Time Series Analysis of the Crude Oil, Maize, and Rice Prices

ECON 312 Time Series Analysis
Final Project

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Introduction

In many countries, prices of basic commodities, particularly staple foods, are normally regulated by a government agency to protect the consumers. In the Philippines for example, the Department of Trade and Industry (DTI) is tasked with monitoring and regulating retail prices, especially goods that are considered necessities. Other than government policies, there are other factors that determine prices of basic goods.

The prices of commodities are known to fluctuate over time. Commodity prices are influenced by a wide range of factors, including global economic conditions, geopolitical events, and supply and demand dynamics. This study aims to analyze the time series data of crude oil, maize, and rice prices and to determine the effect of movements in crude oil prices on the prices of maize and rice.

Crude oil is one of the most important commodities in the world. It is a critical component of the global economy, as it is used to fuel transportation and power industries. The price of crude oil is influenced by a variety of factors, including global supply and demand, geopolitical events, and weather patterns. As a result, the price of crude oil is highly volatile and can fluctuate significantly over time.

Maize and rice are two important commodities that are widely consumed around the world. Maize is a staple food in many countries, and it is also used as animal feed and in the production of biofuels. Rice is also a staple food in many countries, particularly in Asia, and it is an important export crop. The prices of maize and rice are influenced by a range of factors, including global supply and demand, weather patterns, and government policies.

The prices of crude oil, maize, and rice are interconnected, and movements in one commodity can have a significant impact on the others. For example, if the price of crude oil increases, the cost of transportation and production for maize and rice may increase as well, which can lead to higher prices for these commodities. Additionally, if the price of crude oil decreases, it may become more profitable for farmers to produce maize and rice, which could lead to an increase in supply and a decrease in prices.

Therefore, understanding the relationship between crude oil prices and the prices of maize and rice is important for policymakers, traders, and consumers alike. This study aims to contribute to this understanding by analyzing the time series data of crude oil, maize, and rice prices.

Methodology

The study used time series analysis to examine the relationship between crude oil prices and the prices of maize and rice. This study used monthly data on the prices of crude oil, maize, and rice from January 1990 to December 2020. The data was obtained from reliable sources such as the World Bank, Philippine Statistics Authority, and other open sources. The data was in the form of time series data, which are observations recorded at regular intervals over time.

The dataset used in this analysis consists of several variables. The first variable is the monthly average price of crude oil, which is measured in US dollars per barrel. The second variable is the monthly average price of maize, which is measured in US dollars per metric ton. The third variable is the monthly average price of rice, also measured in US dollars per metric ton. In addition, the dataset includes the average monthly price of rice in the Philippines, measured in Philippine peso per kilogram. Furthermore, the dataset contains the average monthly inflation rate in the Philippines, as well as the average inflation rate in the Philippines using 2018 as the base year.

The first step in the analysis was to examine the time series data for each commodity. This involved plotting the data to identify any trends, seasonality, or other patterns. I then used econometric analysis techniques learned in class to determine the degree of dependence between observations at different lags. Next, I tried to examine the relationship between crude oil prices and the prices of maize and rice. This involved using regression analysis to determine the effect of movements in crude oil prices on the prices of maize and rice. The primary analysis was time series analysis, which was used to model the relationship between crude oil prices and the prices of maize and rice. Time series analysis is a statistical technique used to analyze time-dependent data, and it allows us to examine trends, seasonality, and other patterns in the data.

Data Analysis

Descriptive Statistics

Taking the descriptive statistics of the data would not make much sense as the prices tend to increase over time due to many factors. Talking about the average price of crude oil from 1990 to 2022, for example, would not be meaningful. On the other hand, looking at the descriptive statistics of the differences is more meaningful. For example, if we look at the mean of the changes in the price of rice from 1990 to 2022, we can understand it as the average increase, or decrease, in the price of rice over time. The following table shows the mean, standard deviation, and minimum and maximum values in the changes in the prices of crude oil, maize, rice (Thai), and regular milled rice (Philippines). There were no missing data, so there are 371 observations for each variable.

Table 1. *Descriptive statistics of the changes in the prices of the four commodities.*

Commodity	Mean	Standard Deviation	Minimum	Maximum
Crude Oil	0.076	4.61	– 26.97	13.87
Maize	0.251	10.3	– 50.79	65.74
Rice (Thai)	0.657	27.0	– 144.8	313.0
Rice (Philippines)	0.075	0.6	– 2.81	4.54

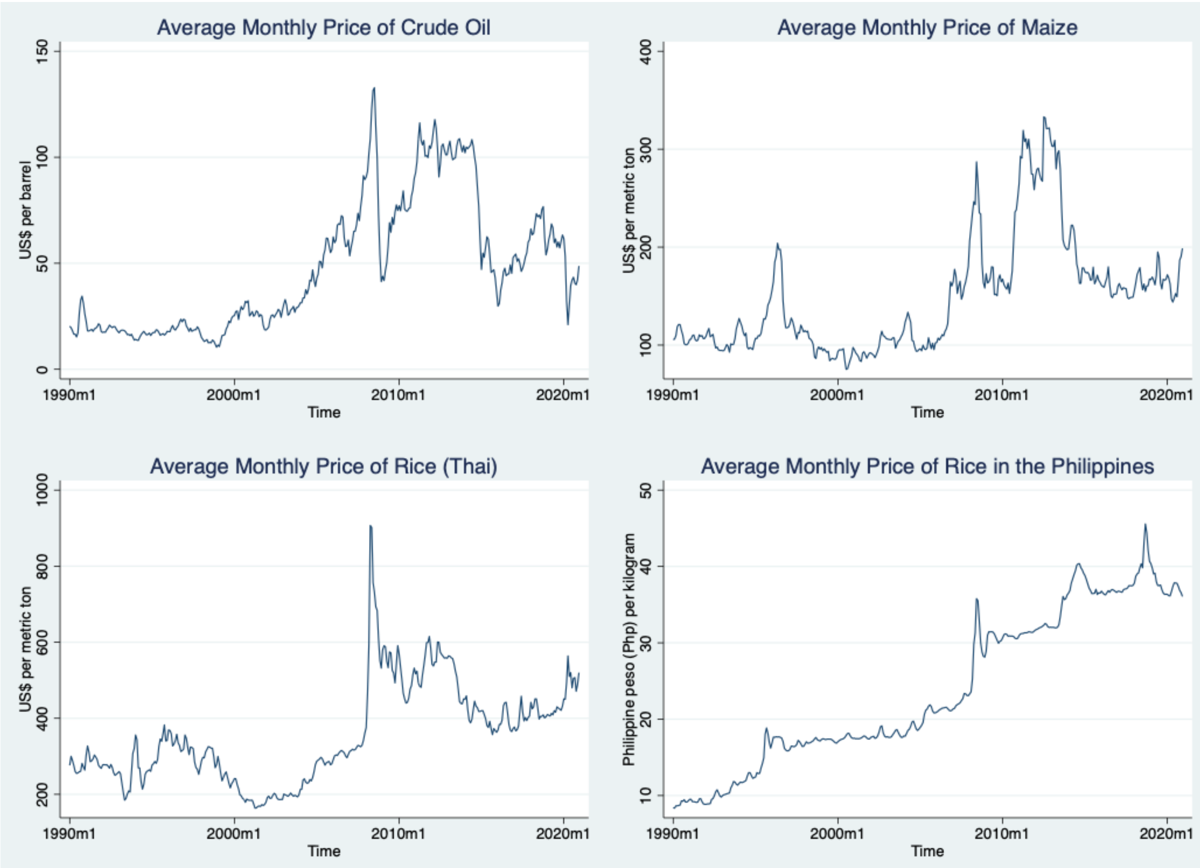
From Table 3, we can see that from 1990 to 2022, the price of crude oil increased by an average of 0.076 US dollars per barrel. We can also see that there was an episode where there is a major drop in the price of crude oil to as much as 26.97 US dollars per barrel. This happened during the economic crisis of 2008 – 2009, which also affected the prices of the maize and rice. More from this table, we can see that the price of Thai rice changes more dramatically, with a range of US$ 457.8 and a standard deviation of 27.0.

Testing for Stationarity

The following graph shows the average monthly price of crude oil, maize, and rice (Thai and Philippines) from January 1990 to December 2022. The graph shows that these four variables are not stationary. This observation is confirmed by running an augmented Dickey-Fuller test for all variables

– crude oil (p-value = 0.4988), maize (p-value = 0.4570), Thai rice (p-value = 0.3511), and Philippine rice (p-value = 0.7623). Even adding more lags or trend did not change the outcomes of the Dickey-Fuller tests.

Graph 1. *Average monthly price of crude oil, maize, and rice (Thai and Philippines).*



Since I am more interested in capturing the movement in the prices of maize and rice based on the change in the price of crude oil, it makes sense to consider the differences in the prices than the price levels. Looking at Graph 2, the differences in the prices of crude oil, maize and rice (Thai and Philippines) seemed to be stationary, although some time periods looked like have higher variance than in some time periods. However, an augmented Dickey-Fuller test on the differences in the prices revealed that all variables are stationary, with test statistics less than critical values at all conventional significance levels – crude oil (–12.232), maize (–15.180), Thai rice (–13.624) and Philippine rice (–11.347).

Graph 2. *Changes in the prices of crude oil, maize, and rice (Thai and Philippines).*

Time Series Modelling

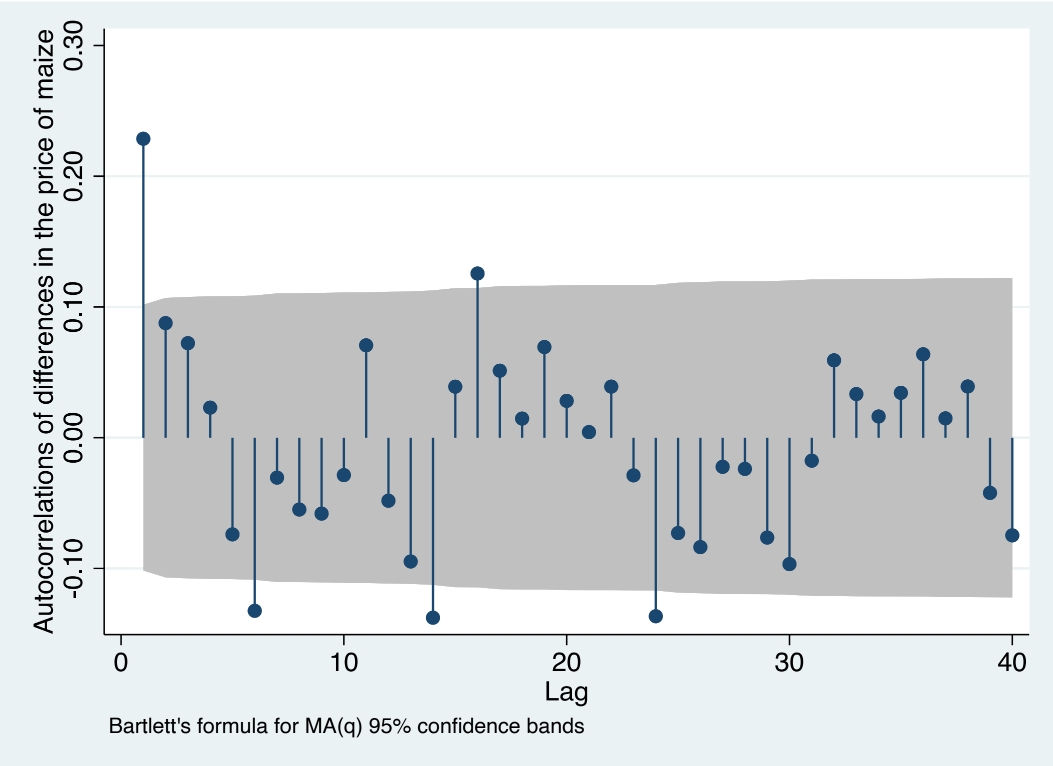
Now that I have established that the difference in price of crude oil, maize, Thai rice, and Philippine rice were all stationary, I can now use either an AR or ARDL time series models.

Crude Oil and Maize

The first relationship that I looked at was the change in the prices of crude oil and maize.

First, I need to check the appropriate time series model. To do this, I inspected the correlogram of the differences in the average monthly price of maize. This is to determine whether lags of the differences in the average monthly price of maize should be included as predictor or not.

Graph 3. *Correlogram of the differences in the average monthly price of maize.*



From the correlogram above, we can see that there are several lags that go beyond the confidence interval, meaning that these lags could be significant predictor for the movement of the price of maize, though these lags are not consecutive. To statistically determine the appropriate number of lags to be included, I used lag-order selection criteria such as the Akaike information criterion (AIC). A summary of these criteria are shown below as obtained from Stata.

Figure 1. *Lag-order selection criteria for maize.*

Sample: **1990m6** thru **2020m12** Number of obs = **367**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1377.46				107.143	7.51204	7.51627	7.52269
1	-1367.65	19.618*	1	0.000	102.122*	7.46404*	7.4725*	7.48532*
2	-1367.39	.51802	1	0.472	102.535	7.46808	7.48076	7.5
3	-1366.96	.85947	1	0.354	102.854	7.47119	7.4881	7.51375
4	-1366.96	.00984	1	0.921	103.413	7.47661	7.49775	7.52982

* optimal lag
Endogenous: **D.m**
Exogenous: **_cons**

From the results shown above, all criteria indicated that one lag is the optimal number of lag. We can also visually see this from the correlogram in Graph 3.

Next, I need to determine the optimal number of lags of the differences in the average monthly price of crude oil to be included in the model. The summary of the lag-selection criteria obtained from Stata are shown below.

Figure 2. *Lag-order selection criteria for crude oil.*

Sample: **1990m6** thru **2020m12** Number of obs = **367**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1083.22				21.5561	5.90854	5.91276	5.91918
1	-1047.96	70.517	1	0.000	17.885	5.72184	5.7303*	5.74312*
2	-1047.55	.82219	1	0.365	17.9425	5.72505	5.73773	5.75697
3	-1044.53	6.029*	1	0.014	17.7466*	5.71407*	5.73098	5.75664
4	-1044.4	.26219	1	0.609	17.8309	5.71881	5.73995	5.77201

* optimal lag
Endogenous: **D.oil**
Exogenous: **_cons**

Three of the criteria, including AIC, indicated that the optimal number of lag is 3, whereas the other two criteria indicated 1 is the optimal number of lag. I followed AIC, and hence, 3 lags of the differences in the average monthly price of crude oil is included in the model.

Thus, the time series model for the maize and crude oil is an ARDL(1, 3) with the following form:

$$\widehat{D.m_t} = \beta_0 + \beta_1 D.m_{t-1} + \alpha_1 D.oil_t + \alpha_2 D.oil_{t-1} + \alpha_2 D.oil_{t-2} + \alpha_3 D.oil_{t-3} + \varepsilon_t$$

where *m* is the average monthly price of maize,
oil is the average monthly price of crude oil,
ε_t is a random disturbance term,
and *D* is the differencing operator.

Using the specification above, I obtained the following time series model:

$$\begin{array}{lcccccc} \widehat{D.m_t} = & 0.134 + & 0.205D.m_{t-1} + & 0.553D.oil_t - & 0.277D.oil_{t-1} + & 0.102D.oil_{t-2} + & 0.037D.oil_{t-3} \\ (t) & (0.26) & (3.96) & (4.45) & (-2.04) & (0.76) & (0.30) \\ (se) & (0.513) & (0.052) & (0.124) & (0.136) & (0.134) & (0.124) \end{array}$$

We can see that the constant term and the third lag are not significant, therefore, I removed the constant term from the model and reduced the number of lags of the crude oil to improve the model.

$$\begin{array}{lcccc} \widehat{D.m_t} = & 0.207D.m_{t-1} + & 0.547D.oil_t - & 0.278D.oil_{t-1} + & 0.118D.oil_{t-2} \\ (t) & (4.02) & (4.45) & (-2.05) & (0.96) \\ (se) & (0.052) & (0.123) & (0.136) & (0.122) \end{array}$$

From this improved model, we can interpret the coefficients in the following way. A one-dollar increase in the difference of price levels of maize in the previous month impacts the change in the price of maize in the current month by 0.207 dollars. Similarly, a one-dollar increase in the difference of price levels of crude oil in the current month impacts the change in the price of maize in the current month by as much as 0.547 dollars. On the other hand, a one-dollar increase in the difference of price levels of crude oil in the previous month decreases the change in the price of maize by 0.278 dollars.

In the real world, we can see this result happening. Consider the case where the price of maize had a positive change in the previous month. It is more likely that the price of maize will have a positive change in the current month as well. Similarly, it is not surprising to see that a positive change in the price of crude oil has a direct impact on the change of price of maize in the same month. The negative impact of the change in the price of crude oil in the previous month can be viewed as a limiting effect. Consider successive positive changes in the price of crude oil. The positive change in the previous month will "limit" or "counter" some of the impact of the positive change in the current month so as the change in the price of maize is not explosive. This is consistent with the price theory from microeconomics.

Crude Oil and Rice

The time series modelling for Thai and Philippine rice are similar to the process of modelling maize. The respective correlograms and lag-order selection criteria are found in the Appendix.

Crude oil and Thai rice

From the correlogram and lag-order selection criteria for Thai rice (see Appendix A), the time series model for Thai rice follows an ARDL (2, 3) model with the following form:

$$\widehat{D.rt_t} = \beta_0 + \beta_1 D.rt_{t-1} + \beta_2 D.rt_{t-2} + \alpha_1 D.oil_t + \alpha_2 D.oil_{t-1} + \alpha_2 D.oil_{t-2} + \alpha_3 D.oil_{t-3} + \varepsilon_t$$

where *rt* is the average monthly price of Thai rice,

oil is the average monthly price of crude oil,

ε_t is a random disturbance term,

and *D* is the differencing operator.

However, after running the modelling on Stata, it indicated that the constant term as well as all the lags of the crude oil were not significant. Thus the model was reduced to AR(2) model with the following equation:

$$
\begin{array}{cccc}
\widehat{D.rt_t} = & 0.393 D.rt_{t-1} & - & 0.190 D.rt_{t-2} \\
(t) & (7.66) & & (-3.71) \\
(se) & (0.051) & & (0.051)
\end{array}
$$

The coefficients of an AR(2) model tell us how much influence the past values of the series have on its current value. In this case, the coefficient of the first lag is +0.393, which means that an increase in the value of $D.rt_{t-1}$ leads to an increase in the value of $D.rt_t$. The coefficient of the second lag is – 0.190, which means that an increase in the value of $D.rt_{t-2}$ leads to a decrease in the value of $D.rt_t$. The magnitude of the coefficients also gives us an idea of how strong the influence of the past values is. A larger coefficient means a stronger influence, while a smaller coefficient means a weaker influence. In this case, the coefficient of the first lag is larger than the coefficient of the second lag, which means that the most recent value of the series has a stronger influence on the current value than the value two time periods ago.

Crude oil and Philippine rice

From the correlogram and lag-order selection criteria for Philippine rice (see Appendix B), the time series model for Philippine rice follows an ARDL (3, 3). However, after running the model, the coefficients of other lags of both the differences in the price of Philippine rice and crude oil were found to be not significant. Hence, the model was reevaluated, and the resulting improved model is an ARDL(2, 2) with the following equation:

$$
\begin{array}{cccccc}
\widehat{D.rm_t} = & 0.499 D.rm_{t-1} & - 0.130 D.rm_{t-2} & + 0.020 D.oil_t & + 0.011 D.oil_{t-1} & - 0.015 D.oil_{t-2} \\
(t) & (9.31) & (-2.44) & (2.86) & (1.43) & (-2.29) \\
(se) & (0.536) & (0.534) & (0.007) & (0.007) & (0.007)
\end{array}
$$

where *rm* is the average monthly price of Philippine rice,

oil is the average monthly price of crude oil,

and *D* is the differencing operator.

Conclusion and Limitation

In this preliminary investigation of the time series models for maize, Thai rice, and Philippine rice, we have identified that the maize model is an ARDL(1,2), the Thai rice model is an AR(2), and the Philippine rice model is an ARDL(2,2). These models indicate that the prices of these commodities are influenced by their past values.

However, it is important to acknowledge the limitations of our investigation. Firstly, the currency for the price of crude oil and Philippine rice are not the same, so foreign exchange rate could be a factor. Secondly, cointegration between crude oil and the other three variables was not tested, which could affect the accuracy of the models. Thirdly, while inflation rate was included in the data, it was not used in the modeling to avoid complicating the model, although inflation is most likely a significant factor in the change in prices of the commodities under investigation.

Therefore, while our preliminary investigation provides some insights into the behavior of these commodities' prices, further exploration is necessary to obtain a more comprehensive understanding of the underlying factors that affect their prices.

APPENDIX

Appendix A. Correlogram and lag-order selection criteria for Thai rice

Graph 4. *Correlogram of the differences in the average monthly price of Thai rice.*

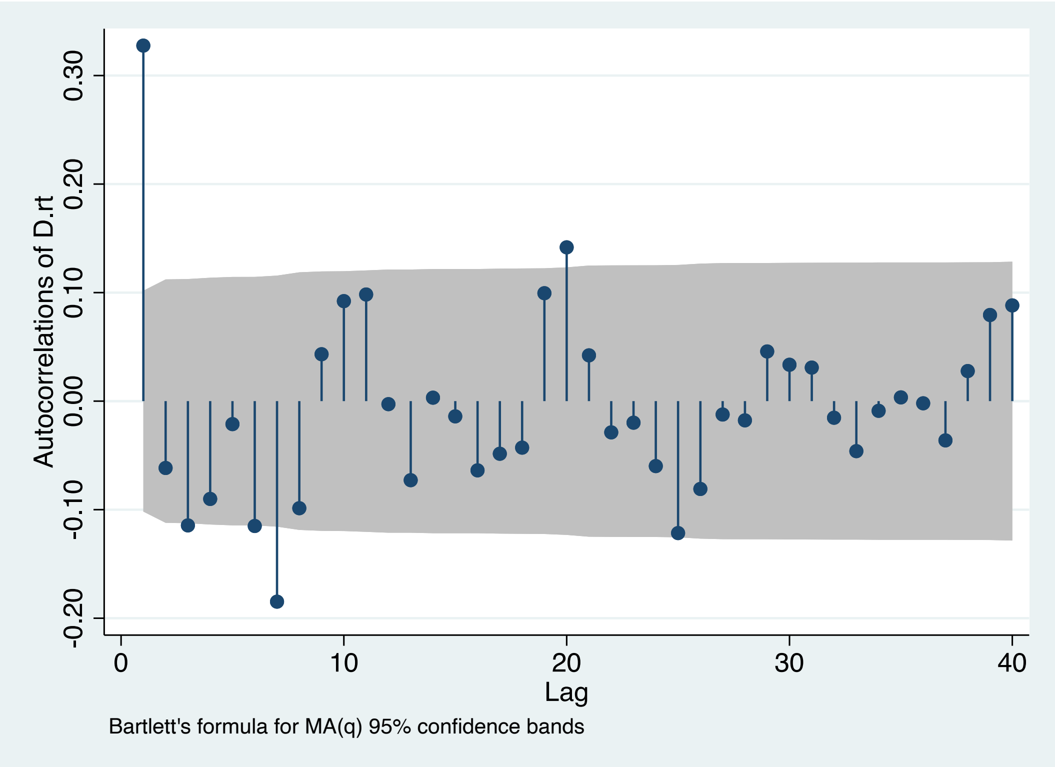


Figure 3. *Lag-order selection criteria for Thai rice.*

Sample: **1990m6** thru **2020m12** Number of obs = **367**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1730.67				734.361	9.43688	9.44111	9.44752
1	-1709.66	42.014	1	0.000	658.504	9.32785	9.3363	9.34913
2	-1702.92	13.473*	1	0.000	638.236*	9.29659*	9.30927*	9.32851*
3	-1702.72	.41109	1	0.521	641.006	9.30091	9.31783	9.34348
4	-1702.2	1.0282	1	0.311	642.706	9.30356	9.3247	9.35677

* optimal lag
Endogenous: **D.rt**
Exogenous: **_cons**

Appendix B. Correlogram and lag-order selection criteria for Philippine rice.

Graph 5. *Correlogram of the differences in the average monthly price of Philippine rice.*

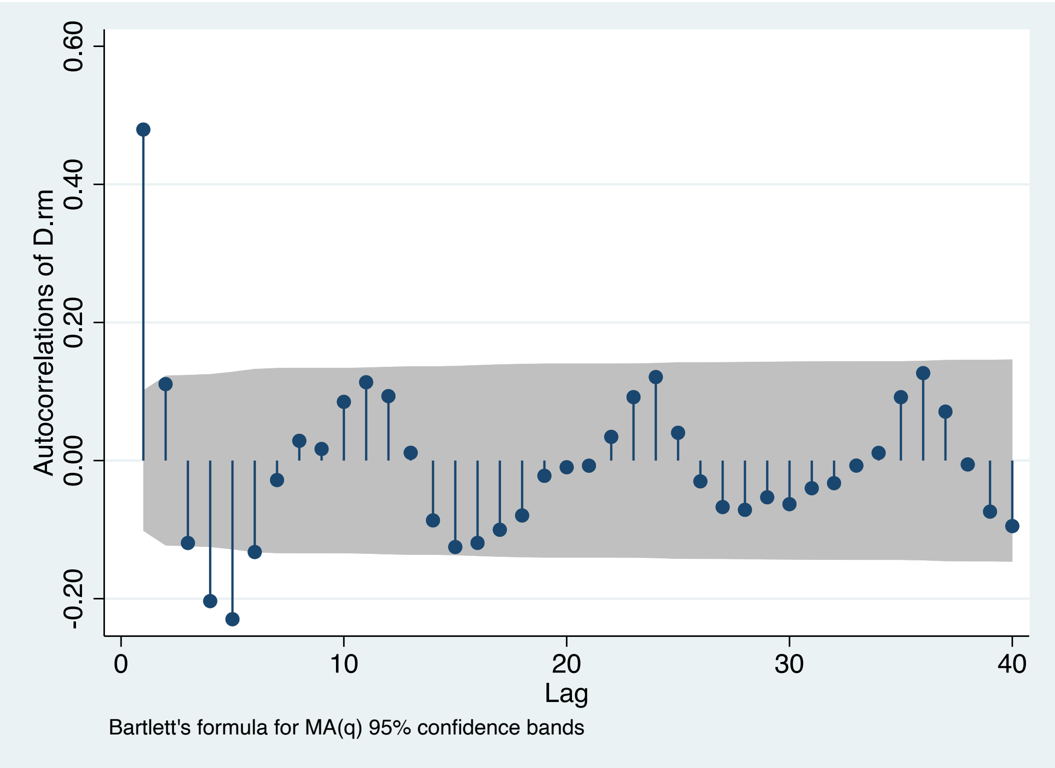


Figure 4. *Lag-order selection criteria for Philippine rice.*

Sample: **1990m6** thru **2020m12** Number of obs = **367**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-344.975				.385793	1.88542	1.88965	1.89607
1	-296.803	96.345	1	0.000	.298339	1.62835	1.63681	1.64964
2	-292.318	8.9688	1	0.003	.292728	1.60936	1.62205	1.64129
3	-288.646	7.3439*	1	0.007	.288496	1.5948	1.61172*	1.63737*
4	-287.263	2.7661	1	0.096	.287895*	1.59272*	1.61386	1.64592

* optimal lag
Endogenous: **D.rm**
Exogenous: **_cons**