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# Oil Price and Brazilian Economic Indicators

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## Abstract

The oil price variations affect the economy of all countries. In 2006, Brazil discovered important oil reserves in the so-called pre-salt and became an important producer. Consequently, it became more affected by fluctuations in the price of this commodity. The impact of changes in oil price on a country's economy can be assessed by looking at its relationship with the economic indicators. The objective of the study was to identify patterns and relationships between the oil price and the following Brazilian economic indicators: Gross Domestic Product (GDP), Trade Balance, Inflation, Tax Collection, and Unemployment Rate. After collecting quarterly data for the last 20 years, between 2000 and 2019, it was applied the statistical tests of Cross-Correlation, Granger Causality, and Cointegration. The cross-correlation test showed that increases in the oil price are moderately associated with increases in GDP and Tax Collection. Oil prices and Inflation showed a weak negative correlation, not showing association. The correlation between oil prices and unemployment was negative moderate, indicating that the increases in oil prices are associated with the fall in employment. Finally, the correlation between oil prices and the Trade Balance varied from negative to positive. Evidence of Granger's causality was found only between the oil price series causing GDP. And it was not found cointegration in any series, which indicates non-existent long-term relationships. The identification of patterns and relationships between oil prices and economic indicators contributes to the adoption of more efficient strategies by the economics agents and, also, to the development of models capable of predicting, interpreting, and testing hypotheses about the variables.

**Keywords:** Oil price • Brazilian economic indicators • Cross-correlation • Granger causality test • Cointegration test

## Introduction

Petroleum is an important commodity for many countries. Variations in its price affect both producing countries and those that need to import this product. One way to assess this impact is to observe the effects of these variations on economic indicators [1]. Economic indicators show the economic situation of a country and serve as a reference for the government to define their public policies, and for investors and entrepreneurs to identify the best opportunities.

In 2006, Brazil discovered large offshore reserves and became an oil producer and exporter [2]. The objective of the work is to identify existing patterns and relationships between the oil price and the following economic Brazilian indicators: Gross Domestic Product (GDP), Trade Balance, Inflation, Tax Collection and Unemployment Rate.

However, seeking patterns and relationships through graphic representation can be subjective. The most accurate way to measure the type and strength of the relationship between two variables is through statistical tests. The following tests will be performed: Cross-Correlation, Granger Causality, and Cointegration. The Cross-Correlation test indicates whether the variables are related. Granger causality, if past data from one variable contributes to improving the prediction of the other variable. And finally, Cointegration, if there is a long-term relationship between them.

## Oil Price

Oil is a commodity, and its price is determined, above all, by worldwide supply and demand. Increases in supply cause a price reduction, while a decrease in supply increases its value. Other factors affect the supply and demand for oil and, consequently, its price. Among them, global crises, the new reserves discovery, the emergence of alternative energy sources, and geopolitical tensions. Global crises, such as that caused by the coronavirus, for example, tend to decrease the countries' economic activity and reduce the oil demand. The discovery of new reserves, on the other hand, contributes to expanding the oil supply in the market (Figure 1) [3].

It is possible to observe, for example, that the price dropped because of the 2008/09 world crisis and by the production of oil shale in the USA in 2014 [4]. The main producers' countries are Russia, followed by Saudi Arabia, the United States, China, and Brazil. Saudi Arabia participates, together with other producer countries, in the Organization of Petroleum Exporting Countries (OPEC) that has a strong influence on the oil price through the control of the quantity offered. These countries produce more than 30% of world production and hold more than 80% of global reserves. The largest importers are the European Union, China, the United States, India, and Japan. Brazil discovered big offshore reserves and, since 2010, it has occupied an important position in the market (International Energy Agency [5].

## Economic Indicators

### Gross Domestic Product (GDP)

The Gross Domestic Product (GDP) measures the wealth generated by a country and it is composed of the sum of all final goods and services produced in a given period [6]. It is an important indicator as it allows comparing the economies of different countries and, following its behavior over time, analyzing the performance of a country.

In Brazil, GDP is calculated by the Brazilian Institute of Geography and Statistics (IBGE). Figure 2 shows the quarterly change in GDP (in real terms, considering the fourth quarter of 2019 as the basis) from 2000 to 2019. Between 2000 and 2008 the average annual growth was 4%. And even in 2008, already in the international financial crisis, the economy performed well. In the last ten years, however, Brazil has been facing recession or low growth rates in its economy Instituto Brasileiro de Geografia e Estatística (IBGE) (Figure 2).

It shows GDP in real terms (R$ Million) and oil price. In 2005, Brazil started to export oil and, thus, it was benefited from the high prices reached by the commodity in the following years: in fact, the gains financed the high investments necessary to produce oil in the pre-salt layer. The GDP series shows seasonality without tendency (Figure 3).

### Trade balance

The Trade Balance (TB) shows the difference between the value of imports and exports of goods and services made by a country. When exports are greater than imports, the trade balance has a surplus and, when smaller, a deficit [6].

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In Brazil, Trade Balance data are released monthly by the Ministério do Desenvolvimento, Indústria e Comércio Exterior (MDIC) and it has been showing positive results over the years. Between 2018 and 2019, oil exports contributed approximately 10% of the Trade Balance. It compares the behavior of the Trade Balance with the price of oil from 2000 to 2019 (Figure 4) [7].

The series seems to show an inverse relationship between the oil price and the trade balance when the oil price increases, the Trade Balance decreases. Until 2010, Brazil was an oil importer, which can explain the behavior of the series. From there, it became an oil exporter and, therefore, benefiting from the increases in oil price. In 2019 occurred a decline in the trade balance despite the price remaining at an average of US$ 55/barrel.

## Inflation

Inflation is the generalized and continuous prices increase, causing a reduction in the real value of the country's currency and in the purchasing power of the population. In Brazil, there are several indicators for calculating inflation. One of the most widely used is the Extended National Consumer Price Index (IPCA) calculated by IBGE (2020). To calculate the IPCA, IBGE considers the prices of a basket of goods and services for personal consumption of households, including health, education, food, housing, transportation, etc. A survey of the prices of these products is carried out in different regions and the national average is calculated by comparing their variation (Figure 5) [8].

The inflation series shows stable behavior with no trend. The relationship between the annual inflation rate and the oil price is not clear. In 2006 and 2007, for example, inflation remained at low levels despite the growth observed in the barrel price. There are periods with rising inflation rates despite the drop in the price of a barrel.

## Tax collection

The tax collection is the amount collected from taxes. It is paid for by society and it is the main source of government collection. The Secretaria da Receita Federal (RFB) is responsible for collecting the data. Brazil has a high tax burden, equivalent to 35% of GDP, but it is among the worst welfare rates of return to society Secretaria da Receita Federal (SRF) [9].

In the oil sector, in addition to the traditional taxes, are collected royalties on total production. It compares the behavior of tax collection and the oil price from 2000 to 2019. Tax collection has been significantly growing year after year, even when the price of oil is falling. Therefore, it is not possible to state that there is an association between the two variables (Figure 6).

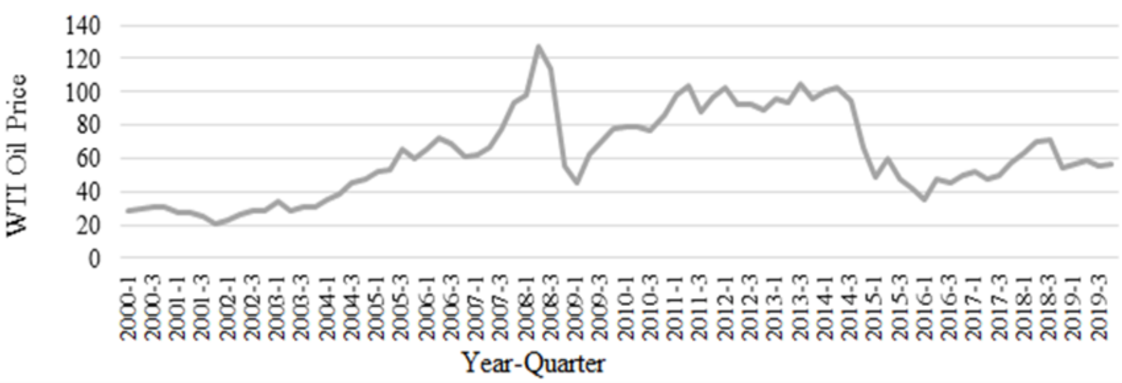


**Figure 1.** Shows the behavior of oil prices (in US$/WTI barrel) from 2000 to 2019.

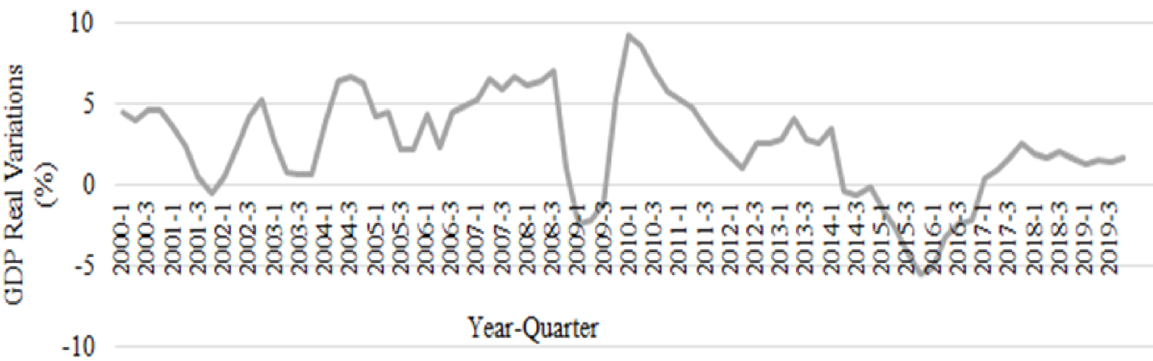


**Figure 2.** GDP real variations.

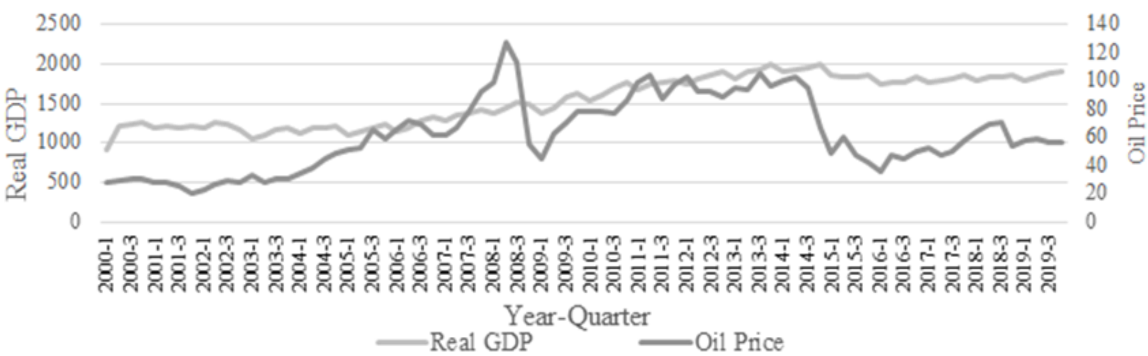


**Figure 3.** GDP (R$ Billion) vs. oil price (US$/barrel WTI).

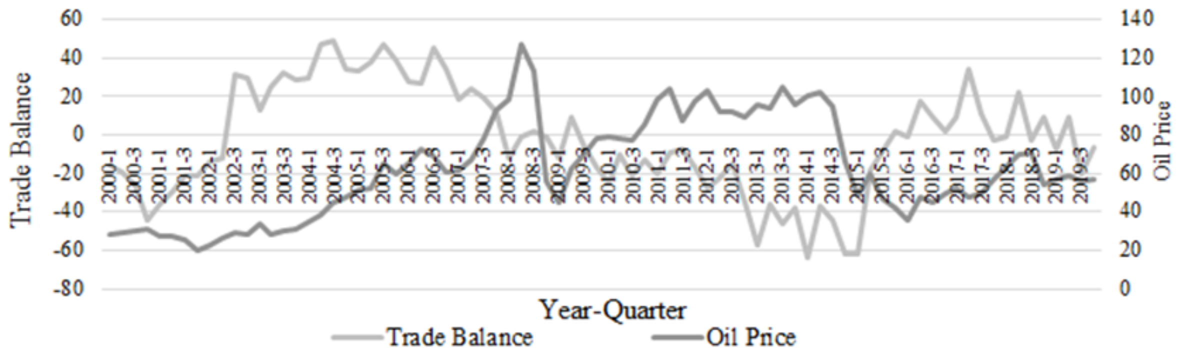


**Figure 4.** Trade balance (R$ Billion) vs. Oil price (US$/barrel WTI).

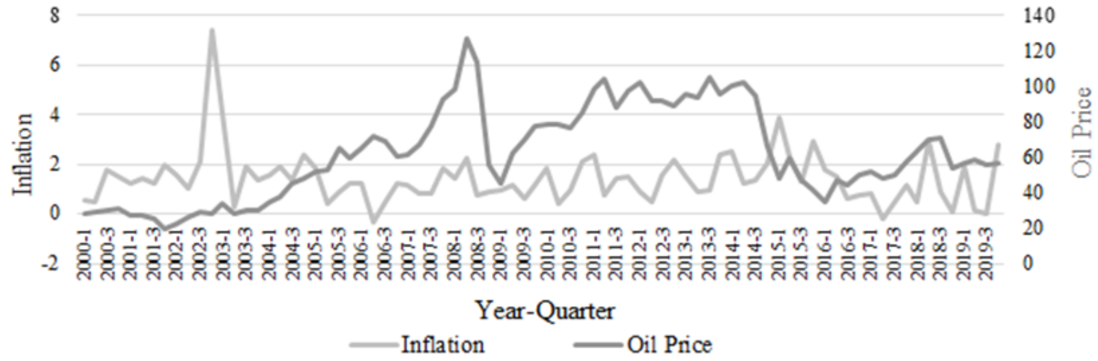


**Figure 5.** Compares the behavior of Brazilian inflation and oil prices from 2000 to 2019.

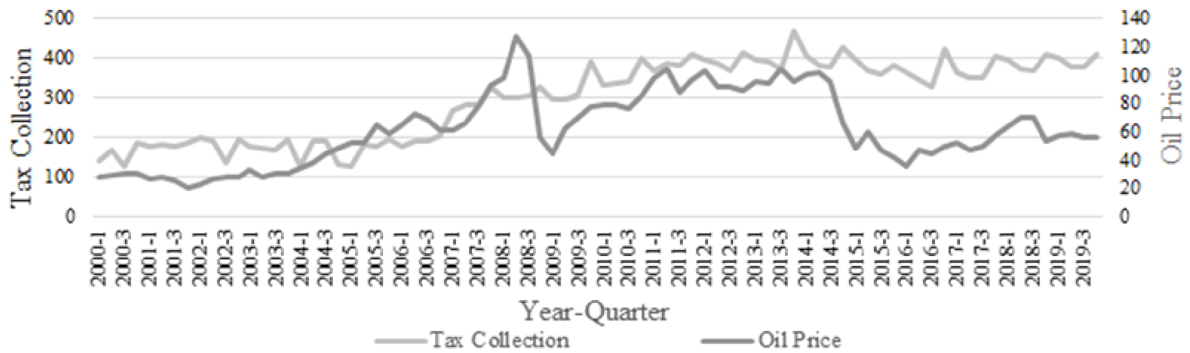


**Figure 6.** Tax Collection (R$ Billion) vs. Oil price (US$/barrel).

### Unemployment rate

The Unemployment Rate indicates the percentage of the economically active population that is looking for work but do not find it. Thus, university students, entrepreneurs, housewives, etc. are not considered unemployed. IBGE is responsible for surveying these numbers in Brazil. It compares the behavior of the unemployment rate and the oil price from 2000 to 2019 (Figure 7).

The Unemployment Rate has fluctuated considerably over the years although showing a downward trend: from 12% in 2003 to 4% in 2014. However, since then, it has been growing and, at the end of 2019, it was over 10%.

Previous studies have shown the existence of a positive relationship between the price of oil and the unemployment rate in importing countries, and a negative in exporters. An increase in the price of oil causes an increase in the price of various inputs, reducing the profit margin and, eventually, the number of jobs generated [10,11].

It shows the consolidated data of the annual averages of the oil real price and economic indicators. Next, the statistical tests used in the work will be described (Table 1).

## Time Series and Statistical Tests

Many statistical tests for estimating, predicting, and inferring time series require, being valid, that the series be stationary. A series is stationary when its mean and variance are finite and constant and the covariance between two periods is a function of the size of the gap and not of the time.

But time series are rarely stationary. Thus, to apply the tests, it is necessary to transform the series into stationary ones. This can be done through the first difference or, when necessary, considering a longer time lag [12].

Granger and Cointegration tests are valid only for stationary series. To check if the series is stationary, the Dickey-Fuller (DF) test was used and, when necessary, differences will be made until stationarity was obtained.

### Cross-correlation test

The Cross-Correlation test is a measure of association (force and direction) that allows comparing and identifying the existence of a relationship between two-time series in a different time. A variable can be related to values passed from the other series, so it is necessary to calculate the correlation with different time lags.

The cross-correlation coefficient is given by equation (1):

$$r_{xy}(\tau) = \frac{\sum_{t=1}^{n-|\tau|} x_t \, y_{t+\tau}}{\sqrt{\sum_{t=1}^{n} x_t^2 \; \sum_{t=1}^{n} y_t^2}} \quad (1)$$

Where $x_t$ and $y_t$ are the variables analysed in t time and τ is the lag time considered. The correlation coefficient r varies from -1 to 1. A greater correlation in absolute terms indicates a stronger association. If r=-1 the correlation is perfect negative, if r=1 is perfect positive, and finally, there is no correlation if close to zero. We can also calculate the coefficient of determination ($r^2$) which indicates how much of the y variation can be explained by the x variations.

To apply the test is necessary to:

1. Calculate the correlation between the series using different time lags,

2. Identify the time lag that has the highest correlation in absolute terms.

## Dickey-Fuller test (DF)

The Dickey-Fuller (DF) test states as a null hypothesis that the series is non-stationary, that is, with a unit root. Thus, for the series to be stationary, the null hypothesis must be rejected.

To apply the test is necessary to:

1. Estimate equation 2 using the least-squares method.

$$\Delta Y_t = \delta Y_{t-1} + u_t \quad (2)$$

2. Divide the estimated coefficients of the Y (t-1) by the standard error to find the tau (T) and compare it with the critical tau of the Dickey-Fuller table.

3. If the absolute value of the statistic T exceeds the critical value, do not reject the null hypothesis and the series is non-stationary. Otherwise, if T is less than the critical value, the series is stationary.

## Causality Granger's test

The test states that x is Granger's cause of the y if $x_{t-j}$ (x past value) improves the prediction of $y_t$ values. The test is performed in both directions, that is, x causing y e y causing x.

In mathematical terms, the test estimates the regressions of equations (3) and (4) that indicate that x (or y) values are related to x and y past values plus an error.

$$X_t = \sum_{j=1}^{m} a_j X_{t-j} + \sum_{j=1}^{m} b_j Y_{t-j} + u_{1t} \quad (3)$$

$$Y_t = \sum_{j=1}^{m} c_j X_{t-j} + \sum_{j=1}^{m} d_j Y_{t-j} + u_{2t} \quad (4)$$

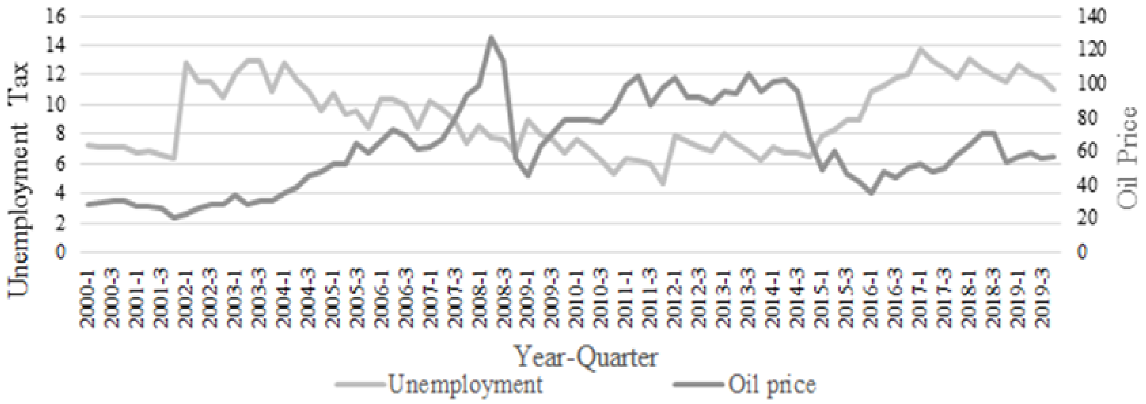


**Figure 7.** Unemployment tax (%) vs. oil price (US$/barrel WTI).

**Table 1.** Annual average in real terms, time series and statistical tests.

| Year | Oil price | GDP | Tax collection | Trade balance | Unemp tax | Inflat |
|---|---|---|---|---|---|---|
| | US$/ barrel | R$ Billion | R$ Billion | R$ Million | % | % |
| 2000 | 29.74 | 2556.1 | 85.8 | 618.5 | 7.1 | 6 |
| 2001 | 25.23 | 1969.1 | 95.0 | 2537.6 | 6.4 | 7.7 |
| 2002 | 26.56 | 1477.5 | 101.8 | 4919.5 | 10.5 | 12.5 |
| 2003 | 30.83 | 1446.0 | 116.6 | 5495.7 | 12.3 | 9.3 |
| 2004 | 41.59 | 1546.1 | 110.9 | 5839.0 | 11.5 | 7.6 |
| 2005 | 57.28 | 1881.3 | 127.7 | 8786.9 | 9.8 | 5.7 |
| 2006 | 66.96 | 2260.3 | 139.1 | 14064.4 | 9.6 | 3.1 |
| 2007 | 74.94 | 2738.1 | 137.4 | 17454.0 | 9.3 | 4.5 |
| 2008 | 98.58 | 3120.6 | 143.3 | 25176.4 | 7.9 | 5.9 |
| 2009 | 63.92 | 2950.6 | 77.9 | 16585.6 | 8.1 | 4.3 |
| 2010 | 79.98 | 3711.1 | 76.6 | 27372.6 | 7 | 5.9 |
| 2011 | 97 | 4054.8 | 74.2 | 33767.4 | 6 | 6.5 |
| 2012 | 94.25 | 3672.9 | 66.2 | 30255.8 | 5.5 | 5.8 |
| 2013 | 97.6 | 3486.9 | 65.7 | 18268.8 | 5.7 | 5.9 |
| 2014 | 91.22 | 3241.9 | 64.8 | 21590.8 | 4.3 | 6.4 |
| 2015 | 49.3 | 2162.4 | 73.3 | 14137.6 | 6.4 | 10.7 |
| 2016 | 44.46 | 2011.5 | 64.7 | 11282.7 | 11.8 | 6.3 |
| 2017 | 51.86 | 2238.9 | 74.2 | 18121.3 | 12.8 | 3 |
| 2018 | 64.54 | 1943.8 | 93.2 | 26100.7 | 11.6 | 3.8 |
| 2019 | 57.09 | 1825.0 | 83.3 | 24002.3 | 11.8 | 4.3 |

The test considers as a null hypothesis that there is no causality, indicating that x does not contribute to the prediction of the values of y and y does not contribute to predicting x.

After estimating regressions, four situations can occur: lagged values of y improve the forecast of x, lagged values of x improve the forecast of y, both x and y contributes to the forecasts and, finally, there is no causality, and the variables are independent [13].

### Engle-Granger cointegration

The Engle-Granger test is used to identify a long-term relationship between time series. It assumes that non-stationary time series can, in the long run, maintain an equilibrium relationship. In this case, the series are co-integrated. The test states as a null hypothesis that the series are not co-integrated.

To apply the test is necessary to:

- Apply the Dickey-Fuller test to check the series stationarity. If the null hypothesis is not rejected, you can conclude that the series are non-stationary and proceed with the test.
- Identify the regression function between the two series:

$$Z_t = X_t + \beta X_t + \varepsilon_t \quad (5)$$

$$\varepsilon_t = \Upsilon t + \alpha \mu \quad (6)$$

- Where $\beta$ is the cointegration parameter, $\alpha$ is the intercept parameter and $\Upsilon$ is the trend parameter.
- Apply the Dickey-Fuller test again to verify that the residues are stationary.
- If you reject the null hypothesis, you can conclude that the residuals are stationary and, therefore, the series are cointegrated.

## Methodology

Initially, was collected quarterly data-from 2000 to 2019-from the following variables: WTI oil price, GDP, Trade Balance, Unemployment Rate, Tax Collection, and Inflation? The oil price was collected on the Macro-trends website and, the economic indicators, in their official sources: GDP, Unemployment Rate and Inflation on the IBGE, Tax collection on the Federal Revenue and Trade Balance at the Central Bank. The data were organized, deflated, and summarized in the graphs presented above. It shows the stages developed in the work (Figure 8).

The free software Real Statistics, an add-in that extends Excel's statistics capabilities, was used to perform the tests. It was considered time lags between 0 to 10 and a significance level ($\alpha$) of 5%. It was applied:

- Cross-correlation test to verify the existence of an association between variables. In this work, Mukaka (2012) criteria will be adopted to indicate the strength and direction of the correlation (Table 2).
- Dickey-Fuller test to verify that the series is stationary. If not, make differences until stationarity is achieved.
- Granger causality test carried out in both directions, that is, variations in the oil price are Granger cause of economic indicators and economic indicators are Granger cause of oil prices variations.
- Cointegration test to verify the long-term relationship between variables.

## Results and Discussion

### Cross-correlation

The correlation measures the association (strength and direction) between two variables. It summarizes the results of the cross-correlation between

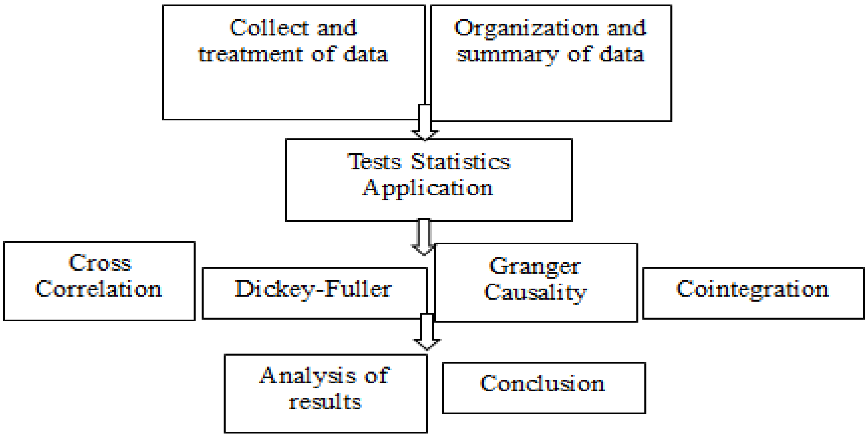


**Figure 8.** Work stages.

**Table 2**. Correlation criteria source: Mukaka (2012).

| r range | Correlation type |
|---|---|
| -1 a -0.9 | Very strong negative correlation |
| -0.89 a -0.7 | Strong negative correlation |
| -0.69 a -0.4 | Moderate negative correlation |
| -0.39 a -0.2 | Weak negative correlation |
| -0.19 a -0.01 | Very weak negative correlation |
| 0 | Without correlation |
| 0.01 a 0.19 | Very weak positive correlation |
| 0.2 a 0.39 | Weak positive correlation |
| 0.4 a 0.69 | Moderate positive correlation |
| 0.7 a 0.89 | Strong positive correlation |
| 0.9 a 1 | Very strong positive correlation |

oil prices and the economic indicators and highlights the highest module correlation [14].

The correlation between oil price and GDP is moderately positive for lags 0 to 3, with a maximum value of 0 (0.54), weak positive for 4 to 7, and very weak positive for the others. The coefficient of determination ($r^2$) indicates that 29% of the GDP variation can be explained by the oil price variation (Table 3).

The correlation between oil prices and Trade Balance is weak: it is weak negative for 0 and 1, very weak between 2 and 6, and weak positive for lags above 7. The changing from negative to positive indicates a break structural. Structural breaks are changes in the dispersion and/or slope of the series. These changes can be abrupt or gradual and, in general, result from external shocks or changes in the country's economic policies.

In the case of Tax Collection, the correlation is moderate positive at lag 0 (0.61). Increases in the oil price are positively associated with increases in tax collection. The coefficient of determination shows that 37% of the variations in revenues can be explained by variations in oil prices [15].

Oil prices and inflation are negatively associated, and the correlation ranged from very weak to weak. The highest correlation in absolute terms occurred in lag 4 (0.27) and its determination coefficient shows that 7% of the inflation variation can be explained by the oil price change. Finally, as for the unemployment rate, the correlation reaches its highest value (-0.47) at lag 0 and is considered moderate. The coefficient of determination indicates that 22% of the variation in the unemployment rate can be explained by the variation in oil prices.

## Dickey-Fuller (DF) test

The Dickey-Fuller (DF) test indicates whether the series is stationary or not. As already mentioned, time-series rarely have stationary behavior, which can be solved by calculating the first difference or even greater lags if necessary. It summarizes the results obtained with the real values and with the first difference, considering a critical T equal to -2.89 (significance 5%). Except for inflation, which was already stationary, the other series could be transformed by calculating the first difference. Thus, it is possible to proceed with the tests (Table 4).

Except for inflation, which was already stationary, the other series could be transformed by calculating the first difference. Thus, it is possible to proceed with the tests.

## Granger's causality test

The oil price is Granger cause if it improves the estimates of economic indicators and vice versa. The p-value must be less than 5% to reject the null hypothesis and thus conclude that there is causality. The test was done for 10 lags and summarizes the result (Table 5).

The only relationship observed was the oil price causing GDP for lags 1, 2, 3, and 4. Thus, GDP estimates improve when considering the price of oil in previous periods.

## Cointegration test

The cointegration test indicates whether there is a long-term relationship between the variables. The stationarity of the series has been verified previously of all the series studied, the only one that showed a stationary behavior before the first difference was inflation. Then the ADF test was applied to the residues to check if they were stationary. The statistical value must be less than the critical value of -3.41 to reject the null hypothesis and conclude that the series are cointegrated. The table summarizes the main results. It shows that the null hypothesis was not rejected and, therefore, there is no cointegration between oil prices and any of the indicators studied (Table 6).

**Table 3.** Cross-correlation test, oil price vs. economic indicators.

| Lags | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GDP | 0.54 | 0.49 | 0.45 | 0.41 | 0.35 | 0.29 | 0.25 | 0.2 | 0.13 | 0.07 | 0.03 |
| Trade balance | -0.31 | -0.26 | -0.18 | -0.06 | 0.03 | 0.07 | 0.13 | 0.23 | 0.28 | 0.28 | 0.33 |
| Tax | 0.61 | 0.59 | 0.56 | 0.51 | 0.45 | 0.4 | 0.35 | 0.29 | 0.24 | 0.22 | 0.18 |
| Inflation | -0.1 | -0.07 | -0.15 | -0.22 | -0.27 | 0.24 | -0.21 | -0.21 | -0.23 | -0.22 | -0.11 |
| Unempl | -0.47 | -0.43 | -0.39 | -0.34 | -0.26 | -0.22 | -0.2 | -0.18 | -0.12 | -0.08 | -0.1 |

**Table 4.** DF test for stationarity.

| Critical-T: -2.89 | Real value | | First difference | |
|---|---|---|---|---|
| | T-Stat | Results | T-Stat | Results |
| Oil price | -2.08 | No | -7.34 | Yes |
| GDP | -1.73 | No | -11.5 | Yes |
| Trade balance | -2.439 | No | -11.167 | Yes |
| Tax collection | -1.805 | No | -13.346 | Yes |
| Inflation | -6.466 | Yes | -10.647 | Yes |
| Unemployment | -2.415 | No | -11.748 | Yes |

**Table 5.** Grangers causality test.

| | GDP | TB | Tax | Inflation | Unemployment |
|---|---|---|---|---|---|
| Oil price causes indicators | Yes | No | No | No | No |
| Indicators cause oil price | No | No | No | No | No |

**Table 6.** Cointegration test.

| Tau-critical -3.41 | Oil price vs. GDP | Oil price vs. TB | Oil price vs. Tax | Oil price vs. Inflation | Oil price vs. Unemployment |
|---|---|---|---|---|---|
| Tau-statistic | -1.45 | -2.08 | -1.47 | -1.8 | -2.62 |
| Cointegração | No | No | No | No | No |

## Conclusion and Policies Indication

The objective of the work was to identify patterns and relationships, through statistical tests, between the oil price and some important economic indicators. Cross-correlation, Dickey-Fuller, Granger causality, and cointegration tests were applied.

The identification of patterns and relationships between oil prices and economic indicators contributes to the adoption of more efficient strategies by the economics agents and, also, to the development of models capable of predicting, interpreting, and testing hypotheses about the variables. This because patterns and relationships indicate the variables that contribute to an estimate of the differential equations used for predictions.

The cross-correlation test showed that increases in the oil price are moderately associated with increases in GDP and Tax Collection. Oil prices and Inflation showed a weak negative correlation. The correlation between oil prices and unemployment was negative moderate, indicating that the increases in oil prices are associated with the fall in employment. Finally, the correlation between oil prices and the Trade Balance was from negative to positive, indicating a break structural.

Structural breaks are changes in the dispersion and/or slope of the series. These changes can be abrupt or gradual and, in general, result from external shocks or changes in the country's economic policies. The occurrence of structural breaks in the period used as a sample can skew the results and, consequently, the analysis. Thus, it is important to better understand its real causes and impacts.

The Granger's test indicated that there was causality only between the oil price and GDP and it was negative for all other indicators. In other words, considering past oil price values improves the GDP forecast, but does not contribute to the forecast of the other indicators. In the other sense, the indicators do not contribute to the forecast for oil prices. Finally, the cointegration test showed that there was no long-term relationship between oil prices and economic indicators.

In conclusion, the main objective was achieved, but not with the results expected, especially when analyzing the inflation time series. A suggestion is to use bigger time series, 40-50 years long trying to find other patterns that may be not seen on the 20 years long.

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