

# An Investigative Analysis on Prediction of Crude Oil Price in the Philippines using Artificial Neural Network

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## Abstract

**Objective:** The Crude Oil industry plays a substantial role in the Philippine economy. The researchers intended to compare models of NARX Neural Network and Multiple Linear Regression through the forecast of the Crude Oil price in the Philippines ( $y$ ) and prediction of the values from October 2018 to December 2023. **Methods/Statistical Analysis:** The researchers observed the behaviour of the factors that impact the Crude Oil price in the Philippines ( $y$ ) and with the application of Multiple Linear Regression (MLR), concluded that among the factors, the substantial predictors are Inflation Rate ( $x_2$ ), Consumption of Crude Oil ( $x_5$ ), Import of Crude Oil ( $x_7$ ) and Export of Crude Oil ( $x_8$ ) while – Exchange rate ( $x_1$ ), Consumer price index ( $x_3$ ), Domestic interest rate ( $x_4$ ) and Production of Crude Oil ( $x_6$ ) are not. Also, NARX Neural Network was used to predict the Crude Oil prices in the Philippines from October 2018 to December 2023. **Findings:** Through using the NARX Neural Network, researchers were able to come up with the predicted Crude Oil prices in the Philippines and concluded that their behaviour fluctuates. **Improvement:** Novelty of work is NARX Neural Network which is the best-fitted model in predicting the Crude Oil price in the Philippines. Thus, predicted values are highly precise.

**Keywords:** Artificial Neural Network, Crude Oil Price in the Philippines, Forecasting Accuracy, Multiple Linear -Regression, NARX Neural Network

## 1 Introduction

Crude Oil is among the world's most vital energy resources, excluding fuel for energy and transport; it is conjointly used for varied functions even in households or industries. Crude Oil prices have affected the Philippine economy adversely in decades since then<sup>1</sup>. During the year 1993, the Philippines experienced severe scarcity inflicting the declination of the economy. This created a colossal result within the crude industry of the Philippines. Despite this, in 1993, the Philippine National Oil Company (PNOC), which was established on November 09, 1973 through

Presidential Decree No. 334, entered into the venture of petrochemicals. Its intention is to run and preserve steady supply of oil within the country<sup>2</sup>. PNOC set up the country's first petrochemical industrialized manor in Limay, Bataan.

One of the subsidiaries of PNOC is the PNOC Exploration Corporation (PNOC EC). It was incorporated on April 20, 1976 that is mandated by the government to entail the lead within the probe, development, and fabrication of the country's oil, gas and coal resources through the support of the Department of Energy (DOE)<sup>3</sup>.

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The PNOEC was converted to the 3 MW San Antonio Gas Power Plants in 1994. The San Antonio Gas Power Plant was located in the municipality of Echague, Isabela. It started its production in 1994 and was able to produce 3.54 BCF of gas until it was decommissioned in 2008<sup>7</sup>.

The government then created the Downstream Oil Industry Deregulation Act of 1998 which states that the government is not permitted to interfere with the pricing, importation, and exportation of oil products.

Even the institution of gas stations, storage, depots, ocean-receiving facilities and gas refineries is prohibited. This Act triggered extreme competition within the market that resulted to unstable pricing of Crude Oil products<sup>5</sup>.

In 2001, the Malampaya Gas Field commenced its operation. The field, since then, has been a stable source of supply of energy that meets thirty five to forty percent of Luzon's power necessities<sup>6</sup>. This project that uses progressive deep-water technology to draw natural gases from deep beneath Philippine waters is the first of its kind within the Philippines. The indigenous gas fuels three natural gas-fired power stations with a total generating capacity of 2,700 megawatts. This is considered the most common and thriving project of the PNOEC, having the ability to affix with the rank of other petroleum majors such as Shell Exploration and Texaco.

At present, there are already seven (7) petroleum Service Contracts in the Philippines that are owned by PNOEC. The SC 37 is located in Cagayan Basin. The others are located in Northwest Palawan, SC 75, in Calamian, SC 57, in West Calamian, SC 58, in West Balabac, SC 59, in Northwest Palawan, SC 74 and SC 63 which is located in East Sabina. SC 3 and SC 63 are being operated by PNOEC while it plays as a non-operating partner in SC 38, SC 57, SC 58 and SC 59<sup>3</sup>.

Another government controlled subsidiary of PNOEC is the PNOEC Renewables Corporation (PNOEC RC). It was organized and incorporated on March 7, 2008 that has an objective to become the prime vehicle of the government in stimulating, emerging and instigating renewable energy and energy potency agendas within the country. Renewable Energy plays a substantial part in the shift towards a low carbon economy. Hence, one of the company's intents is to advocate low carbon development methods that would remarkably sustain the Energy sector's goals of warranting adequate, steady, secure, accessible and reasonably-priced energy supply

and tailing cleaner and adept energy utilization and clean technologies implementation<sup>7</sup>.

## 2. Objective of the Study

This research intends to predict the monthly Crude Oil Price in the Philippines ( $y$ ) from October 2018 to December 2023. This also aims to discern the graphs of the independent variables: Exchange Rate ( $x_1$ ), Inflation Rate ( $x_2$ ), Consumer Price Index ( $x_3$ ), Interest Rate ( $x_4$ ), Crude Oil Consumption ( $x_5$ ), Crude Oil Production ( $x_6$ ), Crude Oil Import ( $x_7$ ) and Crude Oil Export ( $x_8$ ). Also, to distinguish which between Multiple Linear Regression (MLR) and Nonlinear Autoregressive Exogenous Neural Network is the best-fitted model in predicting the Crude Oil Price in the Philippines ( $y$ ).

## 3. Conceptual Framework

### 3.1 Statement of the Problem

The aim of this research is to answer the following questions:

- What is the behaviour of the graph of the Crude Oil Price in the Philippines ( $y$ ) and behaviour of the graphs of the independent variables?
  - Exchange Rate ( $x_1$ ).
  - Inflation Rate ( $x_2$ ).
  - Consumer Price Index ( $x_3$ ).
  - Interest Rate ( $x_4$ ).
  - Crude Oil Consumption ( $x_5$ ).
  - Crude Oil Production ( $x_6$ ).
  - Crude Oil Import ( $x_7$ ).
  - Crude Oil Export ( $x_8$ ).
- Is there a significant relationship among the Exchange Rate ( $x_1$ ), Inflation Rate ( $x_2$ ), Consumer Price Index ( $x_3$ ), Interest Rate ( $x_4$ ), Crude Oil Consumption ( $x_5$ ), Crude Oil Production ( $x_6$ ), Crude Oil Import ( $x_7$ ), Crude Oil Export ( $x_8$ ) and the Crude Oil Price in the Philippines ( $y$ )?
- What are the important predictors of Crude Oil Price in the Philippines ( $y$ )?

- What is the best-fitted model in predicting the Crude Oil price in the Philippines (y)?
- What is the predicted monthly Crude Oil Price in the Philippines (y) from October 2018 to December 2023?

## 4. Scope and Limitation

This study encompasses the monthly data of the Exchange Rate ( $x_1$ ), Inflation Rate ( $x_2$ ), Consumer Price Index ( $x_3$ ), Interest Rate ( $x_4$ ), Crude Oil Consumption ( $x_5$ ), Crude Oil Production ( $x_6$ ), Crude Oil Import ( $x_7$ ), Crude Oil Export ( $x_8$ ) and the Crude Oil Price in the Philippines (y) from January 1993 to October 2018. Furthermore, this research predicts the values of Crude Oil price in the Philippines (y) from October 2018 to December 2023.

## 5. Significance of the Study

One of the most substantial products in the international market is the crude oil. It plays a dominant role in the country's sustainability and economic stability. Crude Oil price is measured as an inclusive economic indicator that is why price fluctuations are observed systematically by the government, oil companies, speculators, hedgers, investors, dealers, and consumers. This study would serve as a guide to future consumers in distinguishing the Crude Oil prices and for them to ascertain what appropriate methods to take in handling the variations.

### 5.1 Review of Related Literature

In<sup>8,9</sup> used multiple linear regression to analyse arrays of exchange rate volatility and the estimated regression coefficients. He explored these variables and was able to display the impact of currencies of some of the advanced countries as nominal anchors for the exchange rates from the chosen markets and then broken down in three shorter sets of data.

In<sup>10</sup> acknowledged the variables that affect the oilfield's output's performance using multiple linear regression. The authors concluded that the percentage error of predicted value from the actual output is only 4.57% which shows that we can apply this method to forecast the oilfield output.

In<sup>11</sup> made an effort for the more precise prediction of the foreign exchange rate. He used the data of a shorter timeframe for the observation of Indian rupee

and USA dollar exchange rate having the World Bank indicator and few economic indicators. NARX was trained with exogenous variables of past years and NARX was determined as a very effective neural network in predicting the foreign exchange rate.

In<sup>12</sup> analysed the inflation rate in Sudan using econometric time series models. This study concluded that the models fulfilled all the economic theories, statistical and econometric criteria. Moreover, it fulfilled the conditions of the best regression model. The inflation rate model has 0.98 coefficient determination and this indicates superiority of the model.

In<sup>13</sup> using stepwise multiple regression, forecasted Malaysia's crude material imports. In this study, MLR recognized four models and the study proved that among the four models, model 1 or the Linear Model is the best. Furthermore, the findings revealed that only four controlled variables influence the value of imports. These variables predict price index of (CM), Gross Domestic Products (GDP) and the value of exports and the average sales tax of (CM).

Select a dynamic ANN as a nonlinear artificial model. This was chosen since traditional and statistical econometric models are inapt in forecasting Crude Oil prices. He examined the aptitude of the NARX method to make an accurate forecast. Furthermore, he concluded that ANN makes a great predictive ability for Crude Oil price forecasting.

In<sup>14</sup> scrutinized the efficiency of the NARX framework in volatility forecasting in the Nigerian Crude Oil market through a study conducted in 2016. They recommended two hybrid models such as NARX I and II. NARX I is used as inputs volatility estimates attained by the fitted GARCH model as well as other endogenous variables. On the other hand, NARX II takes simulated volatility series as extra inputs. As the initial step, a GARCH type model was acknowledged upon which the hybrid model is built. The outputs of the traditional GARCH models show that the EGARCH (3, 3) best fits the noise of the Crude Oil price. Hence, this was used for the construction of the hybrid models. It was proven that NARX II provides better volatility outperforming the two other models.

Also in<sup>15</sup> intended to predict movements in Forex market based on the NARX Neural Network using time-shifting bagging technique and financial indicators. These financial indicators include relative strength index and stochastic indicators. The study presented the advantage of considering NARX Neural Network and time shifting

bagging technique with some external indicators when predicting the Forex market movement.

In<sup>16</sup> used in their study four different approaches namely; GARCH (1,1), GARCH (2,2), EGARCH (1,1) and EGARCH (2,2). This study shows a comparative analysis of the ANN-based models and the econometric models. Moreover, it revealed that MLFFNN and NARX are better methods in terms of predictive efficiency.

A study published by<sup>17</sup> in 2017 presented that the weather, natural factor and national policy decisions will interminably diminish the crude oil's future price at a certain time, which will make the analysis model have a transient failure. The authors established that the analysis method and the analytical model of this study do not have the effect of short-term prediction.

In<sup>18</sup> used multiple linear regressions with two different approaches, considering original data and principal component as inputs, to forecast the next month Consumer Price Index. The findings revealed that the use of the principal component as input gives a more precise result than original data because it focused the number of inputs and therefore decreased the model complexity. Furthermore, the use of principal component-based models was considered more effective, due to eradication of collinearity problem and reduction of the number of predictor variables.

In<sup>19</sup> concluded that the neural network-based modelling gives better accuracy than regression. Their study also showed that ARIMA models and neural network was a clear winner in terms of generalization and the ability to follow changing trends in the out-of-sample forecast. It also demonstrates real potential in multivariate forecasting of Crude Oil prices.

In<sup>20</sup> deliberated new methodologies of NARX-based Forecasting Model. Their case study indicated that NARX neural networks have good potential in learning and understanding stock market developments.

In<sup>21</sup> studied about regression analysis of determinants influencing Crude Oil price, labelled a new model of the most substantial factors that affect Crude Oil prices by using a new method referred as principal component analysis (PCA)<sup>22</sup>. This study determined that the most significant factors that affect Crude Oil prices are the fundamentals and the role of the organization of petroleum exporting countries.

## 6. Methodology

### 6.1 Statistical Methods

#### 6.1.1 Pearson's Correlation Coefficient

Pearson R is a correlation statistic most generally used to measure the degree of association between continuous linearly connected variables<sup>23,24</sup>. To envision for linearity between two continuous variables, the preliminary stage is to draw a scatter plot of the variables. The coefficient of correlation should not be computed for if the relationship between variables is not linear. It does not matter on which axis the variables are plotted in correlation functions. However, conservatively, the independent variables, also called the explanatory variables, are plotted on the x-axis (horizontally). On the other hand, on the y-axis (vertically) lie the dependent variables or response variables.

The Pearson r is given by:

$$r = \frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{[N \sum x^2 - (\sum x)^2][N \sum y^2 - (\sum y)^2]}}$$

Where

$N$  = number of pair scores.

$\sum xy$  = Sum of the products of paired scores.

$\sum x$  = Sum of the  $x$  scores.

$\sum y$  = Sum of the  $y$  scores.

$\sum x^2$  = Sum of the squared  $x$  scores.

$\sum y^2$  = Sum of the squared  $y$  scores.

The closer the scatter of points is to a straight line, the greater the strength of the association there is between the given variables. Conjointly, it does not matter what measurement units are used<sup>25</sup>.

#### 6.1.2 Multiple Linear Regressions

Multiple Regressions is used to compute whether there is a linear relationship between the dependent variables and an independent variable. Equation for multiple linear regressions is exhibited as:

$$\hat{Y} = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_p X_p$$

Where  $\hat{Y}$  is the expected or predicted value of the dependent variable,  $X_1$  through  $X_p$  are  $p$  distinct predictor or independent variables,  $b_0$  is the value of  $Y$  when all of the independent variables ( $X_1$  through  $X_p$ ) are equal to zero and  $b_1$  through  $b_p$  is the estimated regression coefficients. Each regression coefficient signifies the change in  $Y$  relative to a one-unit variation in the respective independent variable. Statistical tests can be done to quantify whether each regression coefficient is significantly different from zero<sup>26</sup>.

Assumptions:

- The relationship between the dependent variables and the independent variables is linear.
- There is no multi-collinearity in the data.
- The values of the residuals are independent.
- The variance of the residuals is constant.
- The values of the residuals are normally distributed.

### 6.1.3 Non-linear Auto-regressive Network with Exogenous Inputs

The nonlinear auto-regressive exogenous neural network prototype is founded on the linear ARX model that is frequently used in time series modelling. The NARX equation is computed as:

$$y(t) = f(y(t-1), y(t-2), \dots, y(t-n_y), u(t-1), u(t-2), \dots, u(t-n_u))$$

Where the succeeding value of the dependent output signal  $y(t)$  is regressed on preceding values of the output signal and an independent (exogenous) input signal.

Diagram 1 is illustrated as a resulting network diagram. It depicts where a two-layer feed forward network is used for the approximation. Not only can it be used as a predictor of the succeeding value of the input signal, it can also be used for nonlinear filtering, in which the target output is a noise-free form of the input signal. One can consider the output of the NARX to be an approximate of the output of some nonlinear dynamic system that one is trying to denote.

Diagram 2 illustrates the procedure of the series-parallel architecture for training a NARX network to model a dynamic system. As shown in the left figure, the output is fed back to the input of the feed-forward neural network. On the other hand, as depicted in the right figure, the true output is used as a substitute of feeding back the

estimated output. This provides two advantages; first, the resulting network has pure feed-forward architecture and static back-propagation can be used for training; the second is that the input to the feed-forward network is more accurate.

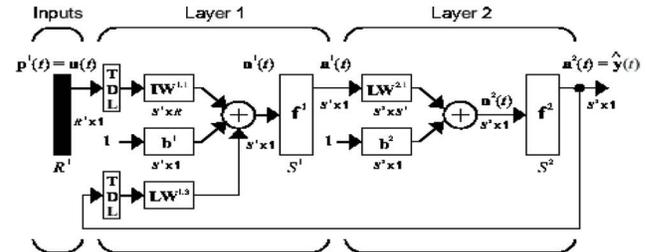


Diagram 1. NARX diagram.

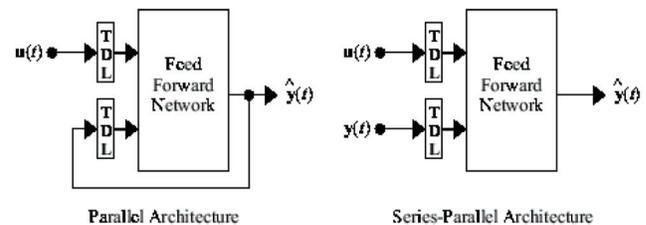


Diagram 2. NARX Architecture.

### 6.1.4 Forecasting Accuracy

#### 6.1.4.1 Mean Absolute Error (MAE)

Mean Absolute Error (MAE) is the measurement of average vertical and the average horizontal distance between each point and the identity line. MAE is also used to calculate the average magnitude of the errors in a set of forecasts, without considering their directions. In addition to that, it is the average over the verification sample of the absolute values of the differences between predicted and the actual observation.

$$MAE = \frac{1}{n} \sum_{i=1}^n |Y_i - \hat{Y}_i|$$

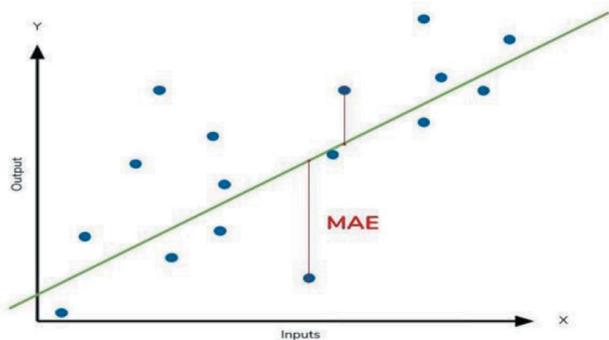
Where:

$n$  is the total number of data points.

$Y$  is the actual output value.

$\hat{Y}$  is the predicted output value.

Figure 1 is a graphical depiction of the MAE. The green line represents the model's predictions, while the blue line points represent our data<sup>27</sup>.



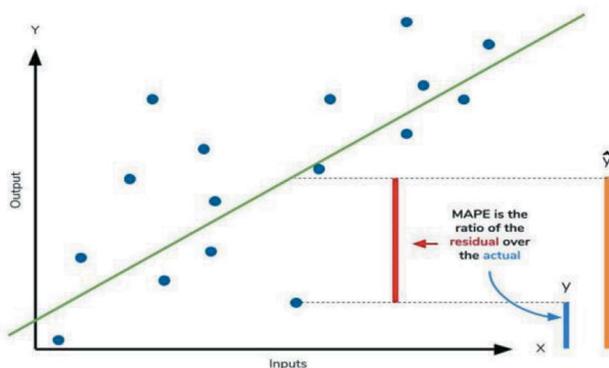
**Figure 1.** Mean Absolute Error [January 1993 – September 2018].

### 6.1.4.2 Mean Absolute Percentage Error (MAPE)

The Mean Absolute Percentage Error (MAPE) is the percentage equivalent of MAE; however, the use of MAPE is more limited. MAPE is also the most common measure of forecast error. It greatly functions when there are no extremes to the data (including zeros). Furthermore, MAPE is the average absolute percent error for each period or forecast minus actual divided by actual.

$$MAPE = \frac{100\%}{n} \sum_{i=1}^n \left| \frac{Y_i - \hat{Y}_i}{Y_i} \right|$$

Similarly, the MAPE can propagate remarkably large if the actual values are notably small as shown in Figure 2. Finally, the MAPE is subjective towards forecasts that are systematically less than the actual values. Hence, MAPE will be lower when the prediction is lower than the actual in comparison to a prediction that is higher by the same amount<sup>28</sup>.

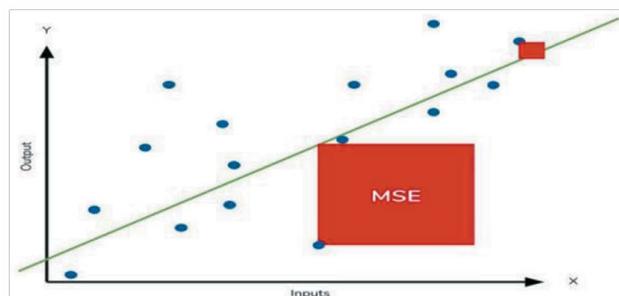


**Figure 2.** Mean Absolute Percentage Error.

### 6.1.4.3 Mean Square Error (MSE)

The Mean Square Error (MSE), as shown in Figure 3, is the average of the squared errors between actual and predicted values in a data sample. It is just like the MAE but uses squared difference instead of using absolute value since squaring the difference exterminates the probability of dealing with negative numbers<sup>27</sup>. Errors are calculated by getting the difference between the measured value and the predicted value at a particular time. MSE is given by:

$$MSE = \frac{1}{n} \sum_{i=1}^n (Y_i - \hat{Y}_i)^2$$



**Figure 3.** Mean Square Error.

### 6.1.4.4 Root Mean Squared Error (RMSE)

Root Mean Square Error (RMSE) is used to identify and calculate how much error there is between two sets of data, associating a predicted and an observed value. RMSE is also known as root mean square deviation and is also one of the most extensively used statistics in GIS<sup>27</sup>.

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (Y_i - \hat{Y}_i)^2}$$

### 6.1.4.5 Normalized Mean Square Error (NMSE)

Normalized Mean Square Error (NMSE) is an estimator of the overall or summed deviations between measured and predicted values<sup>29</sup>. It is well-performing both in space and time if a model has a very low NMSE. On the other hand, high NMSE values do not profoundly mean that a model is entirely incorrect. That case could be due to time and/or space-shifting<sup>30</sup>. It is computed as:

$$NMSE = \frac{1}{n} \sum_{i=1}^n \frac{(Y_i - \hat{Y}_i)^2}{\overline{Y_i \hat{Y}_i}}$$

Where

$$\overline{Y_i} = \frac{1}{n} \sum_{i=1}^n Y_i \text{ and } \overline{\hat{Y}_i} = \frac{1}{n} \sum_{i=1}^n \hat{Y}_i$$

## 7. Results and Discussion

### 7.1 Behavior of the Graph of the Dependent and Independent Variables

#### 7.1.1 Crude Oil Price

Crude Oil prices in the Philippines were lowest from 1993 to 1998 due to the government’s policy identified as the Downstream Oil Industry Deregulation Act of 1998. The objective of this Act is to allow market competition without the government playing the role with the pricing, exportation, and importation of oil products<sup>5</sup>. In the following years, the graph displays a slight increase at first and then abruptly rising until it reached its peak in the year 2007. Moreover, in 2008 and 2014, Crude Oil prices decreased considerably when the government imposed the minimum inventory requirement in the downstream oil industry to guarantee perpetual, firm and soundly Crude Oil products in the Philippines<sup>31</sup> (Figure 4).

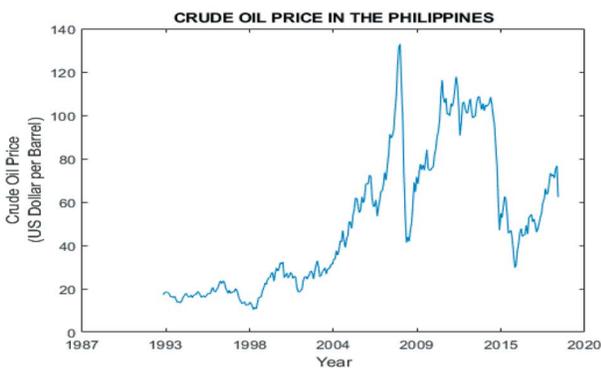


Figure 4. Crude Oil price in the Philippines (y).

#### 7.1.2 Exchange Rate

Observing the illustration, it is perceptible that the exchange rates were at their lowest from 1993 until 1998

attributed to the incidence of Asian Contagion. The Asian financial crisis was a sequence of currency depreciations and other events. The currency first failed in Thailand as the consequence of the government’s decision to no longer fix the local currency to the U.S. Dollar (USD). Currency declines spread suddenly throughout Southeast Asia including the Philippines. As shown in Figure 5, the consumer price inflation went up to 7.6% in 2005 from 3% in 2003 to 5.50% in 2004. The rise in inflation replicated in the collective impact of a depreciating peso and rising petroleum prices causing the Philippines to grasp its peak in the exchange rate in 2004. After 2009, the exchange rate then declined again by 6.6% as the full impact of the global financial turmoil and the continued risk aversion against developing market economies. In 2015 to 2018, the exchange rate kept increasing as a result of low import in the Philippines<sup>32</sup>.

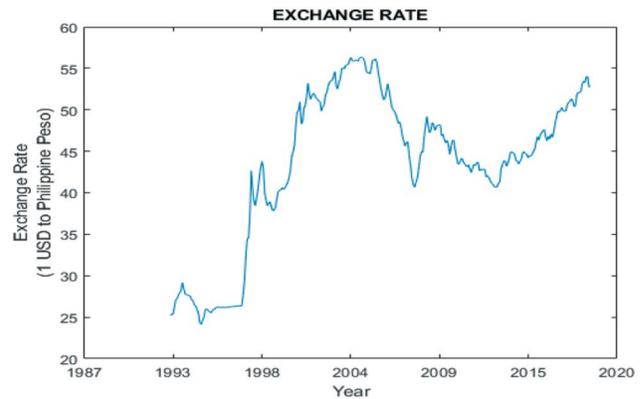


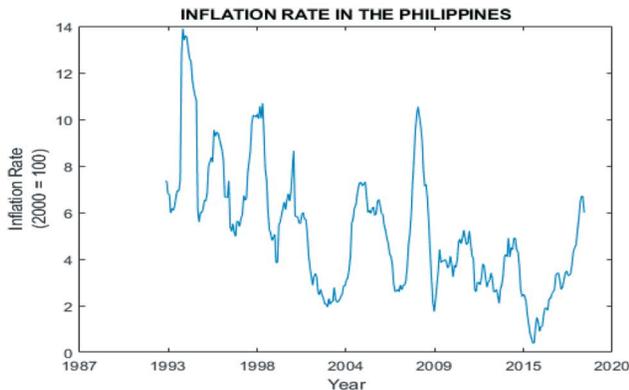
Figure 5. Exchange rate in the Philippines (x<sub>1</sub>) [January 1993 – September 2018].

#### 7.1.3 Inflation Rate

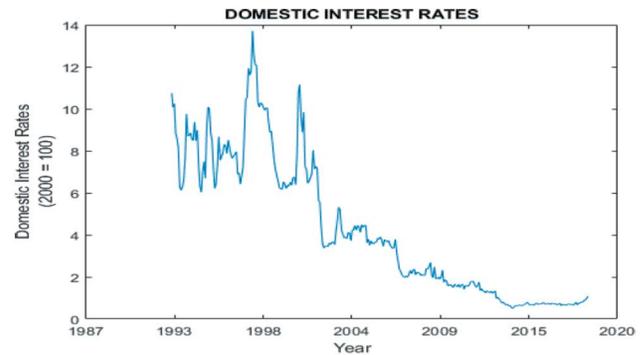
The Philippines’ inflation rate declined in 2015 due to the slower surge in the price of the goods and services. According to the Bangko Sentralng Pilipinas (BSP) annual report the food inflation rate decreased by 2.6% in 2015 from 7.1% of the previous year. In 2008, as shown in Figure 6, the average of inflation reached 9.3%. This increase can be attributed to the oil price hike and increased prices of basic commodities.

#### 7.1.4 Consumer Price Index

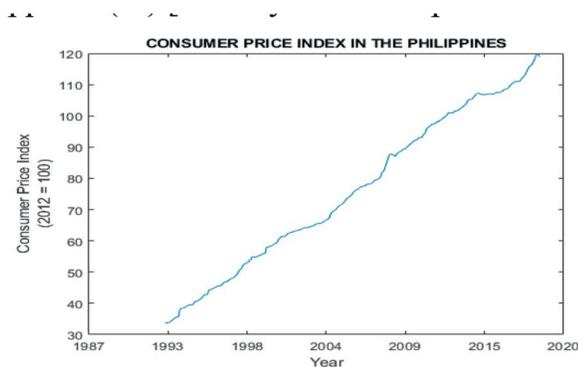
Figure 7 depicts a steady increase of the consumer price index over the years. This can be attributed to the increasing population of the country that resulted to higher demands for the daily commodities.



**Figure 6.** Inflation rate in the Philippines ( $x_2$ ) [January 1993 – September 2018].

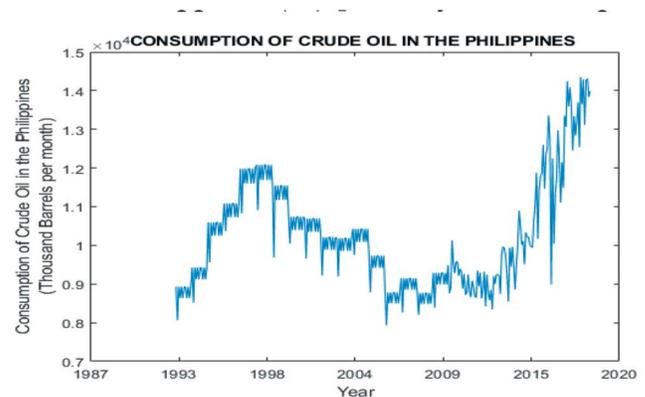


**Figure 8.** Domestic interest rates in the Philippines ( $x_4$ ) [January 1993 – September 2018].



**Figure 7.** Consumer price index in the Philippines ( $x_3$ ) [January 1993 – September 2018].

Figure 9, period ending at 487.47 thousand barrels per day in December 2018<sup>34</sup>.



**Figure 9.** Consumption of Crude Oil in the Philippines ( $x_5$ ) [January 1993 – September 2018].

### 7.1.5 Domestic Interest Rate

Substantial variability of the domestic interest rate between 1993 and 2004 were illustrated in Figure 8. This may be attributed to the Asian Economic Crisis in 1997 to 1998 that triggered the Philippines’ stock market to decline by 32%. Moreover, the currency against the dollar had depreciated by as much as 48% and later level off at 30% at end of December 1997. A side from this, threats of terrorists and insurgency in the country at that time also resulted to slow economic growth and ambiguity<sup>33</sup>. Hence, the gradual decline of domestic interest rates in the preceding years.

### 7.1.6 Consumption of Crude Oil

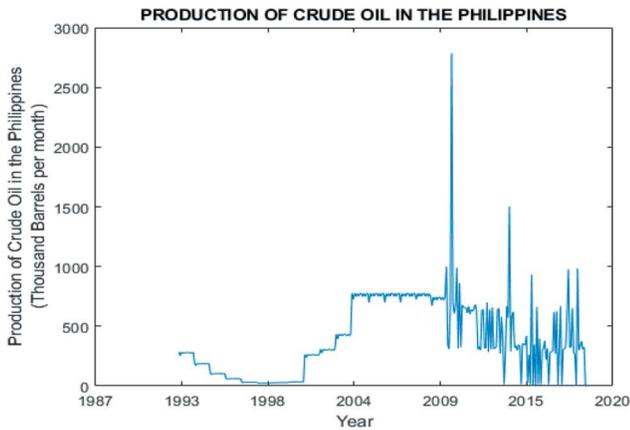
Consumption of petroleum for the Philippines in December 2018 amounted to 487.47 thousand barrels per day. Though Philippine petroleum consumption fluctuated substantively in recent months, it inclined through January 2014 to December 2018 as shown in

### 7.1.7 Production of Crude Oil

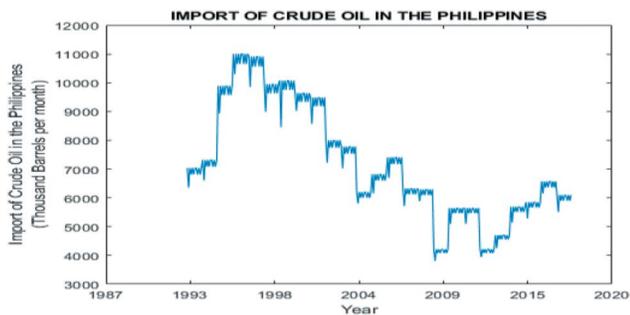
Production of Crude Oil in the Philippines from 2005 until 2008 was stabilized as shown in Figure 10. It reached its peak production record in 2009 attributable to the pressure in the Gaza Strip. On the other hand, the increase in the importation of Crude Oil in the Middle East resulted to the lowest Crude Oil production that transpired between 2013 and 2018.

### 7.1.8 Import of Crude Oil

From the highest record of crude import around 1996, Figure 11 depicts a decline over the years up to its lowest record in 2008. This can be attributed to the initial production of Malampaya gas field. As the years pass, the demand for Crude Oil increased. As a result, the Crude Oil import started to increase in 2012.



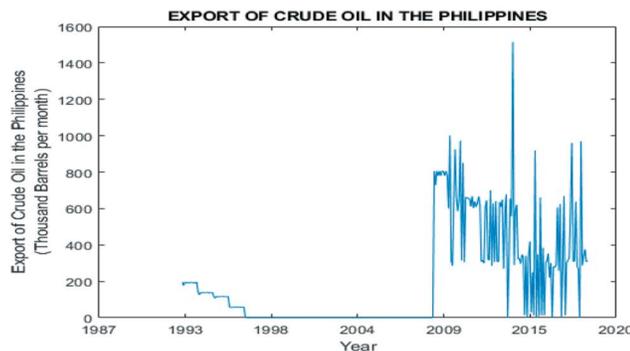
**Figure 10.** Production of Crude Oil in the Philippines ( $x_6$ ) [January 1993 – September 2018].



**Figure 11.** Import of Crude Oil in the Philippines ( $x_7$ ) [January 1993 – September 2018].

### 7.1.9 Export of Crude Oil

The Crude Oil export in the Philippines declined until it dropped to zero from 1995 to 2007 as displayed in Figure 12. Then, the export of Crude Oil records became incoherently fluctuating and unstable. Though Philippine exports of Crude Oil varied considerably in recent months, it declined through January 2014 to December 2018 period ending at 10.55 thousand barrels per day in December 2018<sup>35</sup>.

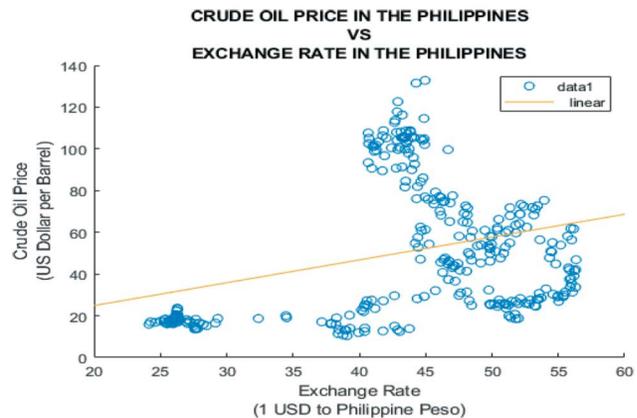


**Figure 12.** Export of Crude Oil in the Philippines ( $x_8$ ) [January 1993 – September 2018].

## 8. Significant Relationship of the Dependent and Independent Variables

### 8.1 Crude Oil Price and Exchange Rate

Exchange rate and Crude Oil price in the Philippines from January 1993 to September 2018 were depicted in Figure 13. It shows a weak positive correlation and the variables are directly related. To conclude, as the exchange rate increases, the Crude Oil price also increases.



**Figure 13.** Crude Oil price in the Philippines ( $y$ ) vs. Exchange rate in the Philippines ( $x_1$ ).

### 8.2 Crude Oil Price and Inflation Rate

The graph exhibits the inflation rate and the Crude Oil price in the Philippines from January 1993 to September 2018. Furthermore, Figure 14 indicates a weak negative correlation and an inverse relationship between the variables. To conclude, as the inflation rate increases, the Crude Oil price decreases.

### 8.3 Crude Oil Price and Consumer Price Index

Figure 15 presents the consumer price index and the Crude Oil price of the Philippines from January 1993 to September 2018. The graph designates a moderate positive correlation and a direct relationship between the consumer price index and the Crude Oil price. Hence, as the consumer price index increases, the Crude Oil price also increases.

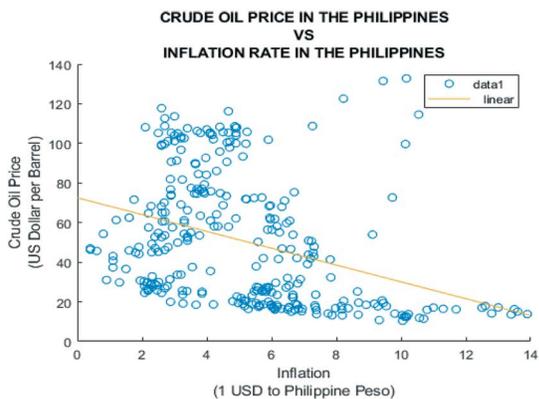


Figure 14. Crude Oil price in the Philippines (y) vs. Inflation rate in the Philippines ( $x_2$ ).

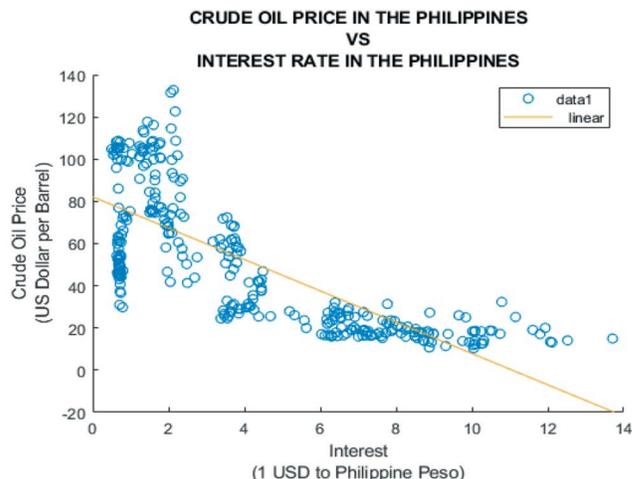


Figure 16. Crude Oil price in the Philippines (y) vs. Domestic interest rate in the Philippines ( $x_4$ ).

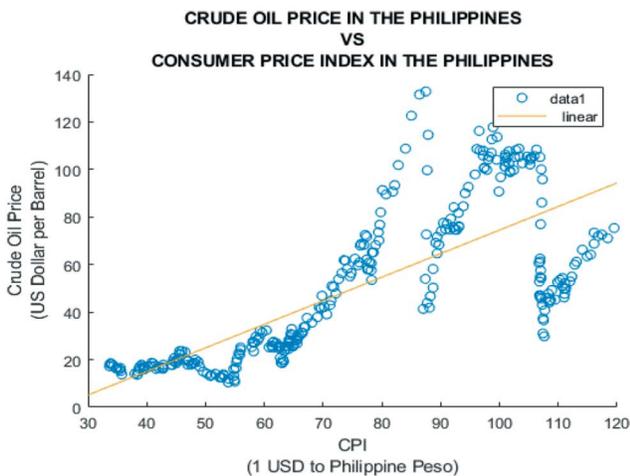


Figure 15. Crude Oil price in the Philippines (y) vs. Consumer price index in the Philippines ( $x_3$ ).

Oil price and consumption of crude oil. Hence, as the consumption of Crude Oil increases, the Crude Oil price decreases.

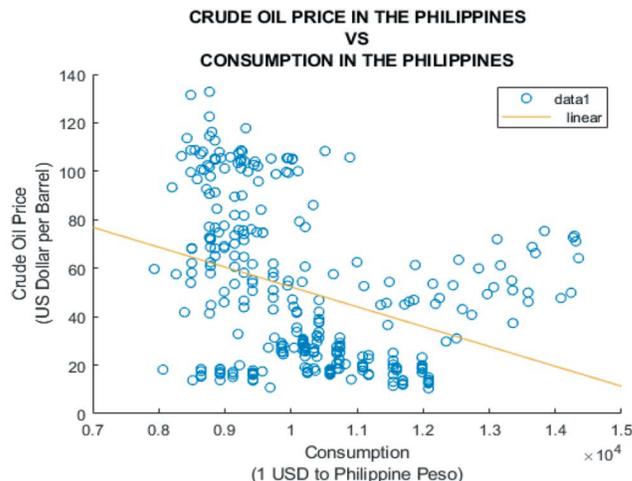


Figure 17. Crude Oil price in the Philippines (y) vs. Consumption of Crude Oil in the Philippines ( $x_5$ ).

### 8.4 Crude Oil Price and Domestic Interest Rate

The interest rate and Crude Oil price in the Philippines from January 1993 to September 2018 are depicted in Figure 16. It expresses a moderate negative correlation and an inverse relationship between the domestic interest rate and Crude Oil price. Hence, as the interest rate increases, the Crude Oil price decreases.

### 8.5 Crude Oil Price and Consumption of Crude Oil

Figure 17 illustrates the consumption of Crude Oil and Crude Oil price in the Philippines from January 1993 to September 2018. The graph portrays a weak negative correlation and an inverse relationship between Crude

### 8.6 Crude Oil Price and Production of Crude Oil

The production of Crude Oil and the Crude Oil price in the Philippines from January 1993 to September 2018 were shown in Figure 18. It indicates a moderate positive correlation and a direct relationship between the two variables. Hence, as the production of Crude Oil increases, the Crude Oil price also increases.

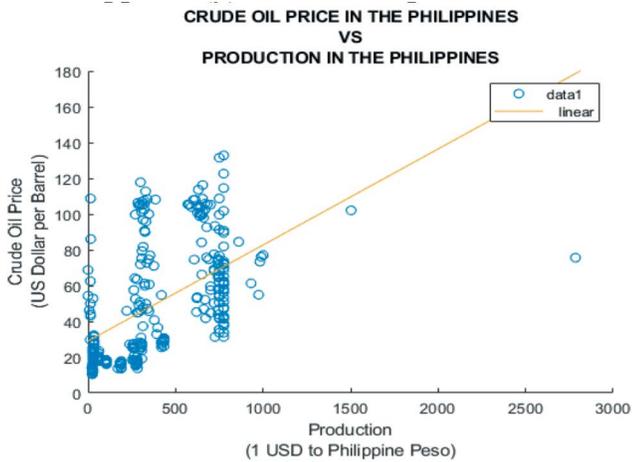


Figure 18. Crude Oil price in the Philippines (y) vs. Production of Crude Oil in the Philippines ( $x_6$ ).

### 8.7 Crude Oil Price and Import of Crude Oil

Figure 19 shows the import of Crude Oil and the Crude Oil price in the Philippines from January 1993 to September 2018. Moreover, it depicts a moderate negative correlation and an inverse relationship between the two variables. As the import of Crude Oil increases, the Crude Oil price decreases.

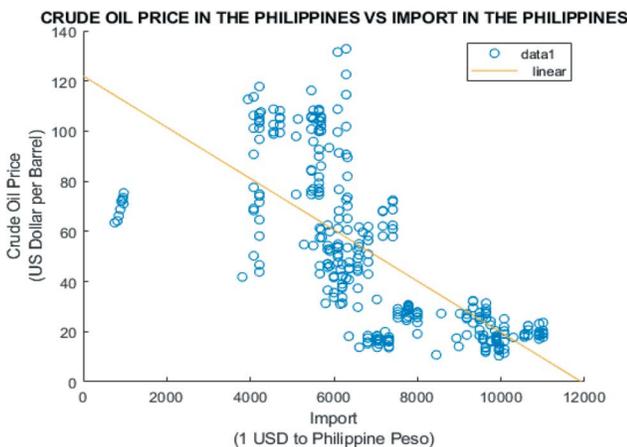


Figure 19. Crude Oil price in the Philippines (y) vs. import of Crude Oil in the Philippines ( $x_7$ )

### 8.8 Crude Oil Price and Export of Crude Oil

The export of Crude Oil and the Crude Oil price in the Philippines from January 1993 to September 2018 were displayed in Figure 20. Furthermore, it denotes a moderate positive correlation and a direct relationship

between the two variables. Hence, as the export of Crude Oil increases, the Crude Oil price also increases.

The decision made for all independent variables is Reject as shown in Table 1. So, the independent variables that are significantly correlated are exchange rate, inflation rate, consumer price index, interest rate, consumption, production, import, and export of Crude Oil in the Philippines.

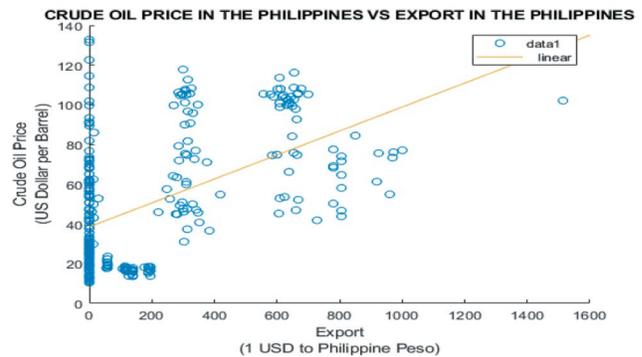


Figure 20. Crude Oil price in the Philippines (y) vs. export of Crude Oil in the Philippines ( $x_8$ ).

## 9. Multiple Linear Regression

The p-values of the exchange rate ( $x_1$ ) and the production of Crude Oil ( $x_6$ ) are both greater than 0.05 which is the significance level based on Table 2. This means that the insignificant predictors for the Crude Oil price include exchange rate ( $x_1$ ) and the production of Crude Oil ( $x_6$ ). On the other hand, the significant predictors for the Crude Oil price in the Philippines are Inflation Rate ( $x_2$ ), Consumption of Crude Oil ( $x_3$ ), Import of Crude Oil ( $x_7$ ), and Export of Crude Oil ( $x_8$ ). (Figure 19).

### 9.1 Multiple Linear Regression Model

$$\hat{Y} = 158.16334 - 1.44849x_2 - 0.00570x_5 - 0.00710x_7 + 0.01696x_8$$

### 9.2 Nonlinear Auto-regressive Exogenous Neural Network

By using the NARX Neural Network on the significant predictors, the prediction of the Crude Oil Price in the Philippines is completed. Training the network, as shown in Figure 21, using Bayesian regularization will generate the model of the network. The NARX Neural Network Model is shown in Figure 22. Two types of NARX Neural Network Model are explained in the study. These are the

**Table 1.** Pearson correlation coefficient for independent variables vs. Crude Oil price

Variable	Pearson r	Verbal Interpretation	p-value	Decision	Remarks
Exchange Rate ( $x_1$ )	0.3144	Weak positive	0.0000	Reject	Significant
Inflation Rate ( $x_2$ )	-0.3560	Weak negative	0.0000	Reject	Significant
Consumer Price Index ( $x_3$ )	0.7561	Moderate positive	0.0000	Reject	Significant
Interest Rate ( $x_4$ )	-0.7636	Moderate negative	0.0000	Reject	Significant
Consumption of Crude Oil ( $x_5$ )	-0.3527	Weak negative	0.0000	Reject	Significant
Production of Crude Oil ( $x_6$ )	0.5389	Moderate positive	0.0000	Reject	Significant
Import of Crude Oil ( $x_7$ )	-0.7037	Moderate negative	0.0000	Reject	Significant
Export of Crude Oil ( $x_8$ )	0.5183	Moderate positive	0.0000	Reject	Significant

**Table 2.** Multiple Linear Regressions estimate coefficient

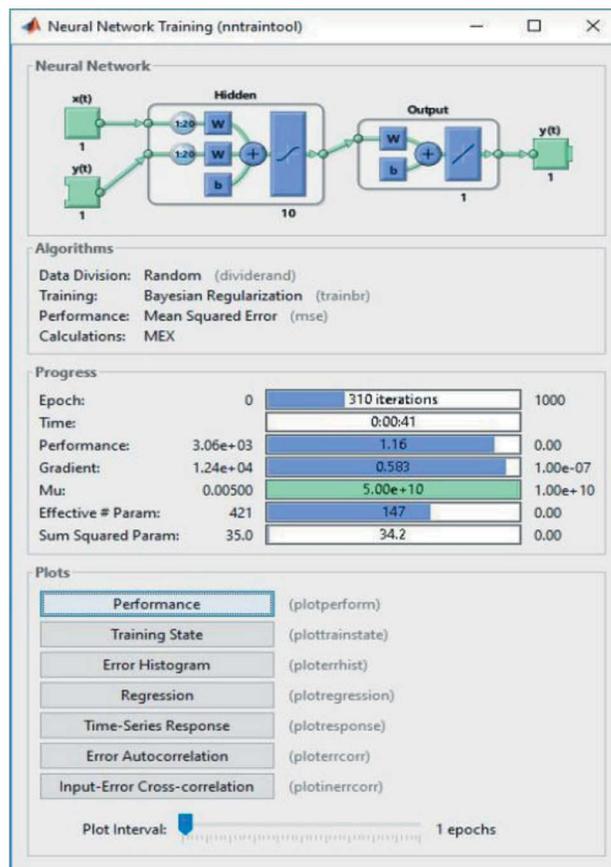
Variable	Beta Parameter	p-value	Decision	Remarks
(Intercept)	158.16334	0.00000	Reject	Significant
Exchange Rate ( $x_1$ )	0.02712	0.89107	Failed to reject	Not Significant
Inflation Rate ( $x_2$ )	-1.44849	0.00776	Reject	Significant
Consumption of Crude Oil ( $x_3$ )	-0.00570	0.00000	Reject	Significant
Production of Crude Oil ( $x_6$ )	0.00827	0.15352	Failed to reject	Not Significant
Import of Crude Oil ( $x_7$ )	-0.00710	0.00000	Reject	Significant
Export of Crude Oil ( $x_8$ )	0.01696	0.00747	Reject	Significant

NARX Neural Network Model (Closed Loop) as shown in Figure 23 and the NARX Neural Network Model (One Step Ahead) as shown in Figure 24.

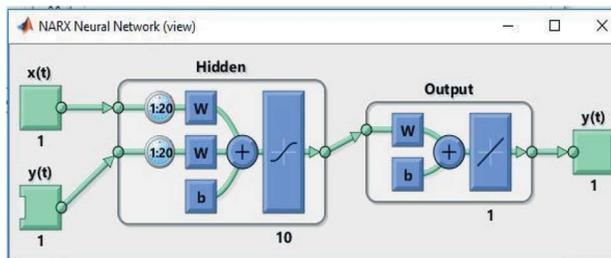
When training and testing the network has been done, the predicted and actual values appeared as the output. Figure 25 illustrates that the actual and predicted values are almost the same.

### 9.3 Forecasting Accuracy

Notice that on Table 3, amongst Multiple Linear Regression and NARX Neural Network, the NARX Neural Network has the least error in MAE, MAPE, MSE,



**Figure 21.** Training the NARX Neural Network.



**Figure 22.** NARX Neural Network model.

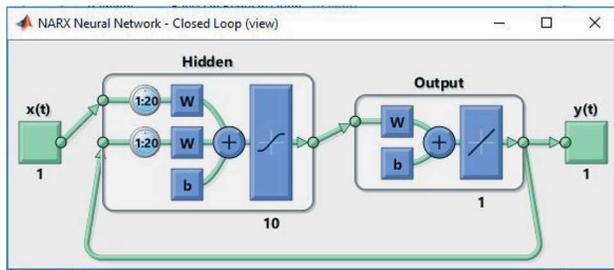


Figure 23. NARX Neural Network model (Closed loop).

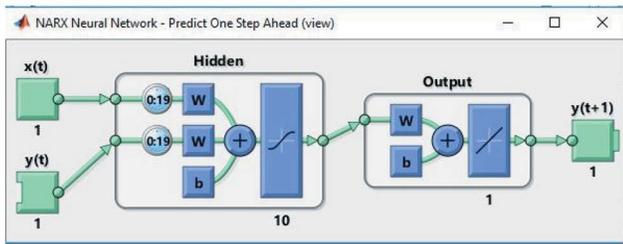


Figure 24. NARX Neural Network model (One step ahead).

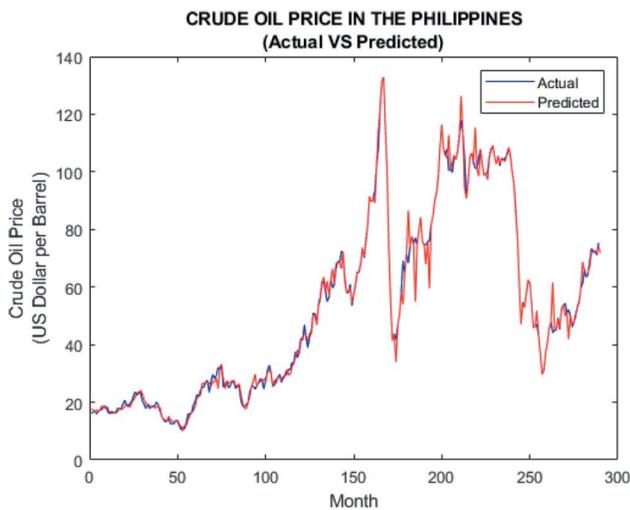


Figure 25. Crude Oil price in the Philippines (actual vs. predicted) [January 1993 – September 2018].

RMSE and NMSE. Thus, the NARX Neural Network is the best-fitted model to forecast the monthly Crude Oil price in the Philippines from October 2018 to December 2023 (Figure 26).

### 9.4 Forecasted Values

The results are presented in Table 4.

Table 3. Forecasting Accuracy of NARX Neural Network and Multiple Linear Regressions

Model	Mean Absolute Error	Mean Absolute Percentage Error	Mean Square Error	Root Mean Square Error	Normalized Mean Square Error
Nonlinear Autoregressive Neural Network with Exogenous Inputs	1.3966	0.0350	10.4278	3.2292	10.4278
Multiple Linear Regression	446.2956	21.1257	446.2956	16.2184	0.5203

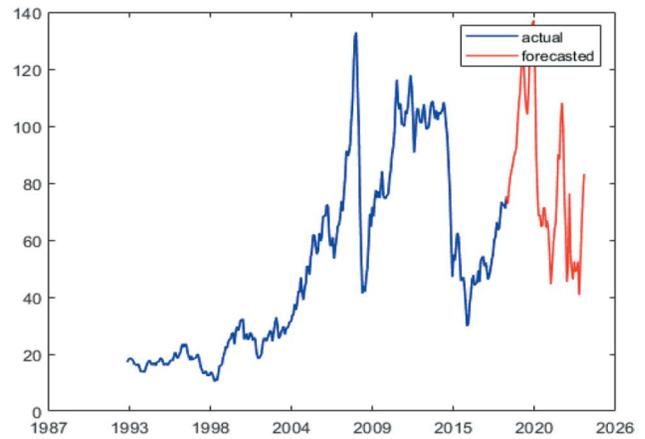


Figure 26. Crude Oil Price in the Philippines (January 1993 – December 2023).

Table 4. Forecasted values (October 2019 – December 2023)

Month	Forecasted Value	Month	Forecasted Value
Oct 2019	72.83104	Feb 2020	104.08609
Nov 2019	77.98951	Mar 2020	113.44269
Dec 2019	81.97331	Apr 2020	128.11649
Jan 2020	84.42498	May 2020	132.54935
Feb 2020	86.46362	Jun 2020	135.99608
Mar 2020	89.19102	Jul 2020	137.03167
Apr 2020	90.55060	Aug 2020	122.31086
May 2020	92.32133	Sep 2020	91.79235
Jun 2020	100.77036	Oct 2020	77.45770
Jul 2020	107.76885	Nov 2020	68.52961

Aug 2019	112.02107	Dec 2020	68.82000
Sep 2019	119.90802	Jan 2021	64.86677
Oct 2019	124.84380	Feb 2021	64.93806
Nov 2019	121.38634	Mar 2021	71.26777
Dec 2019	111.25940	Apr 2021	71.23358
Jan 2020	106.05671	May 2021	64.49885
Jun 2021	66.81687	Oct 2022	45.32770
Jul 2021	63.20192	Nov 2022	51.02556
Aug 2021	55.23974	Dec 2022	76.32552
Sep 2021	44.52223	Jan 2023	54.66482
Oct 2021	50.99010	Feb 2023	49.11076
Nov 2021	58.52990	Mar 2023	46.18217
Dec 2021	63.78078	Apr 2023	52.49371
Jan 2022	66.23530	May 2023	48.89611
Feb 2022	77.77859	Jun 2023	49.47138
Mar 2022	90.08557	Jul 2023	52.43123
Apr 2022	88.39688	Aug 2023	40.74764
May 2022	101.32493	Sep 2023	51.87792
Jun 2022	108.16402	Oct 2023	64.94534
Jul 2022	98.95199	Nov 2023	74.95147
Aug 2022	74.79764	Dec 2023	83.16272
Sep 2022	64.15802		

## 10. Conclusion and Recommendation

### 10.1 Conclusion

To distinguish which factors should be deliberated in forecasting the Crude Oil Price in the Philippines (y), significant relationship should be present among them. Using the Pearson's r, the researchers were able to denote that the independent variables, Exchange rate ( $x_1$ ), Inflation rate ( $x_2$ ), Consumer price index ( $x_3$ ), Domestic interest rate ( $x_4$ ), Consumption of Crude Oil ( $x_5$ ), Production of Crude Oil ( $x_6$ ), Import of Crude Oil ( $x_7$ ) and Export of Crude Oil in the Philippines ( $x_8$ ) are all significantly related. The independent variables are then retested with the use of Multiple Linear Regression. Interpreting the results, the researchers distinguished that there are four significant predictors for forecasting the Crude Oil Price in the Philippines (y), namely Inflation Rate ( $x_2$ ), Consumption of Crude Oil ( $x_5$ ), Import of Crude Oil ( $x_7$ ) and Export of Crude oil ( $x_8$ ). Comparing the forecasting accuracy of multiple linear regression and

Nonlinear Auto-regression Exogenous Neural Network (NARX), NARX Neural Network is the best-fitted model for forecasting the Crude Oil price in the Philippines (y). These significant predictors were used in forecasting, through the use of the NARX neural network. After training and implementation in the results of the neural network, the output showed that the actual and predicted values are very close, that is there is just a very small error or difference between them. Moreover, the NARX Neural Network was able to forecast the future values of Crude Oil price in the Philippines from October 2018 to December 2023.

## 11. Recommendation

For future studies, we recommend using another approach in predicting and forecasting Crude Oil prices in the Philippines (y) such as ARIMA, etc. Furthermore, we recommend using another Artificial Neural Network such as RBFNN.

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