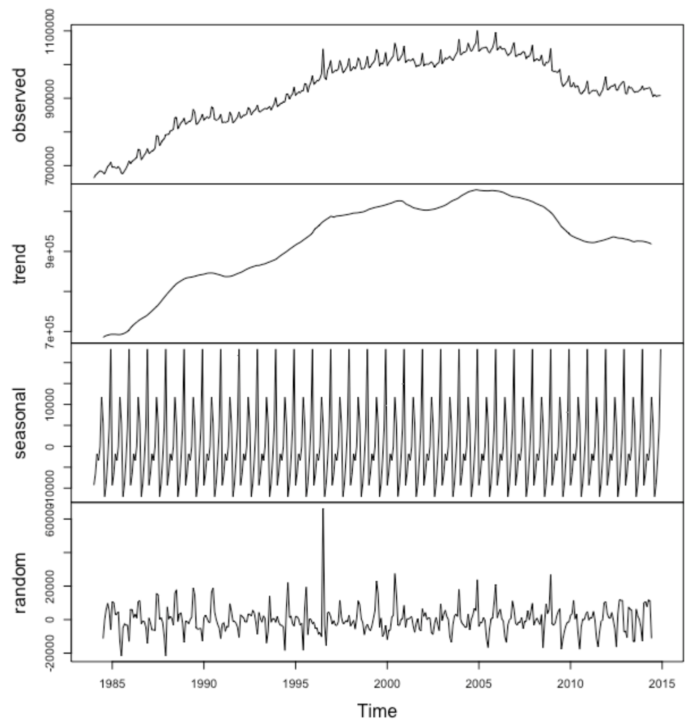

Figure 4e. Data decomposition for the total non-farm employment (TNFE).

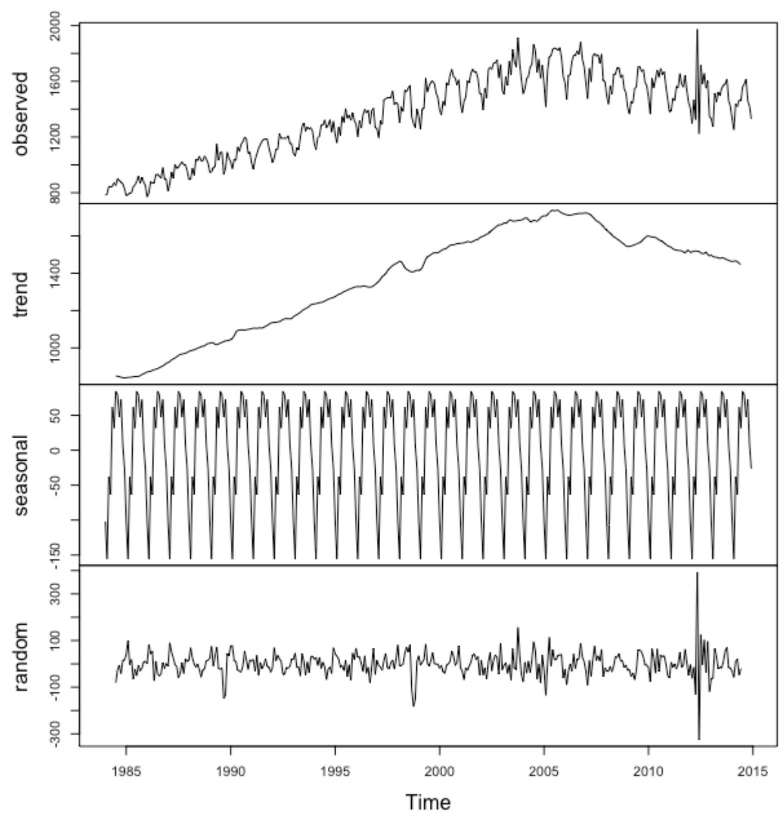

Figure 4f. Data decomposition of the electricity consumption (EC).

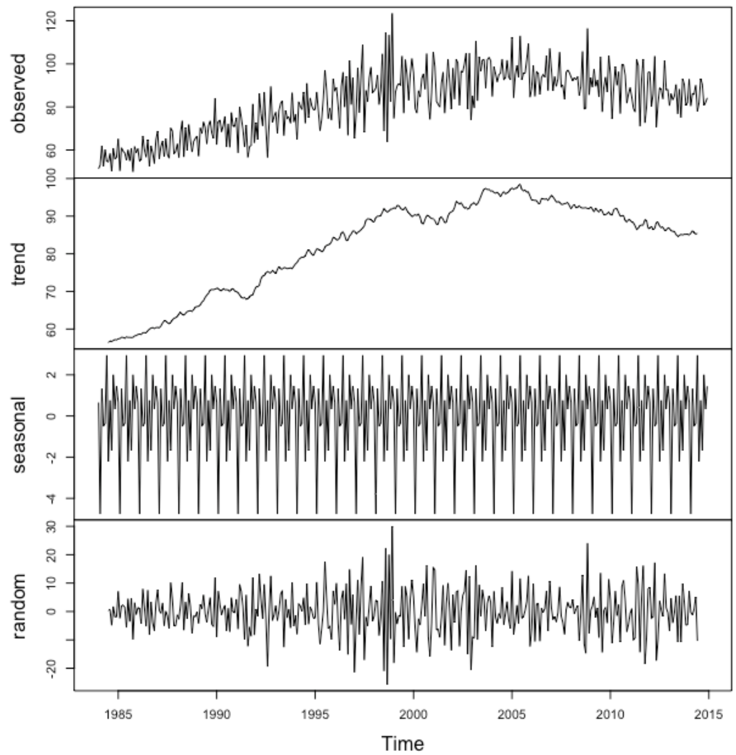

Figure 4g. Data decomposition of gasoline consumption (GC).

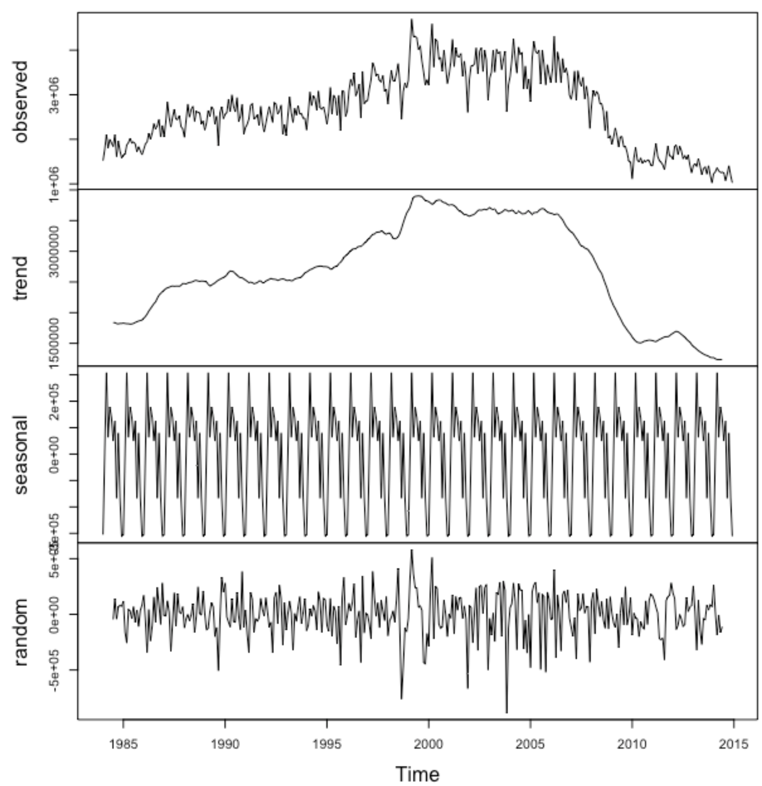

Figure 4h. Data decomposition for cement sales (CS)

3.2. Preliminary Analysis of the Data

All the variables presented evidence of having unit-roots suggesting that they were non-stationary, which means that the variables did not have constant mean and variance. The time-series data were log-transformed to minimize the possibility of serial correlation and differenced once to convert them into stationary series (constant mean and variance). In other words, the time series had I (1) order of integration. After we differenced time series once, the ADF and KPSS unit root test determined the data were stationary and free of unit root processes (Table 1). The VAR select function suggested that the optimal VAR model had 12 lags (Table 2). The VAR model estimated was stable, and all polynomial roots were within the stability plane (Figure 5). The residual graphs and correlogram graphs did not reveal any evidence of serial correlation (Figures 6a-6h), meaning that the models were robust and had a small probability of producing spurious results.

Table 1. Unit root tests.

			ADF	KPSS
		Level	1st diff	1st diff
TNFE	Intercept	-1.62	-3.09*	0.12
	Trend & Int.	-0.62	-3.45*	0.3
	None	0.36	-3.04	-
EC	Intercept	-1.35	-4.91	0.18
	Trend & Int.	-0.34	-5.09	0.11
	None	1.09	-4.69	-
GC	Intercept	-1.45	-14.5	0.13
	Trend & Int.	-1.09	-14.6	0.12
	None	0.76	-14.5	-
CS	Intercept	-1.19	-4.66	0.25
	Trend & Int.	-0.64	-4.91	0.11
	None	-0.62	-4.65	-
OP	Intercept	-2.05	-12.1	0.091
	Trend & Int.	-3.4	-12.8	0.85
	None	-1.08	-12.1	-
FF	Intercept	-1.6	-11.0	0.41
	Trend & Int.	-3.04	-11.0	0.03
	None	-1.93	-10.9	-

EAI	Intercept	-2.55	-8.36	1.45
	Trend & Int.	-0.99	-9.23	0.105
	None	1.30	-9.22	-
PRCPI	Intercept	0.81	-14.1	0.28
	Trend & Int.	-1.77	-14.2	0.09
	None	5.03	-15.0	-

Source: Own elaboration

The asterisk (*) denotes the significance of the ADF (t-stat), and KPSS (chi- square) results at α= 0.05.

Table 3: 0ptimal lag selection*

Lag	AIC	HQ	SC	PE
1	-52.9	-52.6	-52.1	1.1E-23
2	-53.9	-53.3	-52.4	3.8E-24
3	-54.1	-53.2	-51.9	3.2E-24
4	-54.5	-53.4	-51.6	2.1E-24
5	-54.8	-53.3	-51.2	1.6E-24
6	-54.7	-53.0	-50.4	1.7E-24
7	-54.9	-52.9	-49.9	1.5E-24
8	-54.9	-52.6	-49.2	1.5E-24
9	-55.2	-52.6	-48.7	1.2E-24
10	-55.2	-52.4	-48.1	1.1E-24
11	-55.6	-52.5	-47.8	7.7E-25
12	-55.8	-52.4	-47.3	6.5E-25
13	-55.8	-52.1	-46.5	7.0E-25
14	-55.8	-51.8	-45.8	7.3E-25
15	-55.8	-51.6	-45.2	7.2E-25
16	-55.7	-51.2	-44.4	8.5E-25
17	-55.6	-50.8	-43.6	9.8E-25
18	-55.6	-50.6	-42.9	1.1E-24
19	-55.7	-50.3	-42.2	1.1E-24
20	-55.7	-50.1	-41.5	1.2E-24

*/ The criteria used were Akaike Information Criterion (AIC), Hannan-Quinn Information Criterion (HQ), Schwarz Information Criterion (SC) and Final Prediction Error (FPE).

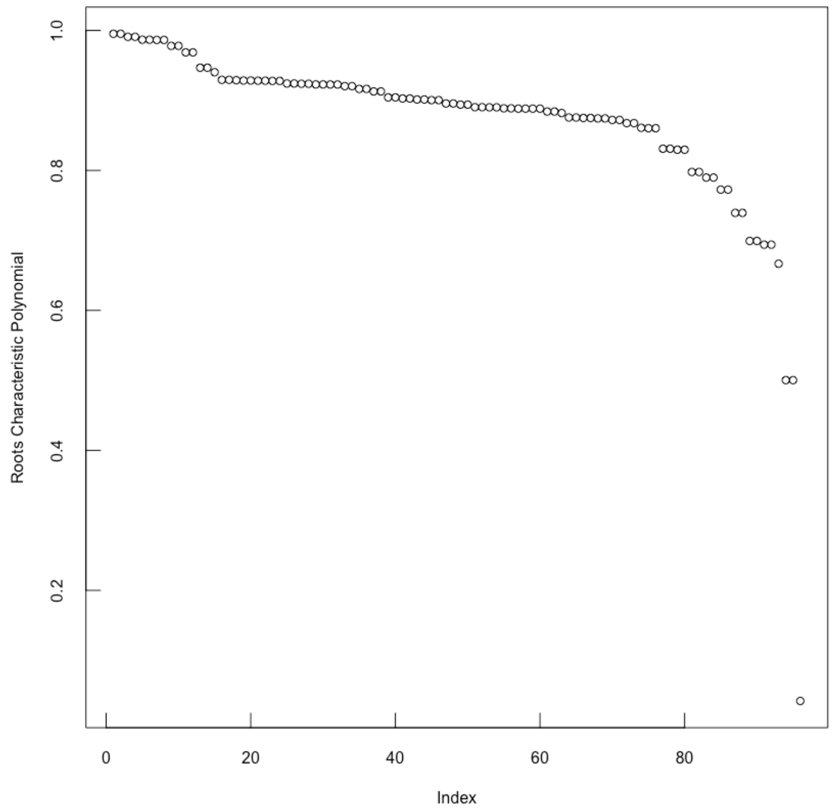

Figure 5: All roots of the characteristic polynomial lie with the stability plane.

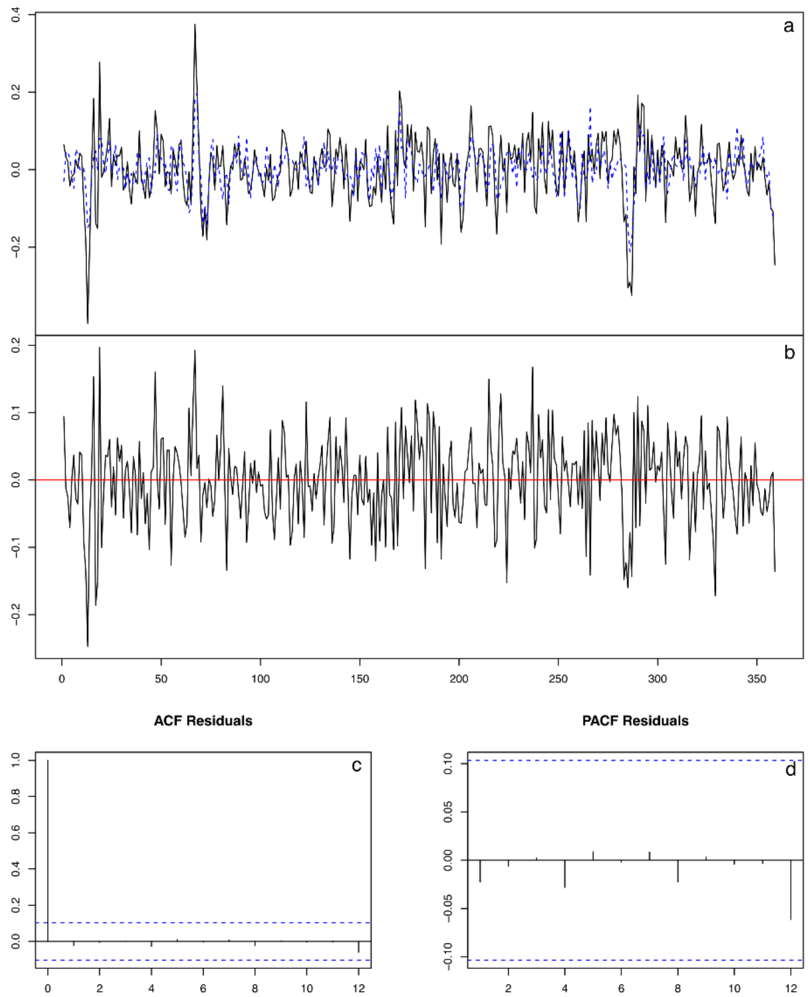

Figure 6a. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for oil prices.

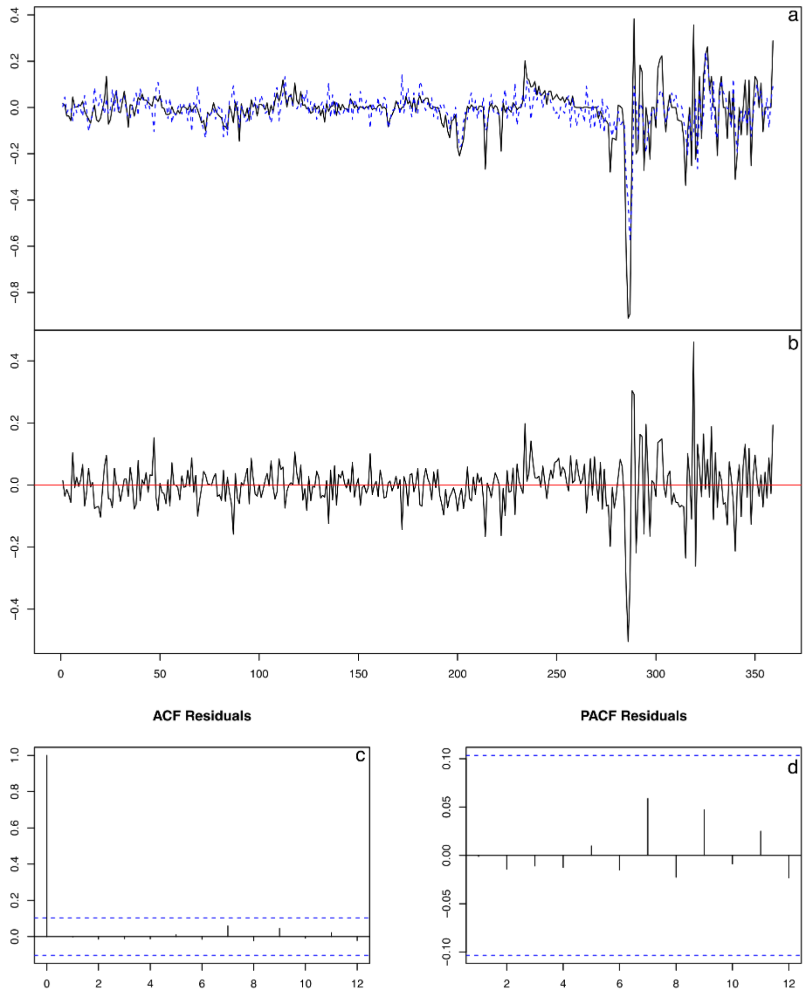

Figure 6b. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for Federal Fund rates

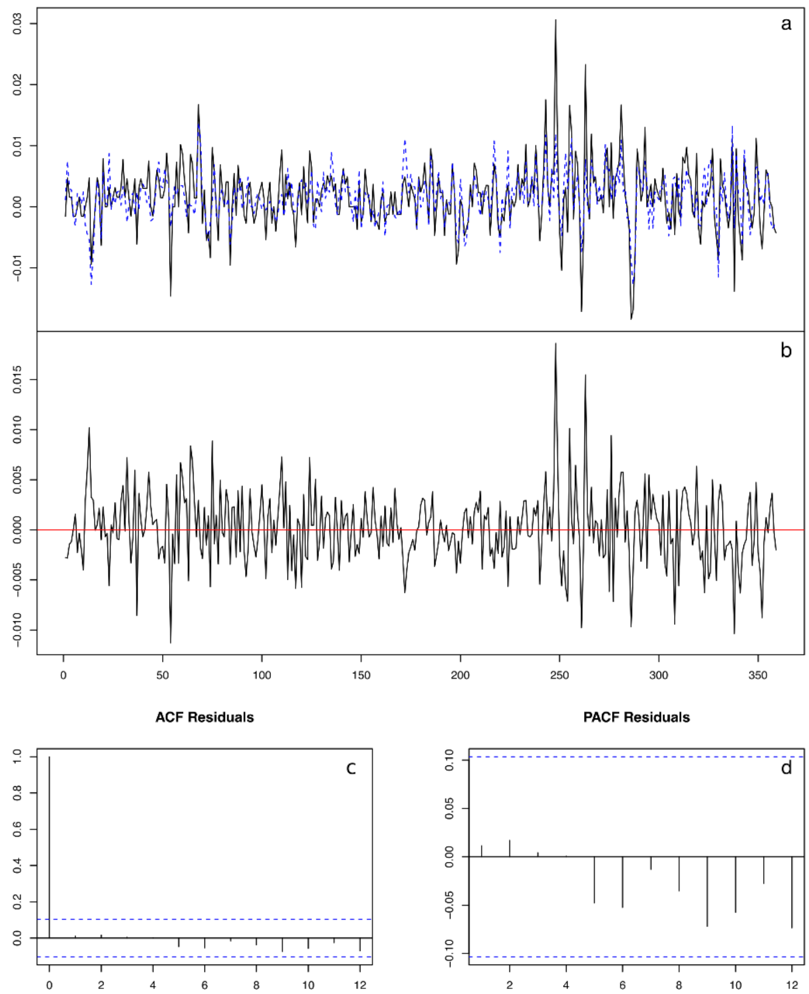

Figure 6c. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for Puerto Rico Consumer Price Index (PRCPI).

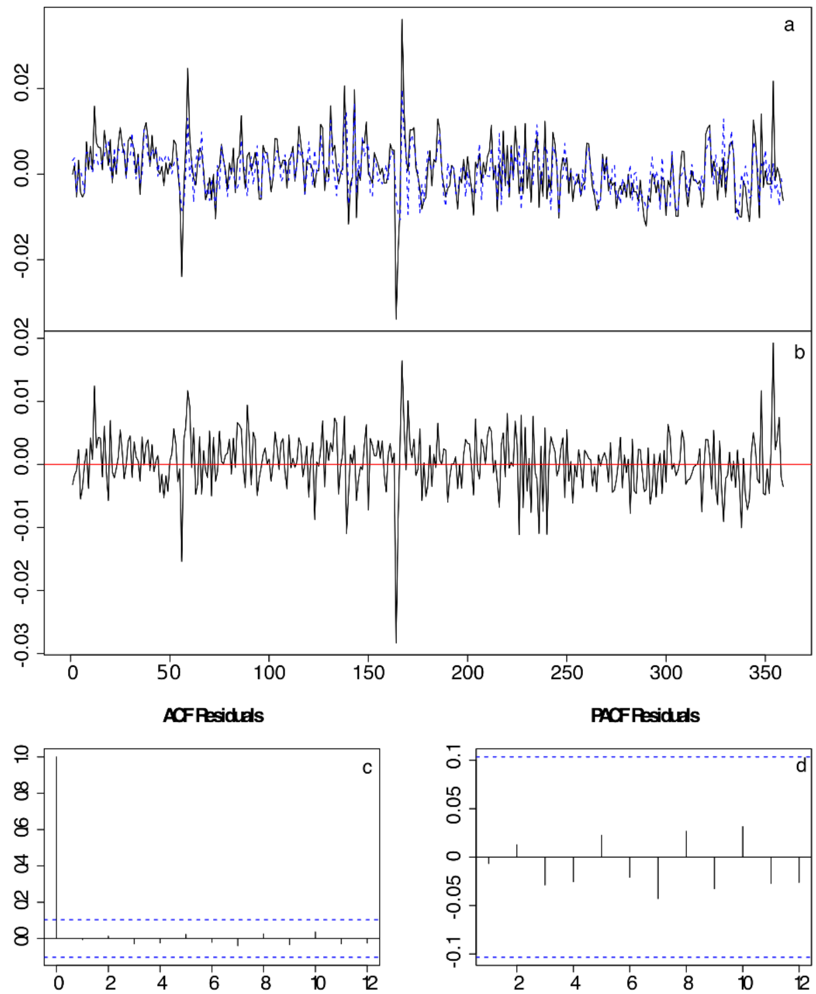

Figure 6d. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for Economic Activity Index (EAI).

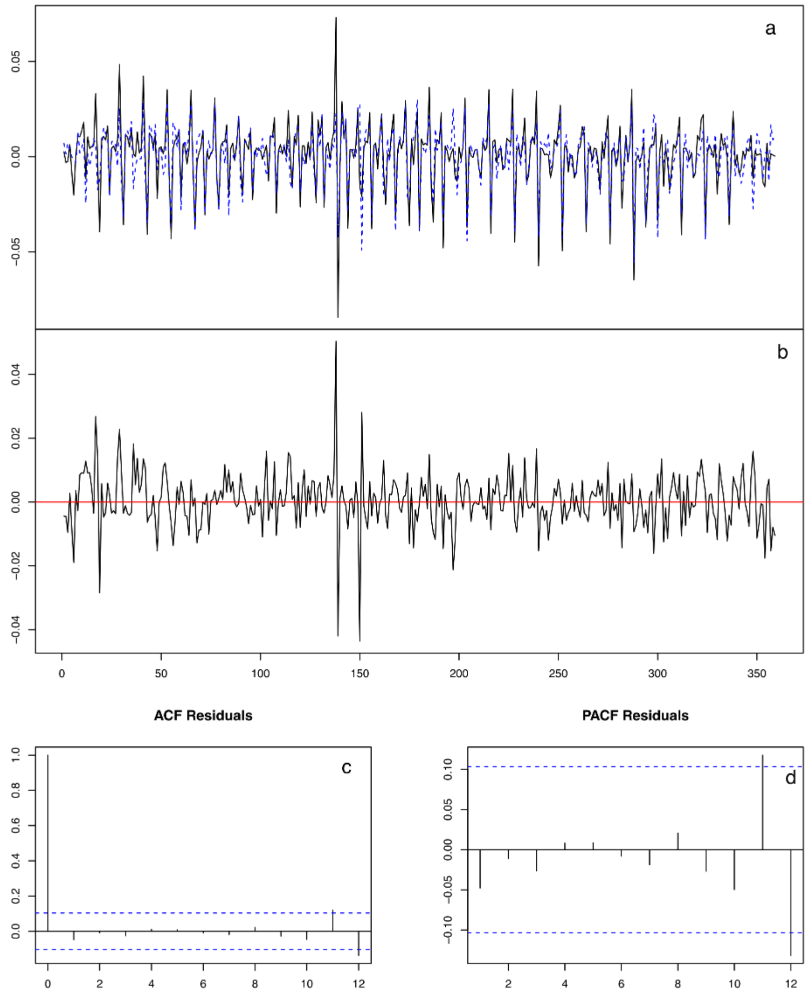

Figure 6e. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for total non-farm-employment (TNFE)

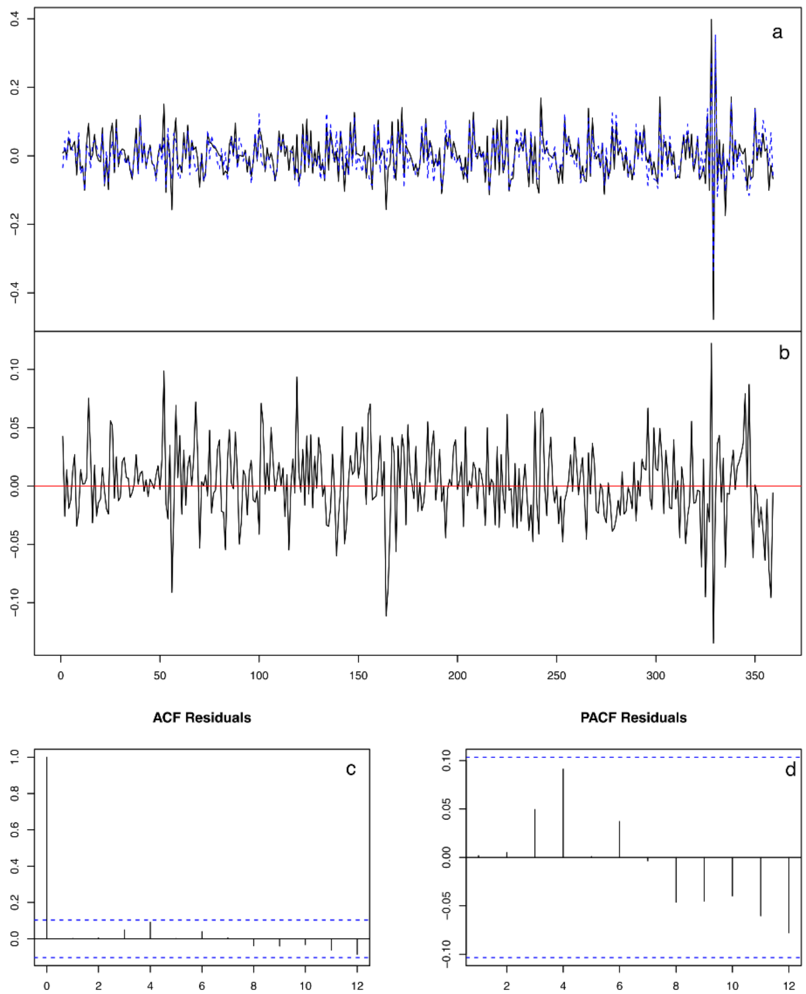

Figure 6f. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for electricity consumption.

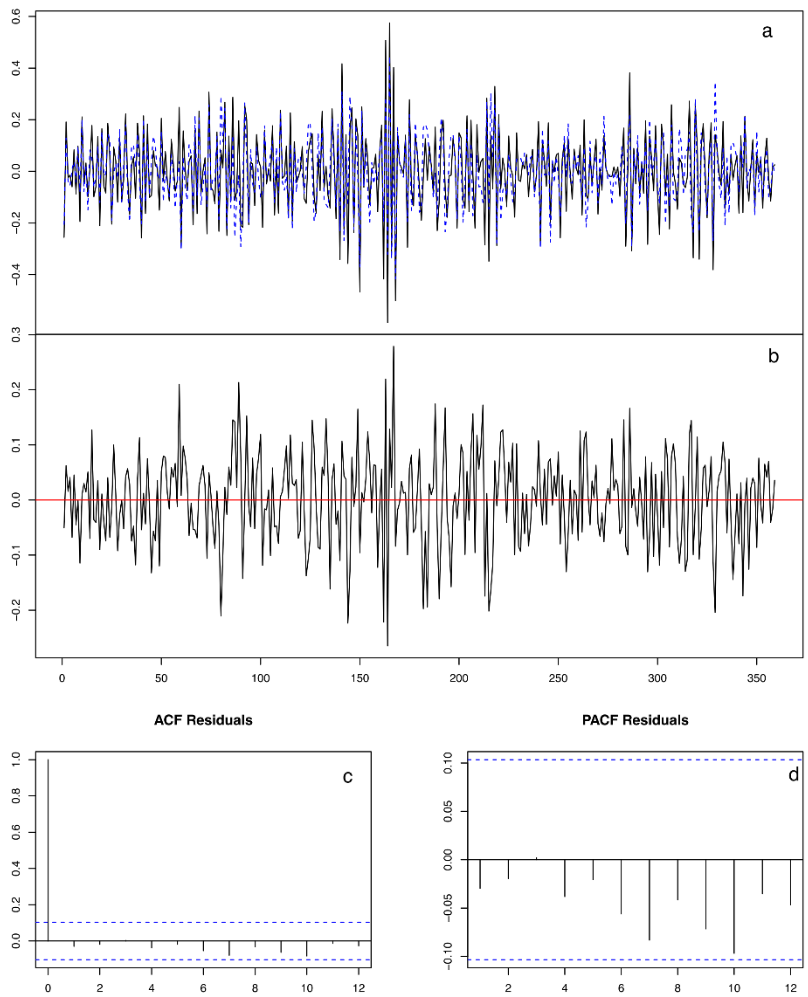

Figure 6g. Appendix 4iv. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for gasoline consumption (GC).

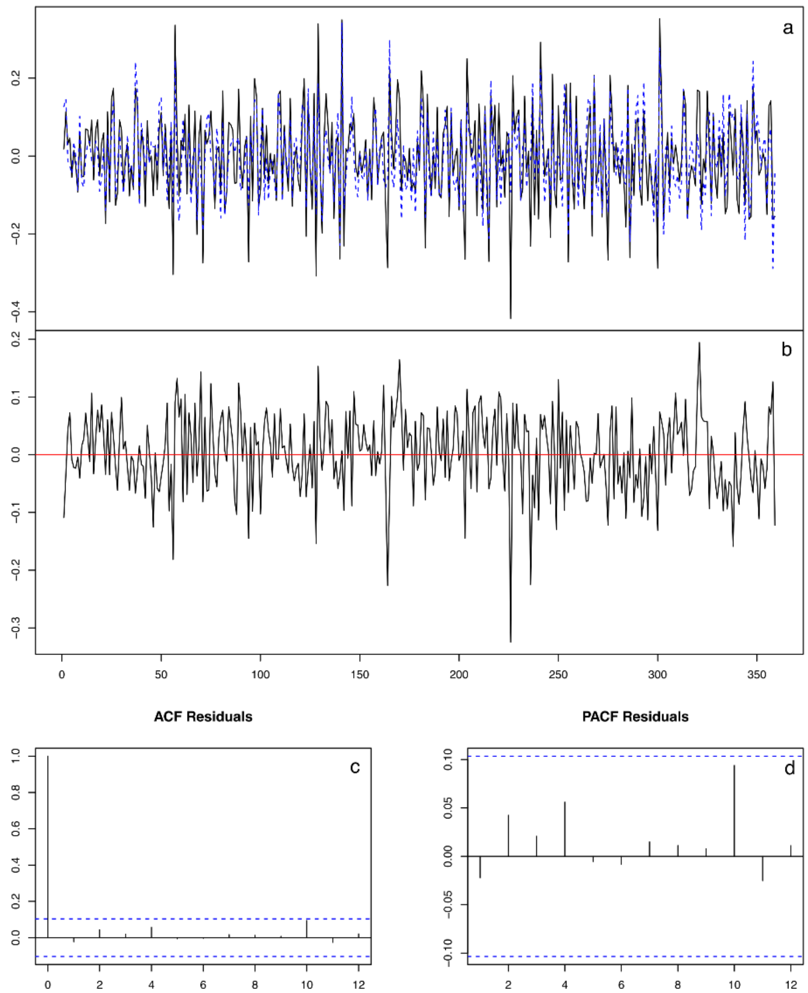

Figure 6h. Residual and fitted data, autocorrelation and partial autocorrelation correlograms for cement sales (CS)

Table 3 indicates the existence of a stable, long-term relationship between the variables. Table 4 presents the Johansen procedure trace test. According to this, there are at least four cointegrated vectors. The presence of at least four cointegrated vectors implies the existence of at least one long-term solution. Linear combinations that represent linearly independent vectors can also be a possible solution. Because of the property of cointegration, the least squares estimators are unbiased, and there is no problem with spurious regressions.

Table 3: Cointegration tests

Cointegration Tests	Null Hypothesis	Calculated Value	Critical Value
Engle-Granger	Non-cointegration	-4.989	-3.803
Phillips-Ouliaris	Non-cointegration	-4.988	-3.803
Gregory-Hansen	Non-cointegration	-5.409	-4.92

Source: Own elaboration

Table 4: Johansen Procedure

Rank	Eigen Value	Lambda-max	Trace	Trace-95%
1	0.170	67.198	209.522	143.530
2	0.110	41.985	142.324	111.680
3	0.095	36.102	100.339	83.820
4	0.074	27.683	64.237	59.960
5	0.039	14.339	36.554	40.100
6	0.028	10.128	22.215	24.210
7	0.025	8.948	12.087	12.280
8	0.009	3.139	3.139	4.070

Source: Own elaboration

This cointegration relationship implies that the deviations may be represented as a stationary series and tend to become more improbable as the magnitude of the disequilibrium increases. It expresses the mechanisms and magnitudes of economic agents' adjustments as they force the different variables to return to equilibrium in the presence of a disequilibrium. The coefficients of this cointegration vector express the relationships used by economic agents to maintain the considered variables in the equilibrium trajectory.

3.3. Structural Vector Autoregressive Model

According to the discussion presented in the second section of this work, two different structures are presented to identify structural shocks: the first and main one uses long-term restrictions, while the second triangulates the contemporary relationships between the variables. This second identification scheme did not yield very different results from the first, which is why only the results of the decomposition of the projection error are reported. The long-term multipliers associated with the first identification scheme are

found in table 5. The point estimates for the cumulative effect of ΔOPt on ΔTNFEt, ΔCSt, ΔGCt, and ΔEAIt are negative, while for ΔECt and ΔPRCPIt they are positive. Concerning ΔFFt, all are positive except for ΔPRCPIt. The greatest effect of ΔOPt falls on ΔCSt, ΔPRCPIt and ΔEAIt and that of ΔFFt on ΔCSt, ΔEAIt, and ΔTNFEt.

Table 5: Long-run multipliers

Variables	ΔOP_t	ΔFF_t	$\Delta TNFE_t$	ΔCS_t	ΔGC_t	ΔEC_t	ΔEAI_t	$\Delta PRCPI_t$
ΔOP_t	0.0729	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ΔFF_t	-0.0078	0.2345	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\Delta TNFE_t$	-0.0002	0.0056	0.0131	0.0000	0.0000	0.0000	0.0000	0.0000
ΔCS_t	-0.0126	0.0412	0.0301	0.0215	0.0000	0.0000	0.0000	0.0000
ΔGC_t	-0.0008	0.0008	0.0129	-0.0012	0.0090	0.0000	0.0000	0.0000
ΔEC_t	0.0008	0.0031	0.0113	-0.0005	0.0027	0.0077	0.0000	0.0000
ΔEAI_t	-0.0011	0.0073	0.0137	0.0010	0.0011	0.0019	0.0011	0.0000
$\Delta PRCPI_t$	0.0082	-0.0048	0.0051	-0.0057	0.0002	0.0031	0.0025	0.0058

Source: Own elaboration

The dynamics in the short term suggest that all impulse response curves of the endogenous variables reached zero at the end of the forecast horizon, which confirms that the SVAR model was stable. The oil price and monetary policy shocks had more significant impact on gasoline consumption (Figures 7 and 8), electricity consumption (Figures 7 and 8), and cement sales (Figures 7 and 8), than on Puerto Rico Consumer Price Index (Figures 7 and 8), total non-farm employment (Figure 7 and 8), and Economic Activity Index (Figure 7 and 8). The oil price shock had a more significant impact on gasoline consumption than on electricity consumption and cement sales. On the other hand, monetary policy shock had a more significant impact on cement sales, rather than on gasoline or electricity consumption. The oil price shock had a more significant impact on gasoline consumption, followed by cement sales, and followed by electricity consumption.

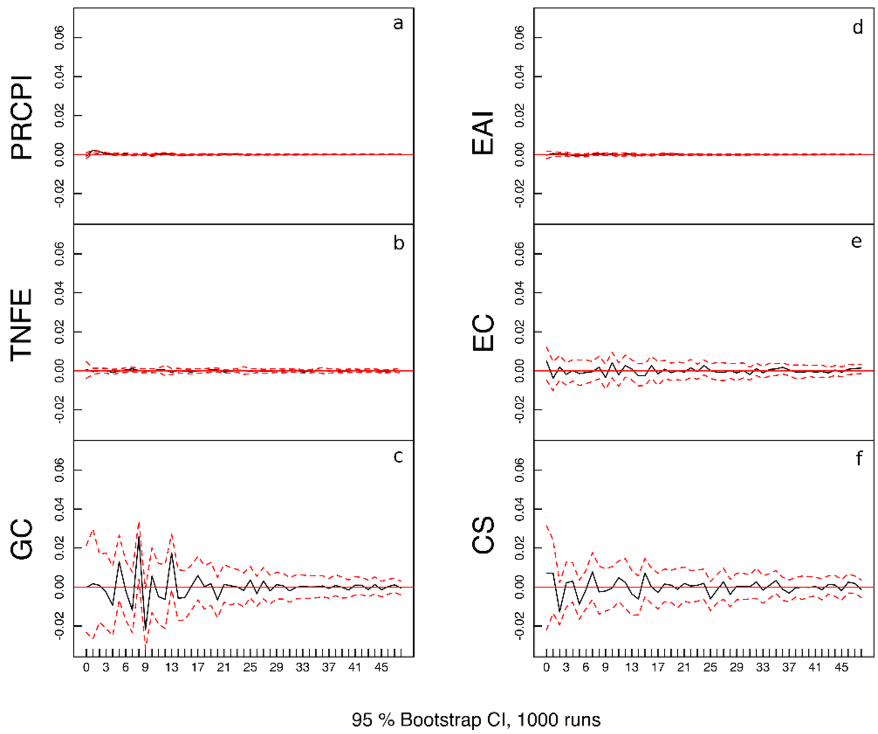

Figure 7. Impulse response of the Consumer Price Index (PRCPI), employment (TNFE), gasoline consumption (GC), Economic Activity Index (EAI), electricity consumption (EC), and cement sales (CS) to a 1± S.D. innovation shock of oil price (WTI). The x-axis represents the 48-month forecast horizon.

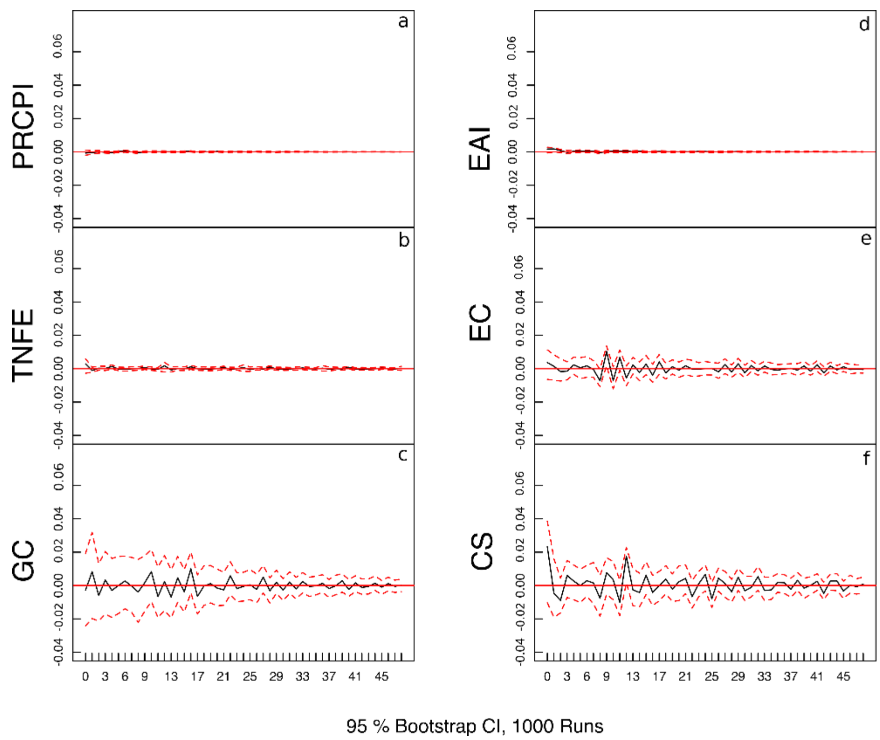

Figure 8. Response of Consumer Price Index (PRCPI), Economic Activity Index (EAI), employment (TNFE), electricity consumption (EC), gasoline consumption (GC), and cement sales (CS) to a 1 ± S.D. innovation shock in federal fund interest rates. The x-axis represents the 48-month forecast horizon.

The forecast error variance decomposition (FEDV) measures the variance contributed by each of the independent variables of the system of equations to the SVAR model (Figure 9). The oil price initially contributes 63 %, but its contribution decreased as the time horizon increased. By the end of the time horizon, oil price contributed 48 % to the variance. The variance that other variables contributed to the oil price equation stayed approximately the same. Concerning the federal fund interest rate equation of the SVAR model, the federal funds' interest rate initially contributed the most variance to its equation, with 52 % followed by the EAI that contributed 40 % to the total variance of the equation.

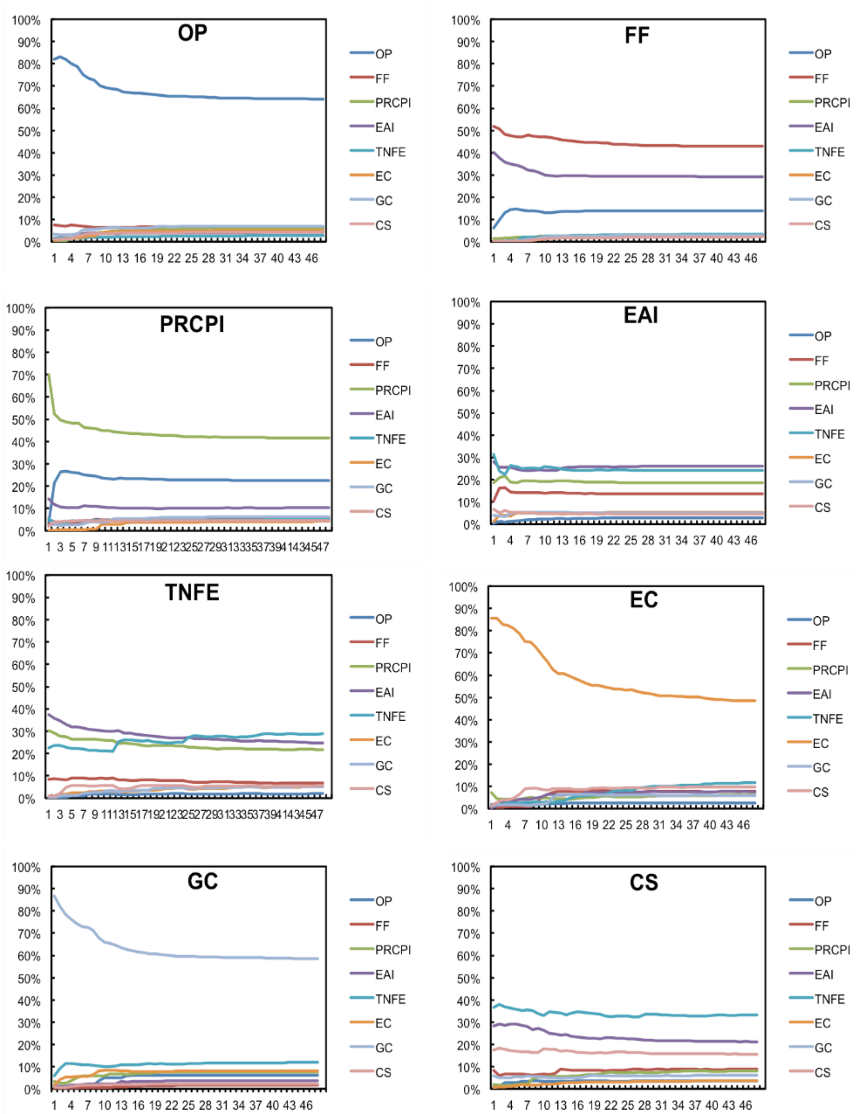

Figure 9. (a) Forecast error variance decomposition graph for the SVAR model. Each graph represents the variance contributed by each variable for each of the equations of the model. The title of each panel graph represents the dependent variable of the equation: (a) OP= 'oil price'; (b) FF= 'federal fund interest rates'; (c) PRCPI= 'Puerto Rico Consumer Price Index'; (d) EAI= 'Economic Activity Index'; (e) TNFE= 'total non-farm employment'; (f) EC= 'electricity consumption'; (g) GC= 'gasoline consumption'; and (h) CS= 'cement sales'.

In general, the main economic variables considered in this study, EAI, total non-farm employment (TNFE), electricity consumption (EC), gasoline consumption (GC), and cement sales (CS), responded strongly to increased prices of oil and the local economic recession marked by a decline in the Economic Activity Index (Figure 25d). Also, the results of the impulse response study reflect that GC, EC, and CS had higher impulse responses to the monetary policy and oil price shock than PRCPI, EAI, and TNFE. The oil price shock had a more significant impact on the total gasoline consumption and cement sales than on electricity consumption. On the other hand, the monetary policy shock had a more significant effect on electricity consumption and cement sales rather than on gasoline consumption.

4. DISCUSSION

4.1. EAI and its components

The economic downturn took hold around 2005 and 2006 when the 10-year phase-out period of Section 936 of the IRS ended. The cement data suggested that the early stages of the economic recession started in Puerto Rico within the year 2000. Cement sales had the most significant contraction (Figure 1 and 4h), as the construction sector came to a halt, and the labor market saw substantial declines. By 2010, cement sale figures were lower than the early 1980s. One characteristic of the economic slowdown that Puerto Rico has experienced is the continuous growth of the PRCPI (Figure 1 and 4c), which translates to the increasing prices of basic stuff.

There is a constant contraction of the EAI (Figure 1 and 4d), and this is an important observation because it describes an inverse relationship between the prices of commodities, goods, and the economic activity in Puerto Rico after 2006. This inverse relationship between both indices is evidence that the cost of commodities in Puerto Rico is not dependent on economic activity. It depends on events of the economy of the U.S. and its monetary policy. All the EAI components have seen a negative trend since the recession started in 2006. The decline of the EAI components is in part due to the congressional repeal of Section 936 of the IRS federal tax code that granted corporate income tax exemptions to U.S. firms in Puerto Rico. Due to the elimination of Section 936, most of the firms that benefited from its provision relocated their operations to other jurisdictions such as Mexico, China, or Ireland, which had more attractive business benefits. The construction and energy sectors were one of the most heavily affected by the elimination of Section 936.

4.2. Federal funds interest rates and oil price shocks

The monetary policy and oil price shocks, although entirely independent events, had similar effects on the endogenous variables. Both types of shocks had more significant effects on the sector variables than on the aggregated variables. The oil price shock had a more noticeable impact on gasoline and electricity consumption because of their immediacy to the consumer and the inelastic nature of their demand. FF and OP shocks did not have a noticeable effect on the aggregated variables because of the direct dissociation to the consumer and their lack of a concrete supply or demand for them.

The FF shock on EC had a more significant effect than the OP shock. The responses of both energy variables (GC and EC) to the oil price shock, when compared, show that GC has a higher initial response than EC. However, GC and EC eventually reach the equilibrium state before the oil price shock. The oil price (OP) and the monetary policy (FF) shock affected the other variables, and they initially react negatively and have a very volatile response. The most unexpected results were the minimal responses of TNFE, PRCPI, and EAI to the oil price and monetary policy shocks. TNFE was not significantly impacted by the monetary policy shocks, and this was not initially expected.

There is no easy recipe to avoid oil price shock if Puerto Rico does not reduce its dependence on imported fossil fuels, especially residual fuel oils. An energy transition from fossil fuels to renewable energy resources will help minimize the oil price shock vulnerability. Puerto Rico has various renewable energy resources that have not been adequately quantified. Irizarry-Rivera et al. (2008) attempted to estimate the quantity of energy from renewable energy sources in Puerto Rico, but their study did not assess the subject with validation. The energy transition might mean a reengineering of the economic development model of Puerto Rico. An energy transition away from fossil fuels might also mean a transition from GDP and economic growth driven economic policies. Maybe the government of Puerto Rico must embrace the economics of Degrowth, steady-state economics, or biophysical economics (Hall and Klitgaard 2017). The problem with ANY of these alternative economic schools of thought is that they are against the neoclassical economics regime implemented in Puerto Rico, and the U.S. Renewable energies and a degrowth or a steady-state economy are compatible, as the need for energy will not be for growing the economy, but for keeping a desirable sustainable and possible economic output.

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