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The Effects of Oil Price on Energy Production and the Ecuadorian Economy

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ABSTRACT

Through an empirical analysis of the impact of variations in the international price of oil on the economic production of different strategic sectors and on energy production from various sources in Ecuador, the study seeks to show evidence on the economic effects of the price of oil. in a Latin American economy strongly linked to oil production. For this, relevant data were collected on production in different economic sectors, on the type of ownership in oil production and on energy production in various energy sources in Ecuador and statistical analyzes were carried out to evaluate the relationships between these and the international oil price. The results indicate that the effect of the oil price varies between the economic sectors of Ecuador. Some sectors, such as financial services and construction, show positive responses, while others, such as agriculture and fishing, appear less affected. The oil and mining sector in Ecuador is strongly linked to variations in the price of oil. The positive and significant response of the Oil and Mines GDP underlines the sensitivity of this sector to changes in international prices. Furthermore, energy production in Ecuador exhibits heterogeneous responses to variations in the price of oil. Forms of energy such as wind, solar and thermal energy show positive and significant responses, while hydropower presents a negative response in some periods. Positive responses in forms of energy such as wind, solar and thermal may indicate that the increase in the price of oil positively influences investment decisions in these energy sources. The study provides a significant contribution to the field of energy economics in oil-exporting countries and, particularly, in developing countries, as well as highlights the importance of energy diversification for these types of economies.

Keywords: Oil Price, Energy Production, Economic Growth, Ecuador
JEL Classifications: C32; O13; O47

1. INTRODUCTION

The Ecuadorian economy, intrinsically linked to the ups and downs of the international oil market, has experienced a deep and complex relationship with the volatility of crude oil prices. In the last decade, Ecuador's historical dependence on oil revenues has generated an economic scenario susceptible to fluctuations in the international price of oil. This research aims to examine in detail the impact of oil prices on the Ecuadorian economy, focusing on its discernible effect on the Gross Domestic Product (GDP) of various sectors. In addition, the influence of oil price on the production of various forms of energy in Ecuador, from traditional resources to renewable energy sources, will be explored. This comprehensive approach will allow for a more complete understanding of the interaction between global oil market dynamics and Ecuador's internal economic structure.

The strategic importance of this research lies in its potential to inform more resilient and sustainable economic and energy policies. By unraveling the complex linkages between oil price, GDP, and energy production in Ecuador, it is intended to provide a solid empirical basis for government decision-making and the design of strategies that mitigate the risks associated with oil market volatility and foster economic and energy diversification.

The intrinsic connection between the Ecuadorian economy and the international oil market has been the subject of extensive analysis in the economic literature. Authors such as Fontaine (2002) and Sawyer (2004) have highlighted how Ecuador's historical dependence on oil revenues has generated a notable susceptibility to fluctuations in crude oil prices. This phenomenon has been particularly evident in the last decade, during which the country has experienced a number of economic challenges directly linked to the volatility of the global oil market (Sarker et al., 2023).[1]

The impact of oil prices on the Gross Domestic Product (GDP) of various economic sectors in Ecuador has been studied by academics such as Paladines (2017) and García-Albán et al. (2021). Their detailed analysis reveals the importance of specifically assessing how different sectors, such as agriculture, industry, and services, respond to changes in oil prices. This research aims to contribute to this body of knowledge by delving into the sectoral relationship between oil price and GDP in the Ecuadorian context. Paladines' (2017) analysis serves as a framework for this research, which aims to contribute to this body of knowledge through a deeper exploration of the sectoral relationship between oil prices and GDP in Ecuador. The need to address these challenges from a sectoral perspective is underpinned by the inherent heterogeneity of the economy, where different sectors may manifest different responses to changes in oil prices (Davis and Haltiwanger, 2001).

In addition, the influence of oil prices on the production of various forms of energy in Ecuador has been the subject of increasing interest. Previous research such as that of Nwani (2017) and Ponce-Jara (2018) has examined how variability in oil prices affects the country's energy matrix, considering both traditional resources and renewable energy sources. This comprehensive approach reflects the need to understand how the dynamics of the global oil market affect the diversification of the Ecuadorian energy matrix.

In terms of the strategic importance of this research, studies such as that by Ponce-Jara et al. (2018) have highlighted the need for more resilient and sustainable economic and energy policies in Ecuador. Oil market volatility poses significant challenges, and a deeper understanding of the links between oil price, GDP, and energy production is essential to guide government decisions. The present research is positioned at the forefront of this effort by providing a solid empirical base that can inform the formulation of policies and strategies aimed at mitigating risks and fostering economic and energy diversification in Ecuador.

In order to contribute to the growing literature that examines the impact of international oil prices on the economy and energy production of developing countries, this study focuses on comprehensively analyzing the effects of variations in the price of oil on the output of various sectors, energy production, and other aspects relevant to the Ecuadorian economy. Unlike previous research focused on aggregate analyses, this research takes a sectoral approach using time series analysis to understand the dynamics of these influences over time.

For this, we use quarterly data from Ecuadorian and international public sources. The empirical strategy of this work is divided into two parts with a time series approach. Initially, we performed COD estimates with Newey West matrices to assess the effects of the international oil price on oil production and the unemployment rate in Ecuador.[2] Subsequently, we use Autoregressive Vector Models (VAR) to evaluate the international price of oil on public and private oil production, on energy produced by type of source, and on the gross domestic product of different strategic sectors in Ecuador.

The structure of the article is organized into four essential sections: the introduction, which presents the problem addressed and highlights the relevance of the study in the economic context of Ecuador; a historical context that examines the evolution of international oil prices and their effects on the Ecuadorian economy; a theoretical framework that explores the well-known impacts of oil prices on economic and energy variables; methodology, which details the data and methods used in the econometric analysis; the results, which present and explain the empirical evidence obtained by the implemented models, discussing the main findings and reflecting on their scope and implications; and finally, the conclusions, which summarize the contribution of the study and propose possible directions for future research in this field.

2. A BRIEF HISTORY OF RENEWABLE ENERGY PROJECTS IN ECUADOR 2010-2022

The economic relationship between Ecuador and the price of oil has been a central topic in the economic and energy literature, given the South American country's significant dependence on oil revenues. Over the past few decades, Ecuador has experienced economic fluctuations closely linked to variations in international oil prices. Ecuador's relationship with oil has its roots in the 1960s, when the country began exporting oil on a large scale. Commercial exploitation of oil resources intensified in the 1970s, coinciding with the global oil boom. During this period, oil revenues became a crucial source of foreign exchange and financing for development in Ecuador (Fontaine et al., 2019).

The 1980s stand as a crucial chapter in Ecuador's economic history, characterized by a marked dependence on oil that profoundly impacted its financial stability. The global situation of the time was decisive, as there was a sharp fall in international oil prices, a phenomenon widely documented in the economic literature (Hamilton, 1983). The decline in oil prices during this period triggered a series of adverse consequences for the Ecuadorian economy.

The deepening economic crisis manifested itself in a sharp contraction of Gross Domestic Product (GDP), a key

1 Ecuador's susceptibility to oil price swings has been compounded by its historical dependence on oil revenues. The economic literature has pointed out how this vulnerability can impact the country's economic stability (see Fontaine, 2002; Sawyer, 2004).

2 The sources used are accurately described in the methodology section.

macroeconomic indicator that reflects the overall health of an economy (World Bank, 2023). This phenomenon exacerbated Ecuador's already existing external debt, posing substantial challenges to the country's financial stability and its ability to meet international financial obligations (Falconí-Benítez, 2001). The need to diversify the Ecuadorian economy during this period became a strategic imperative, and the economic literature supports this notion. International case studies, such as Karl's (1998) analysis of economic diversification in oil-producing countries, underscore the importance of reducing dependence on oil revenues to strengthen economic resilience.

The Ecuadorian experience in the 1980s has served as a reference in research on economic policies in oil-dependent countries. Auty's seminal work (2002) on the "natural resource curse" highlights the risks inherent in over-reliance on a single resource and advocates diversification as a key strategy to mitigate these risks. Subsequent research, such as the work of Lal (1987) and Mafooki & Kaplinsky (2014), has examined economic diversification policies in natural resource-dependent countries, providing valuable insights to understand the challenges and opportunities Ecuador faced in that period.

In order to counter the lessons learned from previous economic crises, Ecuador deployed strategies aimed at economic diversification and reducing its historical dependence on oil, a response supported by the economic literature that addresses the vulnerability of single-producer economies (Ross, 2015). During the 2000s, proactive policies were developed that sought to promote diversification in strategic sectors such as agriculture, tourism, and the non-oil industry, reflecting a well-grounded approach in the specialized literature on economic development (Auty, 2003).

However, the implementation of these diversification policies has faced persistent challenges, many of which are explained by widely studied economic concepts. The structural complexity inherent in economic diversification, in which factors such as infrastructure, job training, and regulations play crucial roles, has been identified as an obstacle in the development economic literature (Hausmann et al., 2014). Economic inertia, a concept analysed by Mokyr (1992), has also been shown to be a relevant factor, as economies tend to remain in established patterns and resist structural changes even in the face of pro-diversification incentives and policies.

The 21st century has witnessed episodes of volatility in oil prices that have impacted the Ecuadorian economy in a notable way. The fall in oil prices in the 2010s has been the subject of analysis in recent economic literature, which highlights its influence on public finances and the country's persistent vulnerability to oil market fluctuations (Amaiquema & Amaiquema, 2017).[3] This phenomenon aligns with theories about commodity price volatility and its effects on commodity-dependent economies (Frankel, 2012). In addition, various events such as wars in strategic areas and international crises endorse and generate volatility in oil prices.

In this context, the study of the Ecuadorian experience in the 2000s and 2010s provides valuable lessons to the economic literature and offers insights that can be applied to other contexts of economies dependent on natural resources. The continued interaction between diversification policies and oil price dynamics from 2010 to date provides fertile ground for research addressing the complexity of building more resilient and sustainable economies in a changing global environment. The economic relationship between Ecuador and the price of oil has been a complex journey, marked by times of prosperity and challenges. Although efforts have been made to diversify the economy, dependence on oil remains a reality. The future resilience of the Ecuadorian economy will depend on the effectiveness of diversification policies and the ability to adapt to the changing dynamics of the international oil market.

3. DATA AND ESTIMATION TECHNIQUES

3.1. Data

To estimate the effects of the international price of oil on Ecuador's economy and energy production, three sets of dependent variables with high explanatory power from the macroeconomic point of view were selected: the sectoral product, the type of energy produced and the source of oil production. The analysis covers the period from the first quarter of 2010 to the last quarter of 2022. The period of analysis was chosen based on the availability of data and in order to avoid the external shocks of the 2008 crisis and its consequences. The frequency of the data is quarterly and the approach used is time series.

The economic effect of oil prices across economic and energy production sectors has been little studied. Most studies address the issue at a very aggregate level, without considering sectoral effects, or at the microeconomic level (firms or localities). In this work, we use information from the Energy and Resources Regulation and Control Agency of Ecuador and the Central Bank of Ecuador to obtain data at the industry and energy sector level.[4] With this, it was possible to obtain valuable information on the production of electricity in different sectors, the origin of oil production by type of property, and the sectoral performance of the real domestic product in Ecuador.

The main variable of interest in this work, the international price of oil, was estimated from data from the Energy Information Administration of the United States. We decided to use this variable instead of the price of Oriente and Napo crude oil due to the frequency of the information and the fact that the international

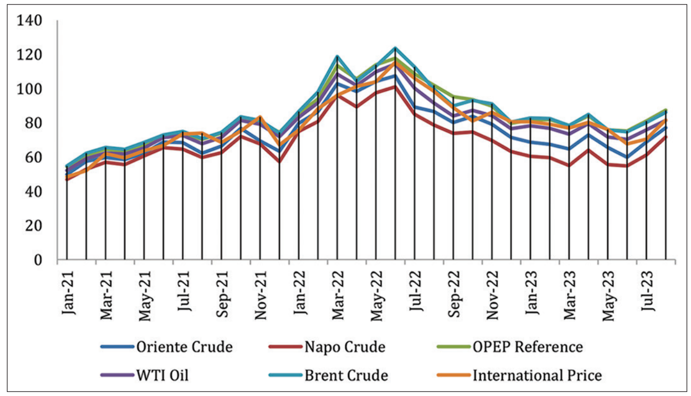
3 In 2014, OPEC decided not to reduce oil production despite oversupply in the market. This strategy sought to maintain market share and affect the economic viability of shale oil production in the United States. The decision caused a further drop in oil prices and generated volatility in the markets.

4 Using the portal of the Agency for the Regulation and Control of Energy and Resources, it is possible to obtain well-detailed balances and reports of Ecuador's energy production and consumption for a given month. For the purposes of our work, it was necessary to aggregate the consolidated data of all the months and adjust the information to obtain quarterly data.

price is highly correlated with the price of Ecuadorian crude oil (>90%), as can be seen in the graph below:[5]

Figure 1 shows the behavior of the main variables of interest. 3 observations are important in these graphs. First, a clear change in behavior is observed in the series from the first quarter of 2020 to the end. This behavior is generated by two coinciding events, the crisis caused by the Sars Covid-2 Coronavirus and Ecuador's exit from the Organization of the Petroleum Exporting Countries (OPEC). In addition, it is possible to observe that the peak of Ecuadorian oil production was in 2013 and 2014, a period during which the price of oil reached record highs. Likewise, the years of higher GDP growth coincide with the rise in the international price of oil.[6] These empirical observations can be observed in temporal perspective through Figure 2.

Figure 1: Comparison of reference prices for ecuadorian oil exports



To measure the effect and economic impact that the international price of oil had on Ecuador's economy and energy production, we selected a set of macroeconomic and demographic variables. First, the unemployment rate variable allows us to validate the results found in the literature that increases in the price of oil have positive effects on the employment rate of net oil exporting countries.[7] In turn, the variable of national oil production allows us to verify whether the increase in the price of oil is compensated by a reduction in its price in Ecuador. This idea is based on the fact that Ecuador was a member of OPEC until January 2020 and followed supply-limiting policies in the face of increases in oil demand. However, we expect to find differentiated effects on public and private oil production, with the former tending to be more strategic and the latter tending to maximize profits.

In this work, we obtained information from 4 different sources. As shown in Table 1, data on the international price of oil were obtained from the Energy Information Administration of the United States; the unemployment rate and wage income in Ecuador were obtained from the National Survey of Employment, Unemployment and Underemployment; the total and disaggregation of the energy produced were found in the Energy and Resources Regulation and Control Agency; finally, the GDP and national oil production was obtained from the Central Bank of Ecuador.

3.2. Model Specification

The empirical strategy was divided into two parts. Initially, aggregate analyses of the effect of oil prices on unemployment and oil production in Ecuador are performed through an Ordinary Least Squares model with macroeconomic controls to validate the data found by the literature. Second, we divide the effects of oil prices into different segmentations using VAR models to assess their impact on relative energy production by source, oil production by type of ownership (private or public), and the domestic product of Ecuador's main economic sectors.

For the first part of the empirical strategy, model number 1. In it, we are interested in looking at the effect of the international oil price on the Ecuadorian unemployment rate through a controlled OLS model. To this end, we incorporated control variables widely used in the literature to explain unemployment, including the outdated unemployment rate itself, labor productivity, and the general price index, which, in our case, is composed of all those segments of products not dependent on oil (Phillips, 1958; Ramcharran, 2002; Salimova et al., 2022).[8]

Model 2 seeks to obtain evidence on the effect of oil prices on oil production in Ecuador. In this study, we use other controls found in the literature that partially explain the movements of oil production. These are: the outdated oil production itself (a trend component of production), the unemployment rate and labour productivity in Ecuador (Kaufmann & Cleveland, 2001; Cologni and Manera, 2014). In addition, in both models we use a dummy variable that controls both Ecuador's exit from OPEC and the Coronavirus crisis. This happens because since both events happened at the same time, including a dummy for each would generate multicollinearity.[9]

In summary, our models are as follows:

$$\textit{Unemployment Rate}_t = \alpha_0 + \alpha_1 IOP_t + \alpha_2 X_t + \varepsilon_t \quad (1)$$

$$\textit{Oil Production}_t = \beta_0 + \beta_1 IOP_t + \beta_2 Y_t + \mu_t \quad (2)$$

5 Ecuador exports two types of oil, Type Oriente and Type Nabo. The cheaper Oriente type has historically represented more than 50% of oil exports, but the prices of both are highly correlated with each other and with the international price of oil.

6 Considering that the measures to contain Covid-19 clearly generated effects on production, the models in this work must contemplate a control for the pandemic.

7 Unemployment refers to the proportion of a country's labor force that is unemployed and actively seeking employment. It is used as a measure of the level of human resource utilization in an economy. Unemployment is calculated by dividing the number of unemployed people by the economically active population. In this paper we use total unemployment and do not discriminate by its type.

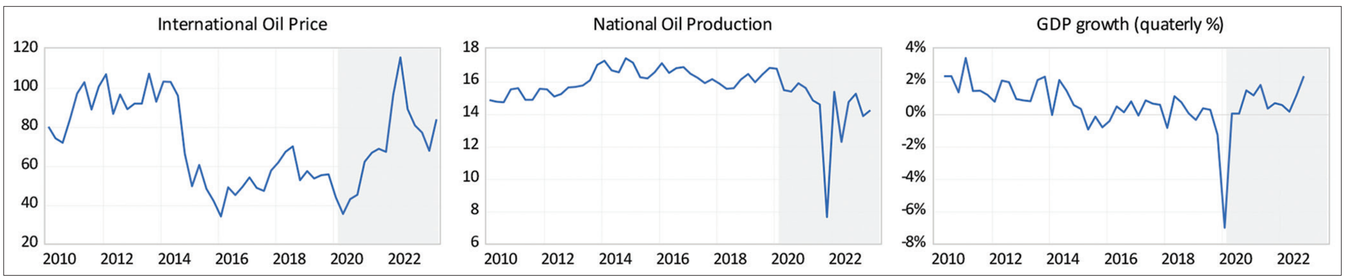
8 The past unemployment rate, which represents the region's labor history, can affect the current unemployment rate in rural areas. Research has shown that high unemployment rates in the past can have lingering effects due to loss of job skills, demotivation, and migration. In addition, the recurrence of high unemployment rates can lead to a negative perception of job opportunities, which in turn can discourage active job seeking, contributing to chronically high unemployment rates.

9 The COVID-19 pandemic has had a significant impact on employment around the world. Academic literature has shown that pandemic-related lockdowns and restrictions have disproportionately affected certain economic sectors, such as tourism and hospitality. This has led to an increase in unemployment rates and a reduction in output (Bartik et al., 2020).

Table 1: Descriptive statistics and source of variables

Stats	Source	Mean	Median	Maximum	Minimum	Std. Dev.
International Oil Price	Energy Information Administration (EIA)	71.325	67.600	115.400	33.900	21.825
Non-Petroleum Price Index	National Institute of Statistics and Census	101.405	105.343	113.344	83.730	8.073
Unemployment rate	National Survey on Employment, Unemployment and Underemployment	0.047	0.045	0.062	0.032	0.008
Labor Income	National Survey on Employment, Unemployment and Underemployment	468.298	463.841	543.615	418.504	32.411
Total Energy Produced	Energy and Resources Control and Regulation Agency	1396315	1363336	2304380	607399.6	508264
Covid Dummy/OPEC Exit	-	0.222222	0	1	0	0.419643
National Oil Production	Central Bank of Ecuador	15595.24	15676.19	17394.03	7636.825	1456.488
GDP	Central Bank of Ecuador	16311591	16864758	17615448	12941210	1224564

Figure 2: Variables of interest – international oil price, national oil production and real gross domestic product growth in Ecuador. Source: Authors' own elaboration with data from the Energy and Resources Regulation and Control Agency. National Oil Production data is in the thousands of barrels.



Where ε_t and $\propto_t \sim N(0, \sigma_2)$ y X_t and Y_t are the vectors of independent control variables that will be explained later.

Equations (1) and (2) are estimated by ordinary least squares (OLS) that use the Newey-West matrix (HAC) to avoid problems arising from autocorrelation or heteroscedasticity.[10] All variables are used in their level form. To check if the series have unit root, we performed the Fisher (ADF) and Philips-Perron (PP) unit root tests that can be found in the Table 2.

The results indicate that all series are I(1). The usual procedure in these cases would be to use differentiated series for the estimates, but this could imply a loss of important information about the long-term relationship between the variables, since the results of a Johansen test show that the series are cointegrated and we do not have many observations. To avoid this problem, Hamilton's (2020) recommendation is followed and models with series at the level are estimated, as well as some empirical studies (Barboza and Zilberman, 2018; de Mendonça and Díaz, 2023).

In the second part of the empirical strategy, we provide evidence through the impulse-response analysis of the Autoregressive Vector (VAR) model to know the duration of a shock transmitted by the "international price of oil" on the source of energy production (model 3: relative source of energy), oil production by type of property (model 4: Oil Production Differentiated by Ownership) and the product by type of sector (model 5: Gross Domestic Product by Sectors). Based on Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998), we apply the generalized impulse response function to obtain an impulse response that is invariant to any rearrangement of variables in VAR.13 Therefore, the reduced form of the VAR model is:

$$OPO_t = \gamma_0^0 + \sum_{i=1}^{p} \gamma_i^1 OPO_{t-i} + \sum_{i=1}^{p} \gamma_i^2 IOP_{t-i} + \omega_t \quad (3)$$

$$OREP_t = \delta_0^0 + \sum_{i=1}^{p} \delta_i^1 REP_{t-i} + \sum_{i=1}^{p} \delta_i^2 IOP_{t-i} + \mu_t \quad (4)$$

$$GDPS_t = \varphi_0^0 + \sum_{i=1}^{p} \varphi_i^1 GDPS_{t-i} + \sum_{i=1}^{p} \varphi_i^2 IOP_{t-i} + \epsilon_t \quad (5)$$

Where: I = 1,…,p (order); δ_0^0, γ_0^0 and φ_0^0 are the constant terms; μ_t, ω_t and ε_t are the terms of innovation (shocks or impulses), and REP=Relative energy produced {biogas; biomass; wind; hydraulic; solar}, OPO=Oil Production Differentiated by Ownership {Private and Public}; GDPS = Sectoral Gross Domestic Product {financial services; agriculture and shrimp fishing; public administration; agriculture; commerce; construction; oil and mining; oil refining; electricity and water supply}.

In the context of our study, the selection of the order of the VAR (Vector Autoregressive) model was rigorously addressed using an approach that combined series cointegration tests and the Schwarz criterion. To determine the presence of long-term relationships between the series, cointegration tests were carried out, considering both the range and the number of models. The choice of the order of the VAR model was based on the

10 The Newey-West matrix is essential in the analysis of time-series COD regressions because it corrects for autocorrelation and heteroscedasticity problems, ensures consistency and efficiency of estimates, and allows reliable hypothesis testing. Its use is essential to obtain valid and robust results when working with time series data in econometrics.

Table 2: Unit root test

Variable	Prob.	Fisher-ADF			Philips-Perron			
		CV (10%)	Lag	Max Lag	Lags	Prob.	Bandwidth	CV (10%) MZt
International Oil Price	0.4872	−1.612	0	10	0	0.508	3	−1.620
Non-Oil Price Index	0.9802	−1.612	2	10	0	1.000	5	−1.620
Unemployment rate	0.1987	−1.612	3	10	2	0.210	15	−1.620
Labor Income	0.6367	−1.612	4	10	0	0.689	16	−1.620
Total Energy Produced	0.7819	−1.612	5	10	2	0.730	50	−1.620
National Oil Production	0.5771	−1.612	1	10	0	0.586	13	−1.620
GDP	0.9962	−1.612	0	10	10	0.979	4	−1.620

Levels of significance: *** denotes 0.01, ** denotes 0.05 and * denotes 0.1. Standard errors in parentheses. OLS equation based on Newey & West estimators (1987)

Schwarz criterion, which provides a measure of the complexity of the model and seeks to avoid overfitting. The resulting matrix, organized by ranges and models, reflects the careful evaluation of various combinations to identify the optimal configuration that balances the complexity of the model with its ability to capture the essential relationships between the analyzed variables. This robust methodological approach strengthens the statistical underpinnings of our time series analysis and supports the inferences derived from VAR modelling in the framework of our research. Table 3 above contains a summary of the cointegration tests and their results.

Determining whether a VAR model should include an intercept and what the appropriate order should be involves a detailed analysis of cointegration tests and the Schwarz criterion applied to different combinations of ranges and models. In the context of cointegration testing, the aim is to identify long-term relationships between series. If the test indicates the existence of cointegration, an intercept may be required to capture such a long-term equilibrium relationship. However, if there is no evidence of cointegration, it might be appropriate to dispense with the intercept.

The VAR order, on the other hand, is selected by evaluating different combinations of lags based on Schwarz's criterion. This criterion penalises more complex models and favours parsimony. When examining the matrix organized by ranges and models, we look for the configuration that minimizes the Schwarz criterion. If, for example, a model with an order of 2 has a lower value in the Schwarz criterion compared to other models, it could be inferred that an order of 2 is more appropriate in terms of model fit. In our case, the cointegration tests indicate that we should have models with intercept and without trend of order 2, 2 and 3 for models 3, 4 and 5, respectively.

The ECM includes the error correction term (ECT) and lagged first differences of the endogenous variables. The ECT indicates the extent of variation from the long-run equilibrium which was present in the previous period. The coefficient attached to the ECT fulfills the role of the adjustment parameter, which shows the proportion of the disequilibrium that is covered during the subsequent period. The coefficients attached to the lagged first differences provide an indication of the short run relationship between the endogenous variables (Enders 2004).

4. EMPIRICAL RESULTS

Tests for unit roots were conducted using the Augmented Dickey–Fuller (ADF), Phillips–Perron (PP) and Kwaitkowski–Phillips–Schmidt–Shin (KPSS) tests (Dickey and Fuller 1981, Phillips and Perron, 1988). The KPSS test is used to complement the widely used ADF and PP tests in order to ensure robust results. The results of the unit root tests are reported in Table 1.

To measure the effects of the international price of oil on Ecuador's unemployment rate and oil production, Table 1 shows the OLS estimates for Equations (1) and (2). First, the p-values associated with the F-stat of both models are very low (close to zero), suggesting that the models are statistically significant and provide a significantly better fit than a model without explanatory variables. The p-values associated with the Lagrange Multiplier Test are relatively low for model (1) and high for model (2). This suggests that there is no significant evidence of serial autocorrelation in model errors (2), but there is evidence in model (1). However, the p-values associated with the ARCH test (Autoregressive Conditional Heteroskedasticity test) are also high for both models. This suggests that there is no significant evidence of conditional heteroscedasticity in the model errors. These results, in general, validate the use of Newey-West matrices in estimates. Table 4 shows the main results of the OLS estimators, which will be described below.

The OLS regression highlights essential connections between various variables and the unemployment rate, a finding consistent with the economic literature. The negative and significant relationship between the price of oil and the unemployment rate indicates that a $1 increase in the international price of oil can lead to a 0.01% reduction in Ecuador's unemployment rate, which is consistent with previous research. For example, the study by Blanchard and Gali (2007) examined the dynamics of the unemployment rate in response to shocks in oil prices. Their results support the notion that an increase in oil prices can stimulate economic activity, reduce unemployment, and have a positive effect on production.

Likewise, the observation that the oil sector influences unemployment rates is supported by work such as that of Hamilton (1983), who analyzed the relationship between oil prices and the business cycle. Hamilton proposed that changes in oil prices have substantial effects on the economy and, therefore, on employment. Our results, by suggesting an association between the price of oil and the unemployment rate, align with this perspective, strengthening the empirical evidence of the importance of the oil sector in labor dynamics.

This analysis is placed in the context of broader debates on the

Table 3: Series cointegration test

Number of Cointegrating Relations by Model - Equation (4)					
Test Type	**No Intercept No Trend**	**Intercept No Trend**	**Intercept No Trend**	**Intercept Trend**	**Intercept Trend**
Data Trend	None	None	Linear	Linear	Quadratic
Trace	1	2	2	1	2
Max-Eig	1	1	1	1	1
Rank or n. of E.C.					
0	-42.869	-42.869	-42.4687	-42.4687	-41.963
1	-43.915	-43.024	-43.691	-43.6827	-43.2527
2	-44.420*	-44.564*	-43.3084	-43.2433	-42.8905
3	-42.738	-43.950	-42.7723	-42.6795	-42.4014
4	-41.897	-42.189	-42.0613	-41.8929	-41.6712
5	-41.051	-41.271	-41.1805	-40.9647	-40.82
Number of Cointegrating Relations by Model - Equation (3)					
Data Trend	None	None	Linear	Linear	Quadratic
Trace	0	0	0	1	3
Max-Eig	0	0	0	0	3
Rank or n. of E.C.					
0	38.499	38.499	38.6871	38.6871	38.90619
1	38.766	38.642	38.75486	38.74622	38.88823
2	38.116*	38.049*	39.10433	38.89271	38.95778
3	39.553	39.519	39.5198	39.32458	39.32458
Number of Cointegrating Relations by Model - Equation (5)					
Data Trend	None	None	Linear	Linear	Quadratic
Trace	7	8	7	8	6
Max-Eig	4	5	5	6	6
Rank o n. de E.C.					
0	225.526	225.526	225.8303	225.8303	225.7154
1	225.024	224.941	225.1959	225.2592	225.1271
2	224.791	224.665	224.8816	224.7629	224.7076
3	224.984	224.586*	225.0466	224.8692	224.7458
4	225.286	225.195	225.3005	225.1896	225.0667

Table 4: OLS estimators of the effect of international oil price on the unemployment rate and ecuadorian oil production

Dependent Variables	**OLS**			
	Unemployment Rate		**Petroleum Production**	
Regressors	C	13.594***	C	7301.063*
		(2.781)		(3991.698)
	Oil Price	-0.014***	Oil Price	-11.564*
		(0.005)		(5.969)
	Unemployment Rate (-1)	0.07	Production (-1)	11.21
		(0.167)		(53.040)
	Non-Oil Price Index	-0.055***	Unemployment Rate	275.354
		(0.015)		(246.415)
	Labor Productivity	-0.005*	Labor Productivity	17.204**
		(0.003)		(6.605)
	Covid-Opep Dummy	0.227	Covid-Opep Dummy	-864.256**
		(0.289)		(490.351)
Tests & Statistics	Adjusted R-squared	0.293	Adjusted R-squared	0.302
	F-statistic	5.138	F-statistic	5.506
	Prob (F-statistic)	0.001	Prob (F-statistic)	0.000
	LM test	4.170	LM test	0.503
	Prob (LM)	0.016	Prob (LM)	0.560
	ARCH test	2.119	ARCH test	0.037
	Prob (ARCH)	0.146	Prob (ARCH)	0.845

Levels of significance: *** denotes 0.01, ** denotes 0.05 and * denotes 0.1. Standard errors in parentheses. OLS equation based on Newey & West (1987) estimators

influence of natural resources on employment, a topic addressed by authors such as Sachs and Warner (1999). Their research examined the "resource curse" and posited that economies rich in natural resources, such as oil, could face specific challenges in terms of sustainable development and employment. Our results, by highlighting the relationship between the price of oil and the unemployment rate, contribute to this discussion, underlining the importance of understanding the specific dynamics of the oil sector in the labor context.

On the other hand, the unemployment rate of the previous period (lag -1) does not show a significant association with the current unemployment rate. This could indicate that past fluctuations in the unemployment rate do not robustly predict current variations, possibly pointing to the presence of other factors or the influence of specific economic events.

The finding that the Non-Oil Price Index maintains a negative and highly significant relationship with the unemployment rate finds support in the economic literature. Research such as that of Blanchard and Katz (1999) has explored the influence of macroeconomic conditions, including price indices, on unemployment rates. Their results suggest that an increase in non-oil prices can boost economic activity and, consequently, reduce the unemployment rate. These findings highlight the importance of considering not only the price of oil, but also other indicators, when analyzing labor market dynamics. In addition, the negative relationship identified between the Non-Oil Price Index and the unemployment rate aligns with classical economic theories, such as Okun's Law, which postulates an inverse relationship between economic growth and unemployment rates. Taken together, these studies support and enrich our understanding of the observed relationship between the Non-Oil Price Index and the unemployment rate, providing a solid and relevant theoretical basis for the interpretation of these results.

The connection between labor productivity and the unemployment rate reflects a pattern consistent with previous academic studies. Research such as that of Prescott (2004) and Hall (2005) has explored the relationship between productivity and employment, underscoring the importance of an efficient workforce in boosting employment opportunities and reducing unemployment rates. These studies support the idea that increases in productivity can have positive effects on the labor market, aligning with classical economic theory. In addition, the observed negative relationship coincides with the premises of Okun's Law, which states that an increase in productivity leads to a decrease in unemployment rates (Okun, 1962). Taken together, these scholarly contributions consolidate and enrich our understanding of the identified relationship between labor productivity and the unemployment rate.

Finally, the Covid-OPEC dummy variable, which captures the impact of extraordinary events, does not show a significant association with the unemployment rate. This suggests that, at least in the period studied, the presence of the pandemic and the exit from OPEC did not translate statistically significantly into changes in the unemployment rate, perhaps because these events generated contrary impacts that were cancelled out in the long term.[11]

The OLS regression of model 2 provides fundamental insights into the determinants of oil production in Ecuador. The price of oil emerges as a key predictor and presents a significant and negative association with production, reflecting the direct influence of variations in international oil prices. This finding aligns with the existing literature, supporting the view of Kilian (2009), who previously underlined the sensitivity of oil production to fluctuations in crude oil prices. However, it is important to mention that the negative relationship between price and production is much more expected for public producers than for private ones. This is because public enterprises respond to the objectives of the government and organizations such as OPEC in which supply limitation is common (Ramcharran, 2002). In the private sector, on the other hand, the competitive market hypothesis should be valid. To observe these differences, the VAR models in the second part of the empirical strategy must obtain better results.

Labor productivity also has a positive and highly significant relationship with oil production. This result suggests that a more efficient labor force contributes to an increase in output, supporting the idea of Mankiw et al. (1992) about the importance of productivity in economic activity. In addition, the Covid-OPEC dummy variable shows a negative and significant coefficient, indicating a reduction in oil production associated with extraordinary events such as the pandemic and the exit from OPEC. It is important to note that in this case the dummy variable may be capturing the regressive effect of the pandemic much better than the effect of increased production that was expected from the exit from OPEC. This result is consistent with research that has explored the impact of unforeseen events on oil production, such as the work of Kang et al. (2009).

The second part of the empirical strategy provides more detailed information on the impacts of changes in the price of oil on Ecuadorian crude oil production. In particular, the VAR model resulting from equation (3) shows, through the results of the impulse response in Figure 3, how widespread innovations in the international price of oil affect the private and public production of this commodity.

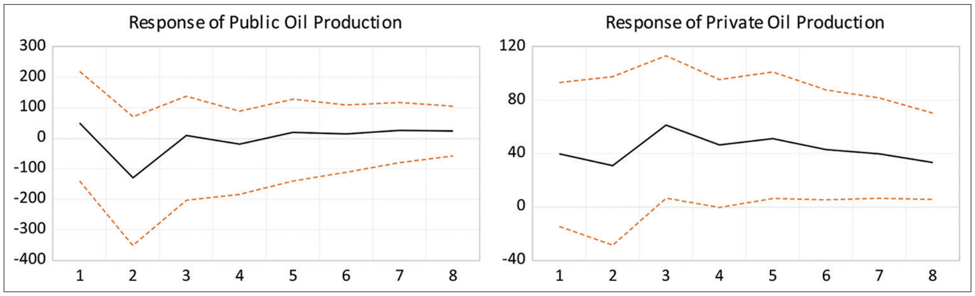
There are two results in this impulse-response function that are very interesting for the objectives of this work. On the one hand, the validation of the OLS result is found in the strong negative effect that the price of oil has had on the crude oil production of public companies during the first two quarters since the crash. This indicates that the ability to coordinate in favor of the objectives of maintaining high prices and limiting supply is much more frequent in public enterprises. A reasonable explanation for this phenomenon is Ecuador's participation in OPEC until January 2020. OPEC member countries rely heavily on oil revenues to fund their national budgets. By limiting production and keeping prices reasonably high, they try to secure sustainable revenues to support their government programs and development projects.[12]

On the other hand, we observe that the private sector has a response much more aligned with the hypothesis of competitive markets, that is, a rise in prices is answered by an increase in supply. In contrast to their public counterparts, private oil production companies take much better advantage of market opportunities in

11 The COVID-19 pandemic in 2020 had a massive impact on global oil demand due to travel restrictions and declining economic activity. The steep drop in demand, combined with the dispute between Saudi Arabia and Russia over production reductions, resulted in a sharp decline in oil prices and extreme volatility in energy markets.

12 OPEC seeks to exert some degree of control over the oil market. Keeping production at levels that avoid oversupply helps preserve OPEC's influence in pricing and allows it to act as a key player in global energy-related decision-making.

Figure 3: Response of Public and Private Oil Production in Ecuador to Widespread Innovations in the International Price of Oil. Note: Innovations of a standard deviation of 90% CI are used using Hall's percentile bootstrap with 1500 repetitions.



the medium term, as they are not tied to price stability objectives and do not need to avoid overbidding. These results are in line with those observed by Ramcharran (2002), who rejected the competitive hypothesis for all OPEC members and indicated that in the case of these countries it is much more reasonable to offer support for the revenue target hypothesis.

The results of the impulse-response function of the VAR model of equation (3) are shown in Figure 4. By analysing the impact of an innovation boost in oil prices on the relative production of energy by type of production, we obtain the following results:

The positive and significant responses of relative wind, solar and thermal energy production from the third quarter onwards suggest that the production of these forms of energy is positively driven by increases in the price of oil. This dynamic could be related to investments and incentive policies that seek to diversify the energy matrix, as pointed out in the study by Apergis and Payne (2014) on renewable energies.[13] The growing participation of wind and solar energy in the Ecuadorian energy market may not only respond to a search for environmental sustainability, but also to a strategy to mitigate risks associated with volatility in oil prices. This diversification of the energy matrix contributes to the resilience of the sector, reducing dependence on fossil fuels and strengthening the country's energy security.

With regard to the production of energy by biogas and biomass, the lack of significance and the proximity to zero in the response of these energy sources suggest that the price of oil has no discernible impact on its production. Literature, such as the work of Shafiee and Topal (2010), can support the notion that certain renewable energy sources may have relative independence from fluctuations in oil prices.

The negative and significant response of hydropower production from the fourth period onwards offers an intriguing perspective on the complexities of the Ecuadorian energy market in relation to fluctuations in the price of oil. This phenomenon can be interpreted through the prism of energy economics, where the lower economic competitiveness of hydropower in contexts of higher oil prices may be related to the associated production and transportation costs. Specific examples could include the maintenance and operation of water infrastructure that, compared to alternative sources, could become less economically attractive when oil prices are high.

Taken together, these results highlight the heterogeneity in the responses of different energy sources to variations in the price of oil. The economic paradigm present here is supported by studies such as that of Stern (2012), which examines the economic complexities of energy sources in the context of oil prices. In addition, this approach highlights the need for a comprehensive strategy tailored to each energy source in the design of market policies and strategies.

To contextualize these findings, reference can be made to international experiences. For example, countries such as Norway have demonstrated relative resilience in their hydropower production despite volatility in oil prices, thanks to continued investments in efficient technologies and a well-developed electricity grid. This example highlights the importance of considering not only economic factors but also investments in technology and electrical infrastructure to fully understand the dynamics between oil price and hydropower production in national contexts.

This observation suggests that the introduction of renewable energy innovations in the rural non-public sector does not have an immediate impact on reducing rural unemployment, but rather takes an appreciable time before their economic benefits are reflected in the employment rate. The lag could be related to business cycles. There may be a time of adaptation before rural employers respond to the opportunities generated by renewable energy innovation. This could be linked to the decision to hire more staff in response to an increase in renewable energy production. In summary, this lag in effects underscores the importance of considering the temporal dynamics in the relationship between renewable energy innovation and the rural labour market.

Our latest VAR model attempts to capture the effects of oil prices on relevant economic sectors of the Ecuadorian economy. To do this, Figure 5 shows the results of the impulse-response function derived from equation (5).

The positive and significant response in the early periods of Financial Services GDP suggests a direct connection between the

13 This phenomenon can be interpreted as an indicator of the effectiveness of investments and incentive policies implemented in the country. Concrete examples of this momentum are found in flagship projects, such as the construction of wind farms and solar plants backed by government initiatives and public-private partnership agreements.

Figure 4: Response of Source-Relative Produced Energy to Widespread Innovations in the International Price of Oil. Note: Innovations of a standard deviation of 90% CI are used using Hall's percentile bootstrap with 1500 repetitions

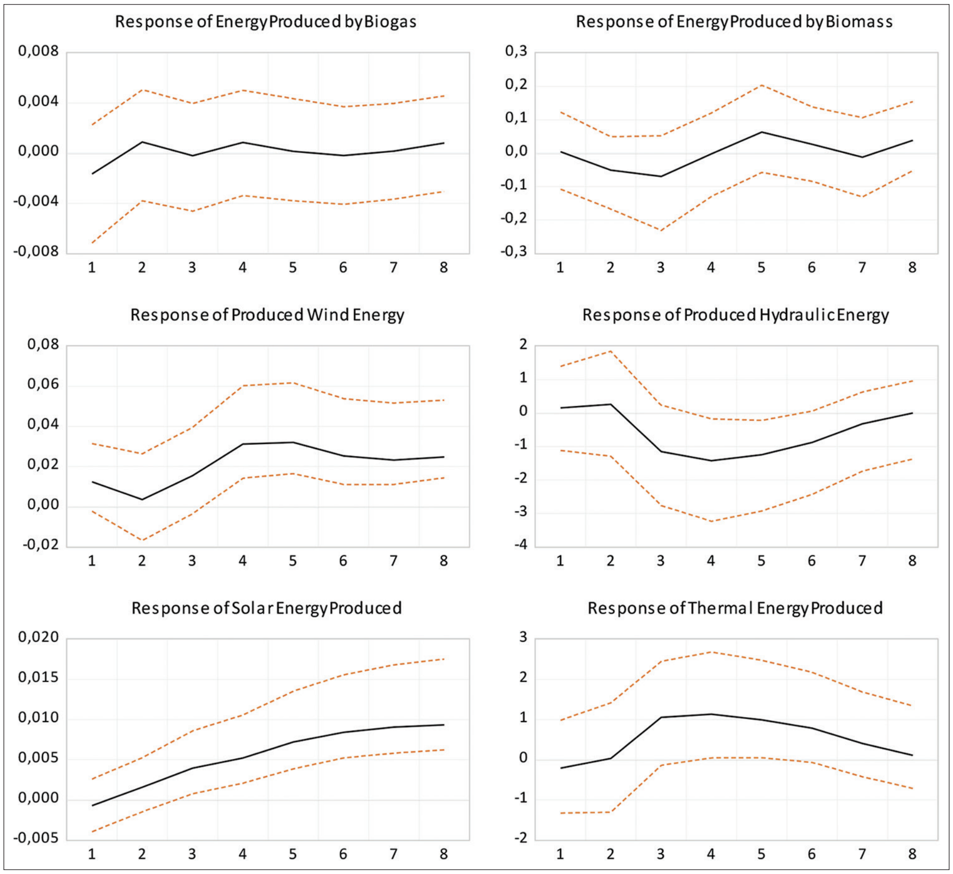
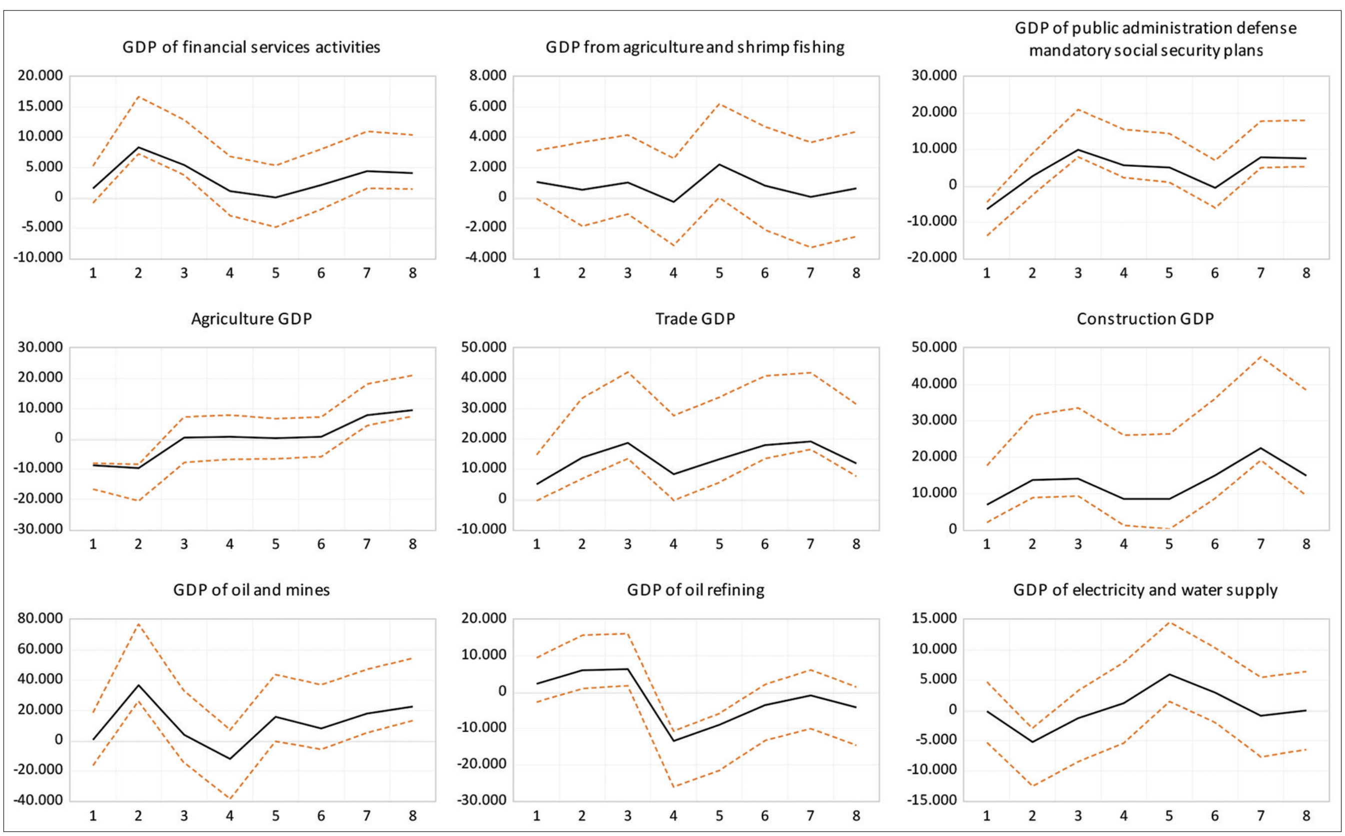


Figure 5: Response of Gross Domestic Product by Sector to Widespread Innovations in the International Price of Oil. Note: Innovations of a standard deviation of 90% CI are used using Hall's percentile bootstrap with 1500 repetitions



increase in the price of oil and economic activity in this sector. This phenomenon can be explained by the theory of "Effective Wealth", which suggests that an increase in oil prices can increase the wealth of oil-producing countries, stimulating investment and financial transactions (Hamilton, 1983). In addition, the literature highlights the influence of oil revenues on the financial system and investment, supporting the idea that changes in the price of oil can affect financial activity (Kilian and Park, 2009; Tala and Hlongwane, 2023; Sharma and Dahiya, 2023; Neifar and Kammoun, 2022).

The lack of statistical significance and the proximity to zero in the GDP response of Shrimp Agriculture and Fisheries suggest that these sectors are not strongly influenced by variations in the price of oil.

With regard to GDP from Public Administration, Defense, and Social Security, the positive and significant response after the third period suggests that the increase in oil revenues may have boosted government investments in these areas. This finding supports the literature highlighting how oil-dependent countries can use revenues to fund government programs and infrastructure projects (Ross, 2015). However, it is also important to take into account the challenges associated with oil revenue management, such as "Dutch disease" and fiscal volatility (Isham et al., 2003).

Agricultural GDP shows a significant and negative initial response that is followed by an equally significant recovery that may reflect the sensitivity of agriculture to sharp changes in oil prices. This pattern aligns with research such as that of Wang et al. (2014), which suggests that agricultural production costs may be temporarily impacted by variations in oil prices. In turn, the subsequent positive response may indicate a successful adaptation of the agricultural sector to changing market conditions.

The positive and significant GDP response of trade activities in all periods supports the idea that trade benefits from increases in the price of oil. This result is consistent with the literature, such as the study by Barsky and Kilian (2002), which notes that periods of high oil prices can boost economic growth and business activity. The additional revenues generated by the oil sector can translate into an increase in overall economic activity. Trade, being a critical sector in the supply and distribution chain, tends to benefit from a more dynamic economic environment. Increased oil revenues are often associated with government-funded infrastructure and development projects.

On the other hand, the positive and significant response of Construction GDP in all periods suggests a robust relationship between oil prices and construction activity in Ecuador. This aligns with research such as that of Cologni and Manera (2008), which highlights the importance of oil revenues in the financing of infrastructure projects. Construction, relying heavily on investments, can benefit from additional resources generated by high oil prices.

The positive and significant response of the GDP of Petroleum and Mines in the first and last periods reveals the close link between Ecuador's oil and mining sector and fluctuations in the price of oil at the international level. This phenomenon aligns with the economic theory and empirical experience of countries that rely heavily on oil revenues. According to Hamilton (1983), there is an intrinsic relationship between the economic activity of oil-exporting countries and changes in crude oil prices. The positive response could be associated with an increase in revenues and economic activity driven by favorable oil prices. In this context, Ecuador could experience an economic expansion, reflected in an increase in production and investment in the oil and mining sector. This initial dynamic can be interpreted as a response to the economic opportunities generated by rising oil prices, which in turn has a positive impact on the GDP of this sector.

With respect to Petroleum Refining GDP, the initial positive response followed by a strong negative response could reflect an initial phase of profit due to favorable refining margins, followed by challenges related to the volatility of these margins and global competition. Economic literature, such as Kilian's (2009) work on oil economics, highlights the complexity and risks associated with oil refining in a context of fluctuating prices.

Finally, the negative influence of oil prices on the GDP of Electricity and Water Supply in the first periods followed by a positive response afterwards could indicate an adaptation of the electricity and water supply sector to changes in the price of oil. This could be related to investments in alternative energy sources and energy efficiency measures, as suggested by the literature on diversification of the energy matrix (Apergis and Payne, 2014; Farooki and Kaplinsky, 2014).

In summary, the exhaustive analysis of the relationship between the international price of oil and energy production, as well as the economic effects on various sectors in Ecuador, reveals a complex and heterogeneous interaction. While renewables such as wind, solar and thermal exhibit positive sensitivities to rising oil prices, hydropower shows a negative response. On the other hand, economic sectors, such as financial services, public administration and trade, show different reactions to variations in the price of oil. These results underscore the need for adaptive political and economic strategies, promoting energy and economic diversification. Volatility in the price of oil highlights the importance of fostering a transition to sustainable sources and resilient strategies, reducing vulnerability to fluctuations in international fossil fuel markets.

5. CONCLUDING REMARKS

This paper has investigated the causal relationship between electric power consumption, GDP, trade openness, financial development, and industry using a Vector Error Correction Model (VECM) for five Sub-Saharan countries over the period 1971 to 2011.

This paper presents a rigorous analysis of the impact that the international price of oil exerted on different economic sectors and on the production of energy by source in Ecuador. This study is based on a sound empirical approach and presents a rigorous methodology. A comprehensive collection of relevant data related

Table 5: A proposal of empirical future research agenda

No.	Method	Dependent variables	Independent variables	Research proposal
1	Logistic Regression	Adoption of renewable energy	Government Policies, Oil Price	Assess how government policies and variations in the price of oil influence the adoption of renewable energy sources.
2	Network Analysis	Interconnection between economic sectors	Oil production, international oil price	Analyze the network of interconnection between different economic sectors and how oil production and price affect these interactions.
3	Survival Analysis	Time to Adoption of Energy Technologies	Economic factors, oil price	Assess the time it takes for different sectors to adopt energy technologies based on economic factors and the price of oil.

to the gross domestic product of various sectors and the energy produced by energy source was carried out in the specific context of Ecuador. Subsequently, these data were subjected to a thorough statistical analysis, allowing an accurate assessment of the complex and dynamic relationships that exist between the international price of oil and the dependent variables of greatest interest, particularly with regard to economic output, crude oil production and energy development from different sources. The significant contribution of this study lies in its ability to provide valuable and evidence-based information, offering a more complete understanding of how the price of oil can heterogeneously impact different sectors and energy sources, which can be useful for both policymaking and future research in this field.

This work generated evidence that the Ecuadorian economy has been highly influenced by fluctuations in the international price of oil, which has affected various sectors. Variations in prices have a direct impact on the Gross Domestic Product (GDP) and on different sectors, highlighting the need for diversification strategies. The effect of the price of oil varies among Ecuador's economic sectors. Some sectors, such as financial services and construction, show positive responses, while others, such as agriculture and fisheries, appear less affected. The oil and mining sector in Ecuador is strongly linked to variations in the price of oil. The positive and significant response of the GDP of Petroleum and Mines underscores the sensitivity of this sector to changes in international prices.

Energy production in Ecuador exhibits heterogeneous responses to variations in the price of oil. Forms of energy such as wind, solar and thermal show positive and significant responses, while hydropower presents a negative response in some periods. Positive responses in forms of energy such as wind, solar, and thermal may indicate that the increase in the price of oil positively influences investment decisions in these energy sources. This could be related to policies to diversify the energy matrix. The fact that renewables, such as wind and solar, respond positively to rising oil prices highlights their potential as viable and sustainable alternatives. This suggests that investing in these energy sources could be strategic in reducing dependence on fossil fuels.

The evidence highlights the need to implement policies that promote economic diversification in Ecuador. The country's economy would benefit significantly by reducing its historical dependence on oil and exploring sustainable and resilient economic alternatives. The research underlines that both economic activity and energy production in Ecuador are strongly influenced by variations in the price of oil, with heterogeneous responses varying across economic sectors and energy sources. Against this backdrop, strategic investment in renewable energy emerges as a potential solution to mitigate the volatility associated with the oil market, while contributing to the sustainability and resilience of the Ecuadorian economy.

One of the difficulties of this study was working with variables that are strongly prone to endogeneity. To address this limitation, we use dynamic OLS and VAR models, however, a more careful treatment of this possibility requires higher levels of freedom. In addition, this work was limited by the use of proxies for key variables, by the little information available and the time it takes to capture some data, however, in a few years Ecuador's databases should offer a greater number of observations, higher data quality and allow for more extensive studies.

This study significantly highlights the importance of energy and economic diversification, not only as a means to boost job creation, but also to reduce vulnerability to accelerating fluctuations in the price of oil. At the same time, however, it highlights the imperative need for a more comprehensive and long-term analysis. This more in-depth analysis must carefully address international dynamics, considering factors such as the trade openness of other countries, the time to adopt alternative technologies to oil, the interconnection between economic sectors, and international geopolitics. It is therefore clear that continued research and a comprehensive approach are required to fully exploit the potential of the data available in this area of research. Table 5 contains some recommendations for possible studies that can contribute to this line of research and use this work as a theoretical basis.

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