DEFENSA DE TESIS

Certificamos que el estudiante **Alberto Valcárcel Rodríguez** aprobó su Defensa de Tesis. Con la defensa de la tesis, el estudiante cumple con los requisitos del grado de Maestría con concentración en Economía. El título de la tesis es:

"Measuring the Impact of Oil Supply and Demand Shocks in Puerto Rico's Economic Growth"

Certificado hoy miércoles, 15 de mayo de 2024; en Río Piedras, Puerto Rico.

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Measuring the impact of oil supply and demand shocks in Puerto Rio's economic growth

By:

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Thesis presented as a partial requirement for the degree: Master's in economics

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May 2024

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Dedication

I dedicate this thesis to my parents, Evelyn and Alberto, whose unwavering support and encouragement have been my foundation throughout this journey. To my brother, Gabriel, for always believing in me and inspiring me to achieve my best. And to my girlfriend, Julie, whose love and patience have been my source of strength and motivation. Thank you all for your endless support and for standing by my side every step of the way.

Acknowledgments

I would like to express my deepest gratitude to my thesis director, Carlos Rodríguez for his invaluable guidance and support. I am also immensely grateful to the members of my committee, for their insightful feedback and suggestions that greatly improved this work. Finally, I extend my heartfelt thanks to all my professors at the Department of Economics who have inspired and challenged me, providing a solid foundation for my academic growth.

Summary

This study measures the impact of oil supply and demand shock, and global aggregate demand shock on Puerto Rico's economic growth. This was achieved using a four-variable Structural Vector Autoregression. Through the impulse response functions, it was possible to demonstrate that the demand and supply shocks of crude oil do not have a significant effect on the economic growth of the island, in turn, these results were supported by the variance decomposition of the structural shocks. However, it was found that these shocks tend to increase inflation, for a period of approximately four months after the initial shock and explain about 31% of the variation in the Consumer Price Index.

Introduction

Since the beginning of the twentieth century with the great technological advances of the last century, a large part of the developed countries, mainly the United States and England, used some type of fossil fuel such as coal or crude oil on a large scale. This too generates the energy that would be used in the production processes and later for the individual's consumption in their motor vehicles and other products. After the Second World War, most states were fully industrialized or had just been industrialized, and the main input for power generation was crude oil. Being a limited fossil fuel, the price of this, like other products, depends largely on production. The problem is that the large oil reserves are in the Middle East, a zone of constant instability. Since the 1950s the Suez Crisis, greatly affected the production of crude oil in the Middle East and resulted in a rise in prices, mainly impacting European countries. Geopolitical events like this or more intense have caused drastic increases in the price of oil, which have led to periods of economic contraction, as verified by Hamilton (1983).

According to the same author, the following geopolitical events produced oil price increases, from January 1957 to February 1957, there was a 9% increase in oil prices due to the crisis in the Suez Canal. Subsequently, between April 1973 and September 1973, oil prices surged by 16% as a result of a substantial increase in demand coupled with supply restrictions. The period from November 1973 to February 1974 saw a dramatic 51% increase in oil prices due to an embargo imposed by oil-exporting countries, particularly OPEC. In May 1979 to January 1980, oil prices rose by 57% following the revolution in Iran. Another significant increase of 45% occurred from November 1980 to February 1981 due to the Iran-Iraq War. Similarly, from August 1990 to October 1990, oil prices skyrocketed by 93% during the First Gulf War. Between December 1999

and March 2000, there was a 38% increase in oil prices driven by a surge in demand. The period from November 2002 to March 2003 saw a 28% increase in oil prices attributed to the Second Gulf War and an oil strike in Venezuela. Finally, from February 2007 to June 2008, oil prices surged by 145% due to strong demand and stagnant supply.

These significant surges in the price of crude oil have caused several effects in different economies, in the case of the United States Hamilton (2011) recalls that during the period 1974: Q1 – 1975: Q1 the GDP contracted by 2.5% due to the rise of oil price because of the OPEC embargo. The other significant drop in GPD (-1.5%) in response to a price hike was from 1981: Q2 to 1982: Q2, the beginning of the Iran-Iraq war that preludes a growing political instability in the Middle East in the coming years and decades. Is important to note that Hamilton (2003) establishes the nonlinearity between oil prices and economic activity and that oil price increases are more important than decreases and if the hike is preceded by a period of low prices its effect on the economy will be less significant.

However, after the seventies, which was characterized by high instability in the price of crude oil due to geopolitical tensions, economies adjusted to these sudden changes. This, accompanied by technological advances in the energy sector such as hydraulic fracturing, has made it possible to easily extract large amounts of oil from new oil reserves. This has caused the US to significantly expand its oil reserves, making its economy less susceptible to geopolitical disturbances in the Middle East. This expansion in global oil production has reduced significantly the oil price volatility and in terms the macroeconomic effects of oil market disruptions.

In the case of Puerto Rico, the problem lies that the island is an oil-importing economy and according to the most recent official data from the Electric Power Authority, 98% of the electrical energy on the island comes from non-renewable sources such as natural gas, coal, diesel, and "bunker c" fuel. The remaining 2% comes from renewable energy sources such as solar photovoltaic and wind power. This has made the island production process highly dependable on the global price of this input and given the current economic situation, this dependency isn't expected to change any time soon. As different authors have verified, this dependency has effects on the economy and its different sectors.

In previous studies of Puerto Rico, the effects of oil prices on the different components of the economy have been observed. For example, Toledo (2014) focuses on the effects of the price of crude oil on the different industrial sectors. The main objective of this study is to observe the effects of crude oil supply and demand shocks on the island's economic growth and which of these shocks have a greater impact, this will be done using a Structural Vector Autoregression (SVAR). The theoretical framework will be based on Kilian (2009) in which the real price of oil is decomposed into three shocks, oil supply and demand, and aggregate demand. Oil supply shocks refer to sudden changes in the availability of oil, whether due to geopolitical events, natural disasters, or production disruptions. These supply shocks can significantly impact oil prices and global energy markets. On the other hand, oil demand shocks result from fluctuations in global demand for oil, stemming from changes in economic activity, technological advancements, or political interventions. These demand shocks can affect oil consumption and market dynamics. Additionally, global aggregate demand shocks are characterized by unexpected changes in the

demand for goods and services across the world economy which can have broad effects on economic growth, inflation, and financial markets.

Given the nature of Puerto Rico's economy, we hypothesize that both oil demand and supply shock have significant and persistent negative effects on the island's economic growth, in this case, such growth is measured via the economic activity index. In the case of the aggregate demand shock, this one will potentially lower economic growth with some lag, given that an increase in aggregate demand will raise commodity prices, and this in time will have a negative effect on the economy, as found by Kilian (2009).

Literature Review

Among the first economists to study the relationship between the price of oil and economic activity is Hamilton (1983) who states that all recessions in the United States after World War II have been presided by a significant rise in the price of oil, except for the 1960 recession. The author uses a macroeconomic model with quarterly variables such as Gross National Product; Unemployment, the implicit deflator of non-agricultural income; compensations per hour, price of imports, and to represent the financial sector he uses M1 which is a measure of liquidity. He then performs a Granger-Causality test for these variables. Through this analysis, he found that increases in the price of oil cause a reduction in production about three or four quarters after the increase and that it would take six to seven quarters to return to normal production levels. Regarding unemployment, this turned out to be a better predictor of the price of oil, but its relationship is not statistically significant at the 0.05 significance level and concludes that the relationship between the price of the input and the future level of employment represents a random coincidence. However, the variable M1, in its growth rates, did not show unusual behavior prior to the price increase.

The author found no evidence that none of the six variables studied are the ones that affect the price of oil and, at the same time, cause recessions. Oil shocks are the consequence of wars, political instability in exporting countries, or oil embargoes such as that of OPEC. Therefore, it concludes that the oil price does influence production and that a large part of the recessions in the US are preceded by a shock in the level of oil prices, although it highlights that this relationship is not linear since decreases in the price of the input will not cause an economic expansion.

The same author Hamilton (2003) used Bayesian techniques to find the functional form of the relationship between oil price and production. For this, he defined an equation where production "GDP growth rate" is a function of four of its own lags and he placed four lags of the price of crude oil in a non-linear function that in turn was the product of a random field "random function". Through a linearity test and using the chi-square statistic, he found sufficient evidence to reject the null hypothesis of linearity and that the four oil price lags have negative effects on GDP growth, although only the fourth lag turned out to be statistically significant. Another purpose of this study was to describe the functional form of the GDP growth expectation conditioned to its own lags and to oil price lags. The author concludes that the relationship has shown instability over time, so a non-linear form is superior to a linear representation of this relationship.

Following the nonlinear relationship between oil price and economic activity, Kilian (2009) highlights the importance of distinguishing the types of shocks that affect the price of oil, since these could have different repercussions on the economy. Among these are the shocks to the global demand for industrial products, the supply of oil, and lastly, the demand shocks that are specific to the world crude oil market. The latter captures movements in the price of crude oil as a result of changes in expectations about the future availability of oil supplies. To observe the effects of these shocks on the real price of crude oil, the author estimated an SVAR with three variables: the percentage change in global oil production, the economic activity index based on ocean freight rates, and the logarithm of the real price of oil.

The model allowed him to quantify the evolution of the global aggregate demand shocks and the supply and demand for oil. He found that global aggregate demand suffered positive shocks

from 1978 to 1980 and oil supply suffered a negative shock during the same period that could be attributed to the cuts caused by the Iranian revolution. During the mentioned period, there were also shocks in the demand for the input because of the change in expectations about the availability of oil supplies in the Middle East, as a result of the Russian invasion of Afghanistan, the revolution in Iran, and the hostage crisis. However, the author points out that unanticipated shocks to the supply of oil have a minimal effect on the real price of crude oil since cuts in production in one oil-producing country would cause an increase in production in another. The increases in the real price of crude oil since 2000 have been caused, mainly, by an increase in global aggregate demand and not by shocks to oil supply or demand. The author concludes that the main causes of oil price increases are due to exogenous events such as wars or revolutions, among others, due to the uncertainty they create about the future availability of crude oil, even though oil production has not changed.

To observe the effects of these shocks on the US macroeconomic aggregates, inflation and real GDP growth, the author estimated linear regressions with these variables as dependent and shocks as independent variables. He establishes that unforeseen interruptions in oil supply caused an instant reduction in real GDP whose effect lasted for an estimated 12 months but was only statistically significant in the first two. This same interruption did not cause changes in the CPI level since these remained stable in the estimating period, although it turned out not to be statistically significant. However, unexpected expansions of aggregate demand had positive, effects on GDP in the first year, followed by a reduction in it after the second year because the increase in global demand will cause an increase in the price of oil and this will have negative effects on the economy in the long-run. As for the price level, it increases with a lag of

approximately three quarters, given an increase in global aggregate demand. Finally, an increase in the demand for crude reduces GDP gradually and at the same time causes a significant increase in the price level. The author concludes that the increase in the price of crude oil as a result of an increase in demand for itself results because of fluctuations in the global economy and not because of supply disruptions and the economic activity would be less affected.

Killian & Park (2009) uses the same SVAR model as Killian (2009) to measure the impact of oil supply and demand disruption on the US stock market. They found that the response of real stock market return to oil price shocks varies, depending on the nature of what causes the oil price hike the first time. For example, an increase in global aggregate demand tends to increase stock market return because of the perception that the economy is doing well, while at the same time, the oil price will increase because of the growth in aggregate demand. In contrast, a price hike as a consequence of a change in precautionary demand in response to growing instability in oil-producing countries especially those in the middle east will have a largely negative effect on US stock market return. In total, they found that oil demand and supply shocks account for 22% of the long-run variation in US real stock return.

(Bjørnland, Larsen & Maih, 2018) focuses on studying the relationship between the volatility in the price of crude oil and the volatility of macroeconomic variables. The study focused on the so-called period of great moderation in the mid-eighties, which was characterized by a reduction in the volatility of macro variables. The authors studied whether this was due to a decrease in the variability in the price of the input. To carry out the study, the authors used a Dynamic Stochastic General Equilibrium model (DSGE), using the New Keynesian model of rational expectations as

a frame of reference. To calibrate the model, they defined timeless consumption functions for the household and firm, the Taylor rule which represents the monetary policy, and one for the oil sector. The variables that were used in the model are the consumer price index, the federal funds rate, the growth of the Gross Domestic Product, consumption and investment, the price of oil, wages, and the growth rate of economic activity. All these variables are quarterly, from 1965-Q1 to 2014-Q1.

To carry out the estimation of the model, they used Bayesian methods by which probabilistic distributions were imposed on the parameters of the previously mentioned equations. For example, the discount rate follows a beta distribution, so this parameter should take values between zero and one. These distributions were imposed depending on what the theory dictates. The solution to this model is computationally intensive, so the authors used different optimization algorithms such as the Newton method and the so-called Metropolis-Hastings to find the optimal values of the parameters and the impulse-response functions. They encountered great macroeconomic volatility during the early 1970s through the mid-1980s. For the years 1984-85, the volatility in the aggregate variables was minimal, although later in 2001-02 a slight increase was reported. Regarding the volatility in the price of crude oil, this was consistent during the 1970s and has been declining since the mid-1980s. The authors did not find sufficient evidence that this decrease in volatility contributed to a decrease in macroeconomic instability in the United States.

Like other studies, this one found that most oil shocks were caused by exogenous events such as the OPEC oil embargo in 1973-74, the Iranian revolution in 1978, the Iraq-Iran war in the 1980s and the first Persian Gulf War in the early 1990s. They also found that after the 1970s, the Federal

Reserve was more aggressive in controlling inflation, which may have contributed to economic stability. Using the impulse response functions of the system, the authors established that after a standard deviation shock to the oil price of approximately 15%, GDP gradually declined by 0.4% to 0.5% in the first two years. This gradual reduction caused production costs to rise, which reduced profits and the accumulation of capital for investment by companies and eventually reduced household consumption. With the increase in production costs, companies decided to replace capital (machinery) with work, which caused an increase in salary growth and, gradually, an increase in inflation, motivating an increase in the interest rate. Finally, through the decomposition of the variance, they found that, in the period of great volatility in the price of oil, it explains around 9% and 13% of the variability in GDP growth and 65% of inflation. In contrast, during periods of little volatility in the price of the input, this explains one percentage of GDP growth and 12% of inflation.

The relationship between the price of oil and economic activity has not been the same over the years. Most of the studies carried out on the subject agree that in the period prior to 1984, oil shocks had greater effects on the economy. Among the most recent studies are (Blanchard & Riggi, 2013) which takes a structural autoregressive vector model previously estimated by Olivier Blanchard as the basis for the study. The system is estimated with quarterly data through two samples, the first from 1960-1 to 1983-4 and the second from 1984-1 to 2007-4. The variables that were included were: the Gross Domestic Product, its deflator, employment, nominal salary, consumer price index, and the real price of crude oil. The only variable they added to the new system was the federal funds rate, in order to observe the possible role of monetary policy. The

model that the authors developed to interpret the impulse-response functions is a New Keynesian, which allows oil to be an input used in production and consumption.

In the model, aggregate consumption and production functions were defined, two functions that describe the behavior of households, one that describes the cost minimization process of the company and the other the reaction of the Central Bank, Taylor rule type. The aggregate production and consumption functions are Cobb-Douglas type and linearized, where the first is a function of labor and oil, the second of spending on locally produced goods, and the consumption of crude oil. The behavior of households is quantified using two equations, the first, consumption as a function of its lag, expected value, and a parameter that indicates risk aversion, the second explains the labor supply and, like the first, is a function of its lag and the marginal substitution. Companies will minimize their costs, depending on labor and the demand for crude oil, so an increase in the price of fuel should reduce employment and their profit margin. Monetary policy in this model is explained through the so-called Taylor rule, where the interest rate responds to deviations of CPI inflation from its target and to the output gap.

Instead of using a Bayesian estimation that uses the results of the SVAR as prior information, when estimating the model, the authors chose the method of estimation of the minimum distance for both samples, due to a large number of parameters and to facilitate inference with previously estimated shocks. Through this analysis, they found that, in the long run, an increase in the price of crude oil would negatively affect employment for both samples, which harms economic stability. As for inflation, it increased significantly with increases in the price of fuel in the period prior to 1984, unlike the second sample, where inflation was not very sensitive to changes in crude

oil. For its part, the interest rate reacts more to inflation than to changes in economic activity, so the price of the input indirectly influences the interest rate in the first sample. The authors' main conclusion is that the economy has undergone two major changes since the 1970s, an increase in real wage rigidity and a substantial increase in monetary policy when fighting inflation. Therefore, the effects of oil shocks on the economy have been reduced since 1985.

Although much of the literature focuses on the effects that oil shocks have had on the US economy, they are not limited to this. In the case of Malaysia, a developing country and like Puerto Rico an oil importer country (Shaari, Pei & Rahim, 2013) focus on the effects that the increase in the price of oil has on the different industrial sectors. For example, agriculture is affected because a large part of the machinery used, such as tractors and cultivators, requires fuel for its operation, so an increase in the price of oil increases production costs. In the same way, the input affects the construction and manufacturing sectors, where oil is used in their production processes. The sector that uses fuel the most is transportation, which, by its very nature, will suffer the effects immediately.

Using quarterly data from 2000-2011, on manufacturing, agriculture, construction, and transportation, which are important sectors for the country's economy, they estimated an unrestricted autoregressive vector system to which they added the price of crude oil in local currency. Through the VAR, the authors carried out a cointegration and causality test to observe if the volatility in crude oil prices has effects on the different sectors of the economy. In the cointegration analysis, they found that oil has long-term effects on different sectors, but the test could not determine the direction of this relationship. For its part, the Granger causality test showed

that the price of oil does affect production in the manufacturing, construction, and agricultural sectors at a significance level of 0.05. However, the null hypothesis that the price of oil does not cause the GDP of the transportation sector could not be rejected. Although the authors limited themselves to these two analyses, they recommend that the government authorize a crude oil price control policy to prevent its volatility from affecting the different sectors.

In Puerto Rico, there have been multiple studies that measure the relationship between the price of oil and economic activity. Among them, Toledo (2011) estimated a system of bivariate autoregressive vectors, with the real Gross National Product and the price of a barrel of oil in real terms as its variables. Through this model, the author performed the Granger Causality test and determined that the oil price affects the GNP growth rate on the island, but the GNP growth does not affect the oil price, which is to be expected because the island has no oil reserves. Using the impulse-response function of the previous model, it was verified that the response of the GNP growth rate to a rise in the price of oil is negative. Lastly, by decomposing the variance of the estimated model, the author found that oil price shocks explain between 13% and 21% of the GNP growth rate deviation from its mean.

Another focus of the author was to observe the stability of the relationship between the price of oil and economic activity over time and to identify the dates on which this relationship received structural changes. For this, he estimated two linear regressions where differentiated GNP and employment are the dependent variables. As independent variables, he took three lags of the difference logarithm of oil price, real investment difference, and a lag of the interest rate. The first variables were differentiated so that they have a constant mean and variance over time (stationary).

He concluded that the relationship between oil price and GNP is negative in all three oil price lags and the relationship between employment and oil price is negative only in the first two. In the first model, the Quantd-Andrews test found three structural changes in 1977, 1984, and 2005. The first two years coincide with periods of a recession on the island, while in the employment model, only one structural change was found in 1976. These changes had the effect of reducing the importance of the cost of this production input in the economic activity of the country.

Finally, the author used an autoregressive model conditioned on heteroskedasticity in which he added binary variables to model the structural changes that he identified in the previous models and obtained a GARCH (1.0). He concluded that the importance of the price of oil in the island's economic activity has decreased in recent years, as evidenced by the positive coefficients of the binary variables with the price of said input. The author concludes that there is an asymmetry in the relationship between the price of oil and economic activity because the increase in this input has caused reductions in local production. However, the decrease in the price of the input does not cause periods of economic expansion, the same conclusion as Hamilton (2003).

(Toledo & Hernández, 2014) studied the effects of oil prices on sectoral economic activity for Puerto Rico and the effects of US monetary policy on these sectors. They estimated an autoregressive vector system with quarterly data from 1990-I to 2007-I in which they included the price of crude oil, and the interbank interest rate to represent the monetary policy, total employment and to represent the activity of the different sectors took the level of employment in each sector. Among the sectors included in their system are manufacturing, agriculture, transportation, public administration, commerce, services, and construction. The authors chose to

model a VAR because it provides the necessary tools to quantify the effects of the oil price on the other variables.

Using the Granger causality test, they found that the price of oil affects employment in the service, transportation, and construction sectors, while the interest rate causes employment in the service, trade, and manufacturing sectors, and marginally in the public administration sector. The impulse-response functions showed that the response to unexpected changes in the price of crude oil is negative in most sectoral jobs, except in construction. Finally, through the variance decomposition, the price of oil is the most important, explaining around 10.3% of the fluctuations in total employment, the sector that is most sensitive to changes in the price of crude oil is services, while the manufacturing, construction, and commerce are not very sensitive. The authors concluded that both crude oil and the interest rate can explain the deviations in sectoral employment, but the price of oil exceeds the interest rate when explaining the deviations in sectoral employment.

The most recent study that quantifies the effects of oil price fluctuation on the Puerto Rican economy is Quintero & Rodríguez (2021). The purpose of the paper was to establish which exogenous shock (oil or monetary policy) has a more significant effect on some of the island's most important macroeconomic variables such as the Economic Activity Index, total non-farm employment, Puerto Rico Consumer Price Index, electricity consumption, gasoline consumption, and cement sale. In addition, the authors calculated the period in which each economic indicator reached its new equilibrium after the exogenous shock. The methodology implemented is a

Structural Vector Autoregression with long-run restrictions to get the Impulse Response Function and Variance Decomposition.

The authors found that an oil price shock had a greater effect on gasoline consumption than electricity consumption and the monetary policy shock had a higher effect on electricity consumption. In the aggregated variables, CPI, employment, and the economic activity index both exogenous shocks had minimal impact. The study concludes that consumers have greater exposure to volatility in the oil price, as their income will be reduced given that they will spend more on utility bills and gasoline for their vehicles.

Methodology

The predominant methodology used in economics when measuring the effect of oil market fluctuation in the economy is the Vector Autoregression model (VAR) which was first proposed by Sims (1980) and became the standard tool in macro-econometrics research. Later these models were criticized for their lack of economic theory foundation as stated by Cooley and LeRoy (1985), that argues these models establish a certain economic structure that does not go along with the theory. As a result, later models were developed, by Bernanke (1986), Blanchard & Watson (1986), and Sims (1986) called Structural Vector Autoregression (SVAR). This method allows the researchers to transform the atheoretical VAR models into a system of structural equations which in terms will be estimated by imposing structural restrictions on the parameters of the system. These models yielded a structural interpretation of the impulse response functions and the forecast error variance decomposition.

When studying the effects of oil market disruptions on the economy VAR models are the predominant methodology used.

A SVAR model was implemented to measure the impacts of oil supply, demand, and global aggregate demand shocks on Puerto Rico's economic growth. Because these types of models provided us with an analysis of the transmissions of the shocks on the variables through the structural IRF and FEVD. The model will have the following representation:

$$\boldsymbol{A_0 Y_t = \alpha + \sum_{i=1}^{n} A_i Y_{t-n} + B\varepsilon_t}$$

Where Y_t = (Global Oil Production, World Industrial Production Index, Real Price of Oil, Puerto Rico's Economic Activity Index) and **n** is the optimal lag determined by the Akaike Information

Criterion. The matrices A_0 and B contain the relationship between the endogenous variables Y_t and the structural shocks $\boldsymbol{\varepsilon_t}$. Other exogenous variables were added to the model, among them, the Strategic Oil Reserves of the United States, a dummy variable of the period of late 2002 until late 2003 to account for the Venezuelan unrest which according to Hamilton (2011) eliminated around 2.1 millions of barrels from December 2002 to January 2003 while o the Iraq Invasion eliminated 2.2 million barrels from April 2003 to July 2003. The other binary variables included in the model were from 2007 to early 2009 to adjust for the changes in the oil market during the Great Recession, another from the period of 2010 to 2012, which represents the Arab Spring a period of high volatility in oil markets. One from late 2014 to mid-2016, this period was characterized by lower oil prices due to a variety of factors, among them overproduction and the OPEC decision to maintain its production levels. The last dummy variable included was from March 2020 onward, due to the structural changes that arose from the COVID-19 pandemic.

The structural equations in the model can be reconstituted into the reduced form by multiplying both sides of the equations by $\boldsymbol{A_0^{-1}}$ which contains a recursive structure such that the errors $\mathbf{e_t}$ can be decomposed according to $\mathbf{e_t} = \mathbf{A_0^{-1}\varepsilon_t}$ as a result we obtain:

$$\mathbf{Y}_t = \boldsymbol{\alpha} + \sum_{i=1}^{n} \boldsymbol{A_i}\mathbf{Y}_{t-n} + \boldsymbol{e_t}$$

Where:

$$\boldsymbol{e_t} \stackrel{\text{def}}{=} \begin{pmatrix} e_t^{prod} \\ e_t^{IPI} \\ e_t^{p} \\ e_t^{PREAI} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} \end{bmatrix} * \begin{bmatrix} \varepsilon_t^{SS} \\ \varepsilon_t^{ADS} \\ \varepsilon_t^{ODS} \\ \varepsilon_t^{Other} \end{bmatrix}$$

This system is identified as Blanchard & Quah (1986), by imposing long-run restrictions on the cumulative impulse response functions. Where SS= Oil supply shock, ADS: is aggregate demand shock, DS: oil specific demand shock, and others; we defined as the innovations that do not come from the identified shocks. Killian (2009) proposed a short-run vertical supply curve since the price does not have instantaneous effects on production, this can be used because the oil-producing countries take time to adjust their production in the face of unexpected changes in the oil price. That is why oil production is the least endogenous variable in the system. Therefore, crude oil demand shocks do not have instantaneous effects on the crude supply as established by the restriction in this model. On the other hand, global aggregate demand shocks do not respond instantly to changes in crude oil prices either. However, both the shocks of crude oil supply and global demand have instantaneous effects on the price of crude oil, this is explained since in practice the price tends to change rapidly in the face of events in the global economy such as wars which tend to affect the crude oil market and the global economy significantly.

Data

The variables included in the model are monthly frequency, which includes the global oil production, world industrial production index, real price of oil, and the Puerto Rico economic activity index, from January 2000 to March 2021. The production and price data come from the U. S. Energy Information Administration, the industrial index from the International Monetary Fund, and the island economic activity index from the Economic Development Bank for Puerto Rico. The last one is an index based on payroll employment, electrical energy generation, cement sales, and gasoline consumption. This index was used as a proxy of economic growth at a monthly frequency. Graph 1 presents the four variables at their level, at first hand, we can see the upward trend of oil during the referenced period. This was mainly due to the increase in the use of hydraulic fracturing in the US which allows the extraction of greater quantities of oil from newly discovered reserves. On the other hand, the industrial production index and oil price experienced significant drops during the great recession of 2007-08 and the COVID-19 pandemic in March of 2020. In turn, the price of crude oil experienced a drop during 2014 and subsequently, the price remained below its historical average, mainly due to overproduction. In the case of the Puerto Rico economic activity index, we can appreciate a downward trend since 2006 since the elimination of section 936 of the US Internal Revenue Code, which provided the island with a competitive advantage through tax incentives to manufacturing companies. Additionally, there have been two drops in the index, one in 2017 because of Hurricane Irma and Maria, and the second one during March 2020 in the wake of the COVID-19 pandemic.

Figure 1: Variables in level (2000m1-2021m3)

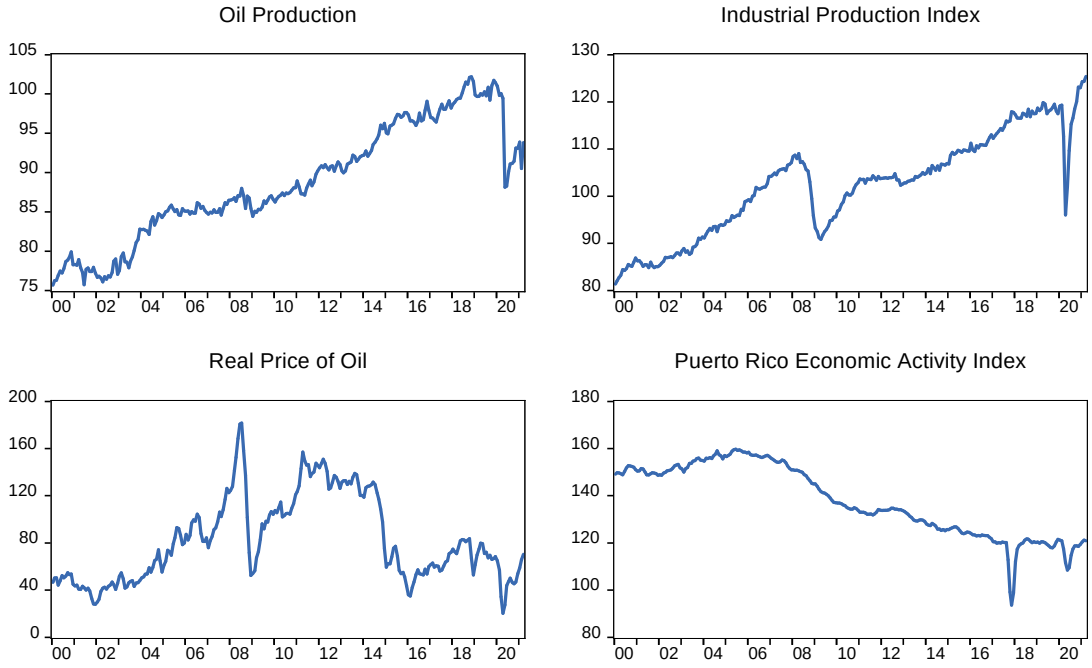

Table 1: Correlation Matrix

	Oil Production	Industrial Production Index	Real Price of Oil	Puerto Rico Economic Activity Index
Oil Production	1	0.934	0.371	-0.787
Industrial Production Index	0.934	1	0.436	-0.702
Real Price of Oil	0.371	0.436	1	-0.113
Puerto Rico Economic Activity Index	-0.787	-0.702	-0.113	1

Given that some of the variables are exhibiting a trend, this means that the variables are nonstationary, and running the model with such variables will produce spurious results. To test the stationarity hypothesis the Augmented Dickey-Fuller (ADF) Unit Root test and Phillips-Perron (PP) test are performed and shown in Tables 2 and 3. As expected, the four variables are

nonstationary, the same test is performed to the first difference of each variable. At their first difference, all the variables are stationary, which means the SVAR Model will be estimated using the logarithm of the first difference of all four variables.

Table 2: Augmented Dickey-Fuller Test

Levels

		Oil Production	Global Industrial Production Index	Oil Price	Puerto Rico's Economic activity index
Intercept	t- statistic	-0.82	-0.24	-2.56	-1.41
	Prob.	0.81	0.93	0.10	0.58
Trend and Intercept	t- statistic	-3.67	-3.64	-3.43	-2.14
	Prob.	0.03	0.03	0.05	0.52
None	t- statistic	1.89	2.22	-0.75	0.18
	Prob.	0.99	0.99	0.39	0.74

Difference

		Oil Production	Global Industrial Production Index	Oil Price	Puerto Rico's Economic activity index
Intercept	t- statistic	-14.63	-12.46	-9.65	-4.23
	Prob.	0.00	0.00	0.00	0.00
Trend and Intercept	t- statistic	-14.61	-12.46	-9.64	-4.47
	Prob.	0.00	0.00	0.00	0.00
None	t- statistic	-14.43	-14.23	-9.66	-4.22
	Prob.	0.00	0.00		0.00

Table 3: Phillips-Perron

Levels

		Oil Production	Global Industrial Production Index	Oil Price	Puerto Rico's Economic Activity Index
Intercept	t- statistic	-0.90	-0.41	-2.38	-1.35
	Prob.	0.79	0.91	0.15	0.61
Trend and Intercept	t- statistic	-3.64	-3.73	-2.71	-1.78
	Prob.	0.03	0.02	0.23	0.71
None	t- statistic	1.81	1.95	0.99	0.14
	Prob.	0.98	0.99	0.29	0.73

Difference

		Oil Production	Global Industrial Production Index	Oil Price	Puerto Rico's Economic Activity Index
Intercept	t- statistic	-18.68	-15.90	-10.31	-9.94
	Prob.	0.00	0.00	0.00	0.00
Trend and Intercept	t- statistic	-18.65	-15.89	-10.29	-9.36
	Prob.	0.00	0.00	0.00	0.00
None	t- statistic	-18.44	-15.75	-10.33	-9.95
	Prob.	0.00	0.00	0.00	0.00

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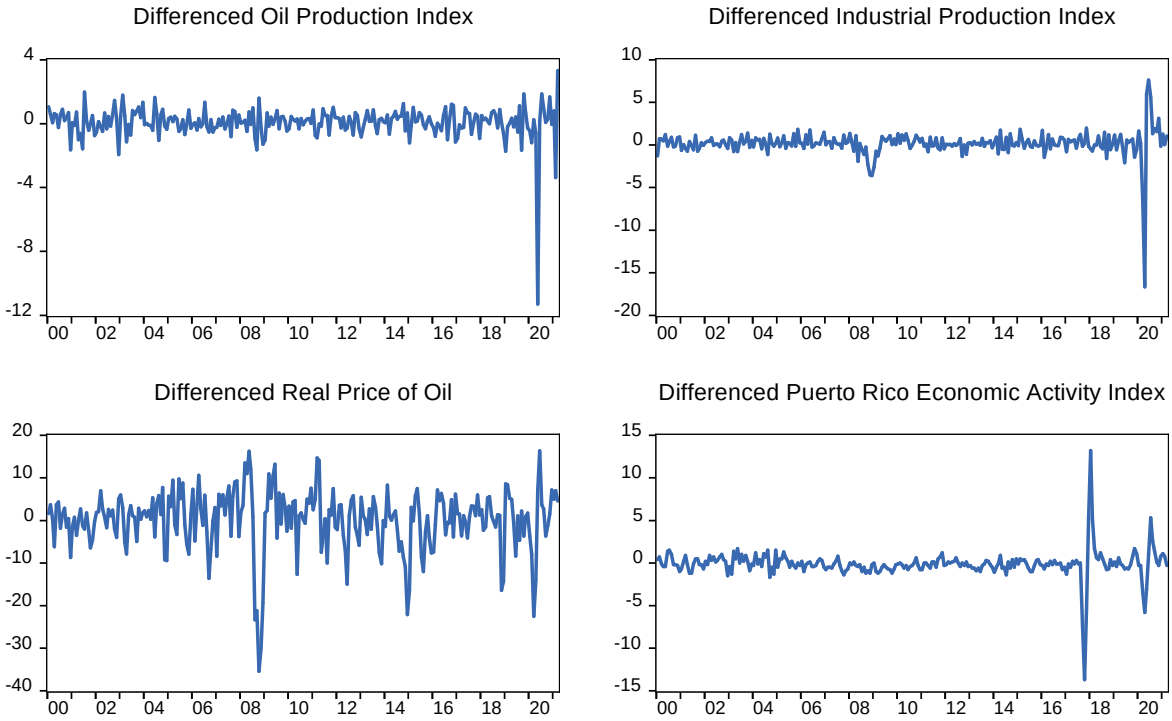
Figure 2: Variables at First Difference



Results

As stated, before the variables used in the Blanchard & Quah SVAR type model will be the logarithm of the first difference of the following variables, global oil production, industrial production index, the real price of oil, and the Puerto Rico economic activity index. According to the Akaike Information Criterion, Schwarz Information Criterion and Bayesian Information Criterion the optimal lag length of the model is two. The last test performed before performing the structural decomposition of the vector autoregression model is the Johansen Cointegration test. Table 4 presents the results of such a test, indicating that there is a linear combination of the variables that are stationary, which means there is a long-term stable relationship among the four variables. According to Johansen (1988), this long-term relationship implies that any deviations from the mean of a variable in the vector **Y** will be forced to return to its equilibrium.

Table 4: Johansen Cointegration Test

Number of cointegrated equations	Eigenvalue	Trace Statistic	Critical Value	Prob.**
None*	0.422253	411.7515	47.85613	0
At most 1 *	0.363501	271.8537	29.79707	0
At most 2 *	0.319543	156.6516	15.49471	0
At most 3 *	0.204933	58.47901	3.841465	0

Trace test indicates 4 cointegrating equations at the 0.05 level
*Denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

After performing the Blanchard & Quah structural decompositions we can get the structural impulse response functions as presented in Figure 3. We can conclude that both oil supply shock and aggregate demand shock have a slightly positive effect on the economic activity index during the first three months, after turning negative for approximately two to four months before the

effects turn to cero. Contrary the oil-specific demand shock has a negative effect on the economic activity index during the first two months of the initial shock. The variance decompositions tell us a similar story, approximately only 8% of the variation in the economic activity index is explained by the three shocks, oil supply shock with 6%, aggregate demand shock, and oil-specific demand shock with approximately 1% each.

Figure 3: Response of the Economic Activity Index to Structural Shock

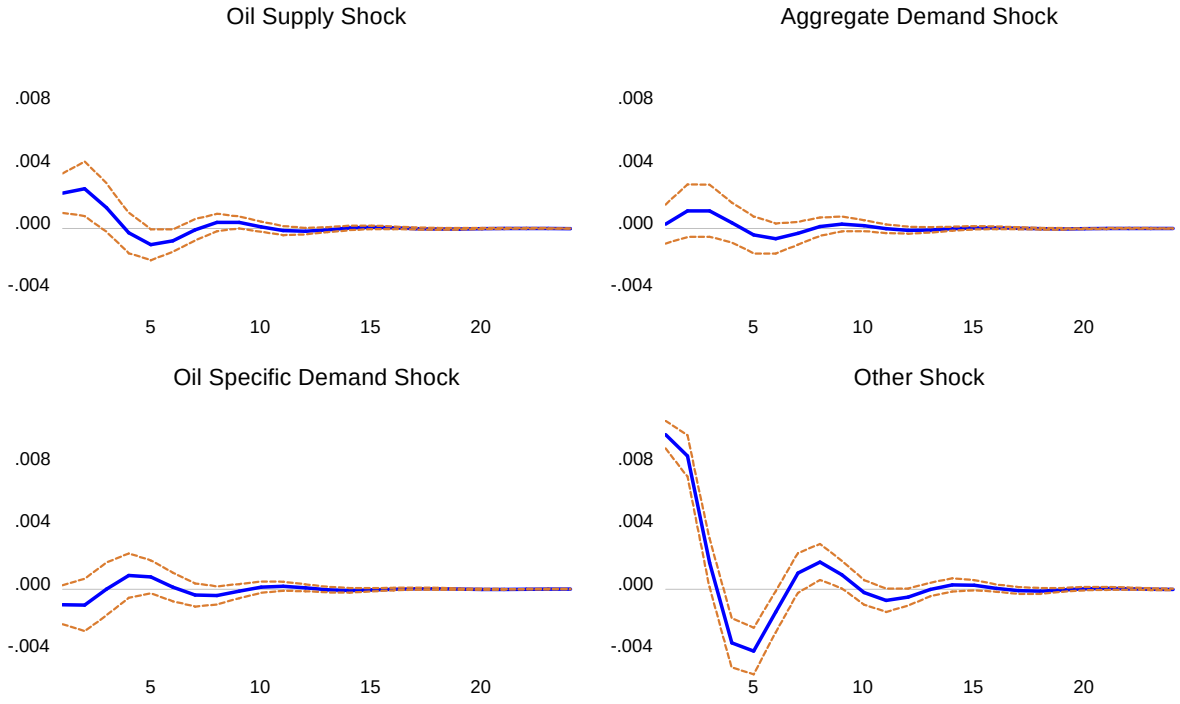


Table 5: Structural Variance Decomposition

Period	S.E.	OSS	ADS	ODS	Other
1	0.01	4.98	0.11	0.36	94.54
2	0.01	6.00	0.69	0.34	92.97
5	0.01	6.22	1.04	0.67	92.06
10	0.01	6.36	1.19	0.75	91.70
15	0.01	6.36	1.19	0.76	91.69
20	0.01	6.36	1.19	0.76	91.69

These results are contrary to our initial hypothesis, that oil shocks have a persistent effect on the economic activity index. However, is possible that the shocks studied do not affect the economic activity index (i.e. economic growth) directly, but they do have effects on another variable that in turn affects economic growth. One possible variable is the Consumer Price Index (i.e. inflation), to answer this question the same model will be estimated with the logarithm difference of the CPI as the fourth variable.

Figure 4: Response of CPI to Structural Shock

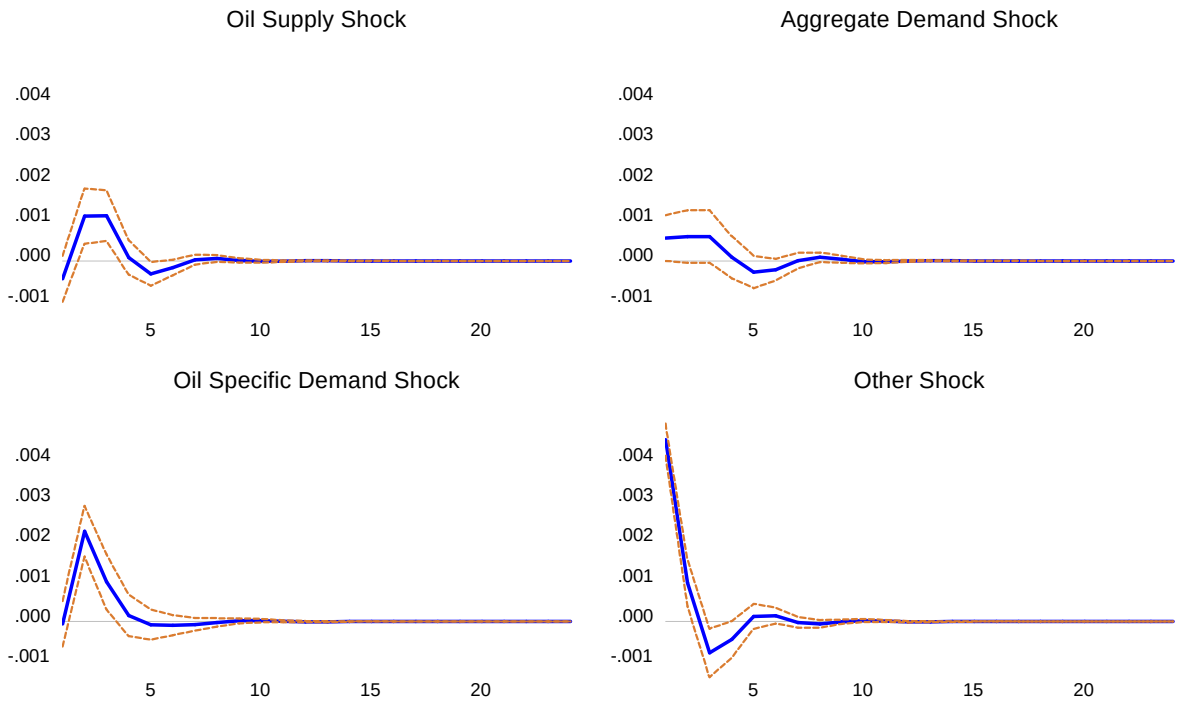


Table 6: Structural Variance Decomposition

Period	S.E.	OSS	ADS	ODS	Other
1	0.01	0.94	1.54	0.01	97.50
5	0.01	8.72	3.54	18.79	68.95
10	0.01	8.78	3.70	18.76	68.75
15	0.01	8.78	3.71	18.76	68.75
20	0.01	8.78	3.71	18.76	68.75

Through the impulse response functions, we can observe that the three study shocks have positive effects on the CPI, which implies that they tend to increase inflation for a period of approximately four to five months after the initial shock. Finally, with the structural variance decomposition, we can observe that the oil-specific demand shock explains approximately 19% of the variations in the CPI, while the oil-supply and aggregate demand shock explain 9% and 4% respectively.

It is clear that oil supply and demand shocks do not significantly impact economic growth, however, these results are similar to those found in Kilian (2009). In terms of the effects of oil supply shock on GDP in the case of the US, it lowered it instantly while in Puerto Rico this reduction occurred with a delay of around 3 months, with regards to the economic activity index (EAI). CPI in the island responded positively in response to the oil supply shock, contrary to the US where said shock has no significant effects, this may be due to the nature of the island economy (oil importer). The aggregate demand shock has a similar effect on US GDP and PR EAI, it increased and decreased after, Kilian (2009) states that this is due to the adverse effects of higher commodities. This is confirmed by the effect of said shock on CPI, which has a significant effect.

The oil-specific demand shock has the same effect on US GDP and PR EAI, the contrast is that in the case of US GDP, the shocks lead to a gradual decline while in PR EAI it lowers it instantly. In the case of CPI in the US the response is positive and persistent over time, while in Puerto Rico the response is significantly positive during the first four months, and the effect dies out after the fifth month. Lastly, comparing these results to those of Quintero & Rodríguez (2021) we can state

that in both cases oil prices do not significantly affect PR EAI, contrary to the response which Quintero & Rodríguez (2021) states that it had a minimal impact while in this study it does have a significant impact. This last one may be due to differences in the methodology approach.

Conclusion

Through variance decomposition and impulse response functions, we can conclude that oil supply and demand shocks don't have a statistically significant effect on economic growth. Even though oil supply shocks briefly increase the economic activity index, the oil-specific demand shock reduces it briefly. The aggregate demand shock increased the economic activity index for four months, the effect dies out after the sixth month. The most significant effect is from the non-identified shock (other) which increased economic growth for around four months and explains 92% of the variation of the economic activity in the long run.

The results suggest that the oil supply and demand shock does not significantly affect economic growth. This may be due that the importance of these shocks on the economy has been reduced over time since the 70s with the first oil price hike and the economy has adjusted accordingly since. However, we test another hypothesis, which is that the studied shocks affect another macro variable that in terms affects economic growth. That possible variable is inflation, measured through the consumer price index. Applying the same SVAR with the CPI, using the impulse response functions we can conclude that the oil supply and demand shock significantly increase inflation during the second and fourth month after the initial shock. With the variance decompositions, we can infer that the oil supply shock explains around 9% of the long-run variation in the CPI, while the oil-specific demand shock explains 19%.

In terms of future research, it will undeniably be necessary to study the effects of the shale revolution on the island's macroeconomic aggregates, given that this event significantly lowered oil price volatility by 25% since 2018 and is expected to lower it by 50% in the long run, according

to Balke, Jin and Yücel, M. (2020). It will also be useful to study the effect of this event on the price of gasoline at the pump and if the shale revolution has reduced the inflation response to oil price hikes. Lastly in terms of policy, even though oil shocks did not have a significant effect on economic growth, it does impact inflation which in terms reduced the buying acquisition power of consumers. At the same time, Puerto Rico is an oil-importing economy that by its nature is dependent on the global price of this input, so the development of alternative sources of energy is highly important to foster a sustainable economy in the long run.

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