Granger-causality between oil price and macrovariables: ARDL approach

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Granger-causality between oil price and macrovariables: ARDL approach

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Abstract

This paper makes an attempt to investigate the short and long-run Granger-causality between oil price and macrooeconomic variables. Russia is used as a case study. We apply a technique called Auto-Regressive Distributed Lag (ARDL) technique which takes care of the major limitations of conventional time-series techniques and allows us to test a mixture of stationary and non-stationary variables. Based on the exogeneity tests (VDC), we found that exchange rate is heavily influenced by oil price and inflation rate. VDC test results were in conformity with the ARDL test results where Oil price was the most exogenous variable. The study also found that value of ruble is in contrast with the inflation rate in Russia. This is in line with the PPP theory which states that exchange rate and inflation move in the opposite direction proportionately. However, our results support the PPP theory partially as 1% change in inflation depreciates Russian ruble by 2.24%.

These findings are intuitive and plausible and have major policy implications for countries like Russia.

Keywords: Oil price, Economic growth, Exchange rate, CPI, ARDL, VECM, VDC

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1. Introduction

In recent years we experienced immense uncertainty in the commodity price movements. Despite overall stable inflation rates, oil price has been fluctuating rather unexpectedly. This is worrying for those nations that rely on oil exports to sustain the nation's economic wellbeing. This is especially true in the case of Russia. Russian government has been trying to diversify its economy from oil dependency. But these efforts took a huge hit due to political and economic sanctions after the 2014 Russian invasion of Crimea. Russian economy sank into decade low in all aspects, such as high inflation and plummeting Russian Ruble.

The consequence of such dependencies of large economies on oil, many researchers have attempted to estimate whether there is a Granger-causality between oil and economic variables. Several studies made about developed countries found that increase in the oil prices decreases the output. On the other hand, there are also studies which found that this relationship is more limited to developing countries. (Vincent & Bertrand, 2011; Arize, Osang, & Slottje, 2000).

Therefore, one ponders the extent of oil price's impact on a nation's economic variables. This becomes especially intriguing in times of rigid economic sanctions.

We found that oil price indeed plays a very important role in determining the economic growth of Russia. Economic growth variables in this sense are attributed to inflation, exchange rate of nation's currency and unemployment rate.

i. *The objective of the study:*

The main objective of the study is to empirically investigate the long-run relationship (causality) between oil price changes, exchange rate of Russian Ruble and Russian economy by using the time-series technique.

ii. *Questions of the study:*

Following are the questions this study aims to answer:

- What is the causality between the oil price changes and exchange rate in Russia as an oil-exporting nation?
- What is the impact of this relation on Russian economic growth?

iii. *Contribution of the paper:*

There are not many literature reviews on the causality between oil prices and Russian ruble exchange rates. The study attempts to fill this gap. Secondly, Russian economy has been greatly damaged due to economic sanctions placed on the nation by the US and the EU in 2014. This study includes these groundbreaking events in its dataset from 1997 to 2017.

Following section reviews relevant researches on oil price and exchange rate causality. It is followed by section 3 where the Theoretical specification, data and methodology is explained. Empirical results are discussed in section 4. Conclusion and the policy implications are discussed in the final section.

2. Literature review

The existence of relationship between oil prices and exchange rates of both importing and exporting countries was proven by numerous research studies. In the case of increase (decrease) of an importing (exporting) good price, if demand is very inelastic, it leads to the trade balance deterioration, which in turn will cause the depreciation of the currency value.

The study of Kin and Courage (2014) used GARCH test to examine the impact of oil prices on the nominal exchange rate in South Africa as an importing oil country. The research used monthly data between 1992 to 2012. The results of the study showed that there is a significant impact of oil prices on nominal exchange rate. The two variables have negative relationship where the increase of oil prices lead to the depreciation of the exchange rate.

The results of Aziz (2009) study conducted on 5 importing countries and 3 exporting ones to examine the long run effect of oil prices and real interest rate on the real exchange rate showed that the future oil price shocks would lead to a depreciation of exchange rate on oil importing countries in the long run.

Another study conducted by the Uddin et al. investigated the relationship of oil price and exchange rates for both importing and exporting countries. The results showed that an oil-exporting country may experience a currency appreciation when oil price rise and depreciation when oil prices fall; whereas, the reverse effect was witnessed in the case of an oil-importing country. Another article from the same authors specifically studied the relationship between oil prices in Japan and Japanese Yen. The findings showed that the strength of the relationship between these two variables keeps changing over time. This would mean that in order to establish more steady currency Japan should emphasize oil prices shocks (Uddin, Tiwari, Arouri, & Teulon, 2013).

Since energy is a crucial part of the production process, the increase in oil prices would cause the production cost to increase and the amount of the expected profits for non-oil related Companies decrease. Moreover, oil importing countries would face the raise in the overall trade deficit with the increase of the oil price. A growing trade deficit will in turn cause future depreciation of the current exchange rate accompanied by higher inflation rate.

Aloui, Safouane, & Aïssa (2016) explained that the effect of oil price movements on the exchange rate is justified by the potential impact of oil shocks in driving term of trade movements.

There are plentiful studies that focused on different channels of the economic activities that were affected by the changes in oil price. Many of them determined significant impact of oil price movements on consumer prices as oil is used in most consumer productions activities. Historical evidence showed that oil prices per barrel in the 1970's rose dramatically, causing the consumer prices to move in the same direction. However, there is probability of the results not being always effective and varying over the time.

The paper of Salisu et.al (2017) studied the role of asymmetries in oil price-inflation relationship for selected net oil exporting and net oil importing countries. The findings show evidence that oil prices have a greater long run impact on inflation of net oil importing countries than oil exporting forerunners.

The effect of global price movements on domestic inflation was examined in the paper of Ribeiro et. al (2017). The study used an unbalanced panel of 72 advanced and developing economies over the period from 1970 to 2015. The findings showed that a 10 percent increase in global oil price increases, on average, domestic inflation by about 0.4 percentage point on impact, with the effect vanishing after two years. The results were similar between advanced and developing economies.

Oil price-inflation nexus in high and low oil dependency countries was investigated by Sek, Teo and Wong (2015). The results of the study showed that the oil price fluctuations have direct effect on domestic inflation in high oil dependency countries, whereas the impact is indirect on affecting the domestic inflation in low oil dependency countries.

Shanying's et al. 2012 research showed that oil price fluctuations driven by political events mainly produce short-term effects on output and inflation in China, while the shocks specific to the crude oil market produce relatively long-term effects.

Nevertheless, many other studies shown limited impact of oil prices on inflation. Blanchard and Gali (2007) explain the oil price shocks does not have too much impact on the prices due to the following reasons. The first reason might be the possibility that consumers are not dependent much on the oil for production and consumption. Second reason might be the effective and credible monetary policy. Another reason could be due to a decrease in real wage rigidities.

No long run impact of oil price shocks on inflation was detected in the study of Jiranyakul (2016). This study used monthly data from 1993 to 2015 to conduct an empirical study on the relationship between oil prices shocks and domestic inflation in Thailand using the two-step approach and co-integration test.

No effect of the oil price movements on the inflation excluding energy and food prices was found from the study of Evans and Fisher's (2011). Their results also conclude that since 1980s there is a little impact of sharp increases and decreases of oil prices on the core inflation.

3. Theoretical Specification, data and methodology

i. Sources of Data and Variables

The research employs quarterly data from 1997 to 2017 to examine the long-run relationship between variables. All the data is extracted from the DataStream.

Table 1 – Variables:

Variables	**Definition**
EX	Exchange rate: Ruble per USD
OP	Oil price
CPI	Consumer Product Price Index
PPI	Producer Product Price Index
GDP	Gross Domestic Product
UR	Registered unemployment

ii. Economic Methodology

To examine the relationship between the variables we could use cross-sectional regression or time series approach. But cross-sectional regression method has major limitations in terms of testing the lead-lag relationship. Additionally, the method makes bold assumptions such as parameters (mean and variance of the variables) remain constant. This assumption is not applicable and not true in real world situation. Especially in the case of developing country such as Russia. The time-series studies of individual countries are more appropriate for testing the temporal or lead-lag relationship between variables (Masih et al., 2009).

Even though conventional cointegration methods made huge advances in regression analysis, by testing the stationarity and cointegration properties of the time series involved, the cointegrating estimates also are subject to several limitations (Masih et al., 2008). For instance, the Engle-Granger test is not able to produce all of the possible cointegrations between variables, and Johansen test requires the variable to be I(1) format.

Therefore, we employ The Auto-Regressive Distributive Lag (ARDL) method (also known as the bounds testing approach) proposed by Pesaran-Shin-Smith (2001). The ARDL approach does not necessarily require the restrictions imposed by cointegration technique that the variables are to be I(1) or I(0). (Pattichis, 1999; Mah, 2000; and Tang and Nair, 2002).

The ARDL technique is conducted in two stages. The first stage tests the existence of a long-run relationship among the variables. We will construct an unrestricted error correction model (VECM) with each variable in turn as a dependent variable. The null hypothesis will be "there is no long run relationship". The model will test whether the 'lagged levels of the variables' in each of the error correction equations are statistically significant or not (i.e., whether the null is accepted or rejected).

The joint significance of the 'lagged levels of the variables' in each of the above error-correction form of the equation will be tested by computing an F-statistic. Then the computed F-statistic is compared to two asymptotic critical values. The null hypothesis of 'no long-run relationship' can be rejected if the test statistic is above an upper critical value regardless of whether the variables are I(0) or I(1). On the other hand, the null hypothesis of 'no long-run relationship' is accepted when the test statistic falls below a lower critical value regardless of whether the variables are I(0) or I(1). However, if the test statistic falls between these two bounds, the result is inconclusive. In this case the researcher may have to carry out unit root tests on the variables.

The first stage will show whether there is any long run relationship. The second stage of the analysis will identify exogeneity and endogeneity of the variables through ECM test. And then we will estimate the adjustment coefficients of the error-correction term. Since the data are quarterly, we chose four for the maximum order of the lags in ARDL model and carry out the estimation over the period of 1997 to 2017.

iii. Model specification

The ARDL model specification of functional relationship between the exchange rate (EX), Oil Price (OP), Consumer Product Price Index (CPI), Producer Product Price Index (PPI), Gross Domestic Product (GDP) and Registered unemployment (UR) can to estimated as below:

$$DEX_t = \alpha_0 \sum_{i=1}^{k} b_1\, DEX_{t-1} + \sum_{i=1}^{k} b_2\, DOP_{t-1} + \sum_{i=1}^{k} b_3\, DCPI_{t-1} + \sum_{i=1}^{k} b_4\, DPPI_{t-1} + \sum_{i=1}^{k} b_5\, DGDP_{t-1} + \sum_{i=1}^{k} b_6\, DUR_{t-1} + b_7 LEX_{t-1} + b_8 LOP_{t-1} + b_9 LCPI_{t-1} + b_{10} LPPI_{t-1} + b_{11} LGDP_{t-1} + b_{12} LUR_{t-1} + \mu_t$$

ARDL bounds technique considers both I(0) and I(1) type of variables. The error correction version of the model is as follows:

$$DEX_t = \alpha_0 \sum_{i=1}^{k} b_1\, DEX_{t-1} + \sum_{i=1}^{k} b_2\, DOP_{t-1} + \sum_{i=1}^{k} b_3\, DCPI_{t-1} + \sum_{i=1}^{k} b_4\, DPPI_{t-1} + \sum_{i=1}^{k} b_5\, DGDP_{t-1} + \sum_{i=1}^{k} b_6\, DUR_{t-1} + b_7 ECT_{t-1}$$

Where, ECT is lagged error correction term. The hypothesis that we will be testing is the null of “non-existence of the long-run relationship”:

H0: b1 = b2 = b3 = b4 = b5 = b6 = 0

Against, existence of a long-run relationship.

H0: b1 ≠ b2 ≠ b3 ≠ b4 ≠ b5 ≠ b6 ≠ 0

4. Empirical results and discussions

i. Unit Root test

In their raw form, most financial data is non-stationary. This one of the reasons why we did not perform ordinary regression to test the relationship between our variables. OLS assumes that variables are stationary and therefore its results are biased. If any variable is non-stationary and there is a cointegration, OLS without the error-correction term derived from the cointegrating equation is misspecified. Non-stationarity of any variable can be fixed by taking the first difference of the data. This way the cointegration between the variables can be tested by OLS. But taking the differenced form of the variable removes its theoretical aspect and results from this test is only applicable for short term basis as stationary variable doesn't contain the theoretical information.

We start off the test with examining if the data is stationary or non-stationary. The expectation is, we expect all variables to be stationary in their differenced forms and non-stationary in their log forms. To perform the Johansen test reliably, all the variables are to be in non-stationary form.

We carried out three types of stationarity tests, namely Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and KPSS. ADF corrects the autocorrelation problem. PP corrects both the autocorrelation and heteroscedasticity problems by using Newey-West adjusted-variance method. We employed ADF and PP tests for this research:

Table 2 - Unit Root test results:

ADF							
Log form				**Difference form**			
Variable	**T-stat**	**C.V.**	**Result**	**Variable**	**T-stat**	**C.V.**	**Result**
LEX	0.77685	-1.9828	NS	DEX	-8.3191	-1.855	S
LOP	0.47627	-1.9828	NS	DOP	-4.6466	-1.9735	S
LCPI	1.6267	-1.9828	NS	DCPI	-6.5844	-1.9735	S
LPPI	2.0065	-1.9828	S	DPPI	-2.5012	-1.9003	S
LGDP	-0.09943	-1.9828	NS	DGDP	-6.0895	-1.9003	S
LUR	-0.91571	-1.9828	NS	DUR	-4.2023	-1.855	S
PP							
Log form				**Difference form**			
Variable	**T-stat**	**C.V.**	**Result**	**Variable**	**T-stat**	**C.V.**	**Result**
LEX	-2.9799	-2.952	S	DEX	-8.3191	-2.8553	S
LOP	-1.7814	-2.952	NS	DOP	-3.2355	-2.8553	S
LCPI	-5.2281	-2.952	S	DCPI	-3.8247	-2.8553	S
LPPI	-5.6969	-2.952	S	DPPI	-5.7415	-2.8553	S
LGDP	-2.6337	-2.952	NS	DGDP	-7.3517	-2.8553	S
LUR	-1.5812	-2.952	NS	DUR	-3.6041	-2.8553	S

Notes: The ADF and PP are used to test the stationarity of the variables both in level form and difference form. The null hypothesis in level form is, variables are non-stationary. Hence, when Test statistics (95% confidence level) is less than the critical value (in *absolute terms), we conclude the variable is non-stationary. In the difference form, when the t-statistics are more than the critical value, we reject the null hypothesis and concludes the variable is stationary.*

The results of the tests show that we have a mix of both stationary and non-stationary variables in their raw form. Since the results of the stationarity tests are not consistent, we cannot suffice with Engle-Granger and Johansen tests for cointegration tests. Thus, we decided to use ARDL technique to test for long-run relationship among our variables. Before we proceed to carrying out the test of cointegration, we determine the order of the vector auto regression (VAR), the number of lags to be used.

ii. VAR order selection

Once we generate the VAR model table, we find the highest value of AIC and SBC to identify the corresponding lag order. If they are not in conformity we may look at Adjusted LR test as well.

<u>*Table 3 – VAR order selection:*</u>

Order	LL	AIC	SBC	LR test	Adjusted LR test
6	1151.8	929.7532	671.0418	------	------
5	1119.5	933.5372	716.7790	CHSQ(36)= 64.4320[.002]	33.0638[.609]
4	1080.5	930.4639	755.6589	CHSQ(72)= 142.5785[.000]	73.1653[.440]
3	1054.9	940.9046	808.0528	CHSQ(108)= 193.6971[.000]	99.3972[.711]
2	1012.4	934.4029	843.5043	CHSQ(144)= 278.7006[.000]	143.0174[.507]
1	933.8075	891.8075	842.8621	CHSQ(180)= 435.8912[.000]	223.6810[.015]
0	776.7011	770.7011	763.7089	CHSQ(216)= 750.1042[.000]	384.9219[.000]

It is evident there is a conflict between the recommendations of AIC and SBC. This can be interpreted as an inherent nature of time series data of our study. As we have yearly data and observation is only 30, we take maximum 3 VAR order, AIC gives us 3 lags whereas SBC shows us 2 lags. In order to proceed to the next stage, we have decided to choose 2 lag order.

iii. Cointegration tests

In this step, we check if our variables are moving in the same direction meaning cointegrated in the long-run to test the theoretical relationship among the variables. We performed

Engle-Granger and Johansen tests of cointegration for our purpose. The main difference between the two approaches is former is based on residual approach while the latter is based on maximum likelihood approach.

The null hypothesis for both tests is "there is no cointegration between the variables".

Table 4 – Johansen cointegration test results: Based on Maximal Eigenvalue of the Stochastic Matrix

Null	Alternative	Statistic	95% Critical Value
r = 0	r = 1	72.1358	43.6100
r<= 1	r = 2	41.7374	37.8600
r<= 2	r = 3	31.6401	31.7900
r<= 3	r = 4	18.1083	25.4200
r<= 4	r = 5	16.1258	19.2200
r<= 5	r = 6	8.1162	12.3900

Table 5 – Johansen cointegration test results: Based on Trace of the Stochastic Matrix

Null	Alternative	Statistic	95% Critical Value
r = 0	r>= 1	187.8635	115.8500
r<= 1	r>= 2	115.7277	87.1700
r<= 2	r>= 3	73.9903	63.0000
r<= 3	r>= 4	42.3503	42.3400
r<= 4	r>= 5	24.2420	25.7700
r<= 5	r = 6	8.1162	12.3900

From Johansen cointegration test results based on Maximal Eigenvalue of the Stochastic Matrix we observe to have two cointegrations, while from Johansen cointegration test results based on Trace of the Stochastic Matrix we observe four possible cointegrations at 95 percent critical value. When the T-statistics is higher than the critical value, we accept the suggested alternative.

The inconsistencies in the results is attributed to the limitations of the cointegration tests employed at this stage with variables that are mix of stationary and non-stationary datasets. To ensure the robustness of the research, we reserve to ARDL technique and disregard the results obtained in Engle-Granger and Johansen cointegration tests.

iv. The Auto-Regressive Distributive Lag (ARDL)

We employ The Auto-Regressive Distributive Lag (ARDL) method (also known as the bounds testing approach). The ARDL technique is conducted in two stages. The first stage tests the existence of a long-run relationship among the variables.

Table 6 – Testing the existence of Long-run relationship (Variable addition test):

Long term relationship			
Variables	**F-value**	**CV lower**	**CV upper**
DEX	7.4177*	2.7616	3.9979
DOP	4.4529*	2.7616	3.9979
DCPI	23.7267*	2.7616	3.9979
DPPI	2.092	2.7616	3.9979
DGDP	6.6896*	2.7616	3.9979
DUR	0.85855	2.7616	3.9979

Note: * denotes significant at 5 percent level

Table 6 shows the F-statistics and the lower I(0) and upper I(1) critical values to test against. The null hypothesis for the test is "there is no cointegration".

We observe that most of our variables are higher than the upper critical value 3.9979 at the 5% significance level. This implies that we can reject the null hypothesis and conclude there is long-run relationship between our variables. Evidence of long-run relationship leaves no the possibility of any spurious relationship existing between our variables. In other words, there is a theoretical relationship between the variables.

Since we have established the theoretical relationship between the variables, we will now proceed to confirm the short-term and long-term relationship.

Table 7 - Estimated Long-Run Coefficients using the ARDL Approach:

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
LOP	-6.6547	3.9619	-1.6797[.098]
LCPI	2.2419	.68006	3.2966[.002]
LPPI	-1.5009	.60989	-2.4609[.017]
LGDP	-.20377	.12498	-1.6304[.108]
LUR	-.53873	.15220	-3.5396[.001]
INPT	34.2771	19.0030	1.8038[.076]

We estimate the ARDL long-run coefficients for the model. The estimated long run coefficients of the long run relationship in Table 7 show that Consumer Product Price Index, Producer Product Price Index and surprisingly, Registered unemployment rate have significant effects on the exchange rate movements in Russia at 5% significance level. One of our focus variable, the oil price, show the highest coefficient at 10% significance level. The strongest influencer at 5% significance level was Consumer Product Price Index. This result is partially in sync with PPP theory which states that states that change in the inflation effects exchange rate at the same percentage but negatively. The direction of the relationship between inflation and the exchange rate is in line with PPP theory where increase in inflation causes depreciation of Russian ruble. However, the level of change is not parallel, where 1% change in inflation depreciates Russian ruble by 2.24%. One counter intuitive result of the Long-run coefficient test was the significant relationship between unemployment rate and exchange rate volatility. There is a negative relationship between the exchange rate movement and rate or unemployment. It can be attributed to the competitive advantage businesses aim to get when ruble depreciates.

The Gross domestic product and the oil price were found to have no significant relationship with the exchange rate movement in Russia.

So far, we found that there is a long-run relationship between the variables. But we still do not know if there is a possibility of a short-run deviation from the long-run equilibrium. We look at Error correction model to understand the adjustment process to equilibrium. The ‘t’ ratio and the ‘p’ value of the error-correction coefficient shows if deviation from equilibrium has a significant feedback effect on the dependent variable (i.e. exchange rate).

Table 8 - Error Correction Models:

Independent Variable	*Coefficient*	*Standard Error*	*P-Value*
ΔOP	-1.9358	1.1684	0.102
ΔCPI	2.1018	0. 24585	0.000*
ΔPPI	0. 49289	0.25128	0. 054
ΔGDP	-0.035375	0. 018037	0. 054
ΔUR	0.15391	0.072166	0.038*
ΔIntercept	-0.093526	0. 027296	0.001*
Ecm(-1)	-0.17360	0. 039696	0.000*

The error correction coefficient estimates that at -0.17360 (0.000) is highly significant with the correct sign and implies moderate speed of adjustment to the equilibrium after the shock. Majority of the coefficients show that they return to the equilibrium within the same quarter. We also find that our dependent variable (exchange rate) is significant and not in short term.

v. Variance decomposition (VDC)

We have identified which on the variables are leading and which are lagging. But we have not been able to say much about the relative endogeneity and exogeneity of the variables. VDC decomposes variance of forecast error for each variable to proportions attributable to shocks from each variable in the system, including its own. The least endogenous variable is therefore that variable is explained mostly by its own past variations.

There are orthogonalized and generalized variance decompositions, and we will use generalized method as orthogonalized method is biased towards the first variable and when one variable is shocked the other variables are switched off.

Table 9 – Generalized VDC results:

	Variables	LEX	LOP	LCPI	LPPI	LGDP	LUR	Total	Rank
Horizon 5	LEX	37.06%	15.53%	29.25%	3.20%	13.86%	1.11%	100.00%	5
	LOP	0.93%	79.37%	1.13%	13.13%	4.63%	0.82%	100.00%	1
	LCPI	36.28%	9.19%	46.35%	1.61%	5.75%	0.82%	100.00%	3
	LPPI	9.45%	4.94%	39.41%	42.65%	0.09%	3.45%	100.00%	6
	LGDP	8.33%	29.33%	13.87%	4.71%	43.56%	0.20%	100.00%	4
	LUR	0.84%	32.90%	0.54%	0.95%	0.39%	64.40%	100.00%	2

	Variables	LEX	LOP	LCPI	LPPI	LGDP	LUR	Total	Rank
Horizon 10	LEX	34.15%	15.13%	25.84%	3.13%	19.58%	2.17%	100.00%	4
	LOP	1.80%	76.41%	2.26%	12.93%	5.88%	0.73%	100.00%	1
	LCPI	36.15%	8.91%	44.87%	2.09%	6.10%	1.87%	100.00%	3
	LPPI	7.60%	2.05%	42.04%	43.52%	0.13%	4.66%	100.00%	6
	LGDP	7.65%	35.16%	14.37%	7.10%	35.32%	0.40%	100.00%	5
	LUR	0.89%	36.54%	0.41%	1.53%	0.17%	60.46%	100.00%	2

	Variables	LEX	LOP	LCPI	LPPI	LGDP	LUR	Total	Rank
Horizon 15	LEX	32.34%	14.88%	23.68%	2.84%	23.78%	2.48%	100.00%	4
	LOP	2.66%	74.34%	3.32%	12.36%	6.52%	0.81%	100.00%	1

	LCPI	36.29%	8.47%	44.61%	2.14%	6.15%	2.34%	100.00%	3
	LPPI	7.04%	1.25%	42.79%	43.56%	0.18%	5.19%	100.00%	6
	LGDP	5.92%	41.41%	11.90%	9.97%	30.44%	0.36%	100.00%	5
	LUR	0.68%	38.20%	0.27%	1.90%	0.12%	58.83%	100.00%	2

Horizon 20	**Variables**	**LEX**	**LOP**	**LCPI**	**LPPI**	**LGDP**	**LUR**	**Total**	**Rank**
	LEX	30.94%	14.86%	22.05%	2.62%	26.98%	2.56%	100.00%	4
	LOP	3.34%	72.84%	4.13%	11.89%	6.90%	0.89%	100.00%	1
	LCPI	36.36%	8.24%	44.49%	2.16%	6.18%	2.57%	100.00%	3
	LPPI	6.45%	0.90%	43.11%	43.53%	0.21%	5.46%	100.00%	6
	LGDP	4.70%	45.75%	9.77%	12.28%	27.20%	0.29%	100.00%	5
	LUR	0.52%	39.26%	0.20%	2.17%	0.10%	57.74%	100.00%	2

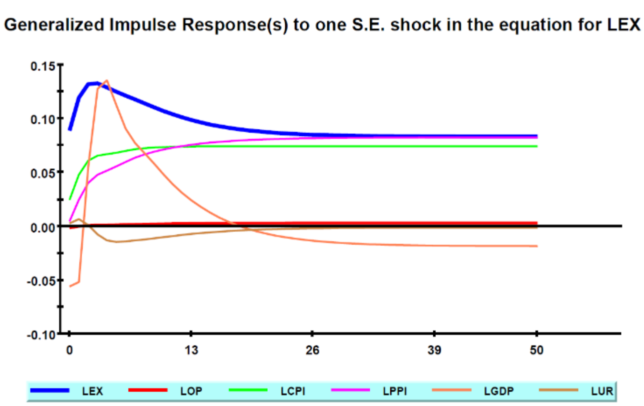
The generalized variance decomposition analysis of 10 quarter number explains the contribution of its own shocks by explaining the error variance forecast of each variable.

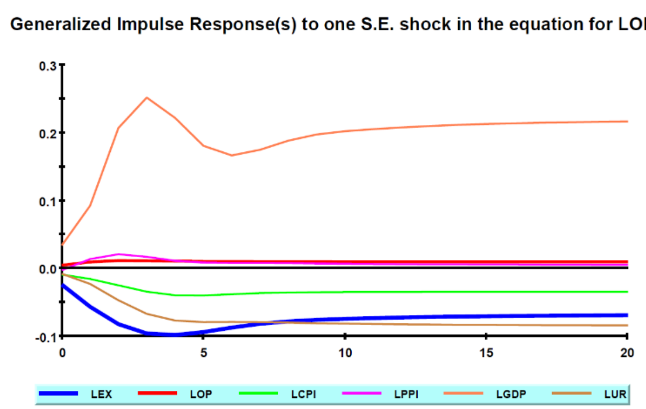
The results show all our focus variables are exogenous except for GDP declining in exogeneity below exchange rate after 10 quarters. The results show that Oil price remains to be the most exogenous throughout the testing time horizon.

The result is in-line with literature discussed earlier and our intuitive expectations that Oil price and inflation played very important role is movement of exchange rate.

vi. Impulse Response Function

The impulse response function generates similar or same results as the VDC results. But it is in the form of graphs. We expect that if a leading variable is shocked, the response of weak variable will be significant.

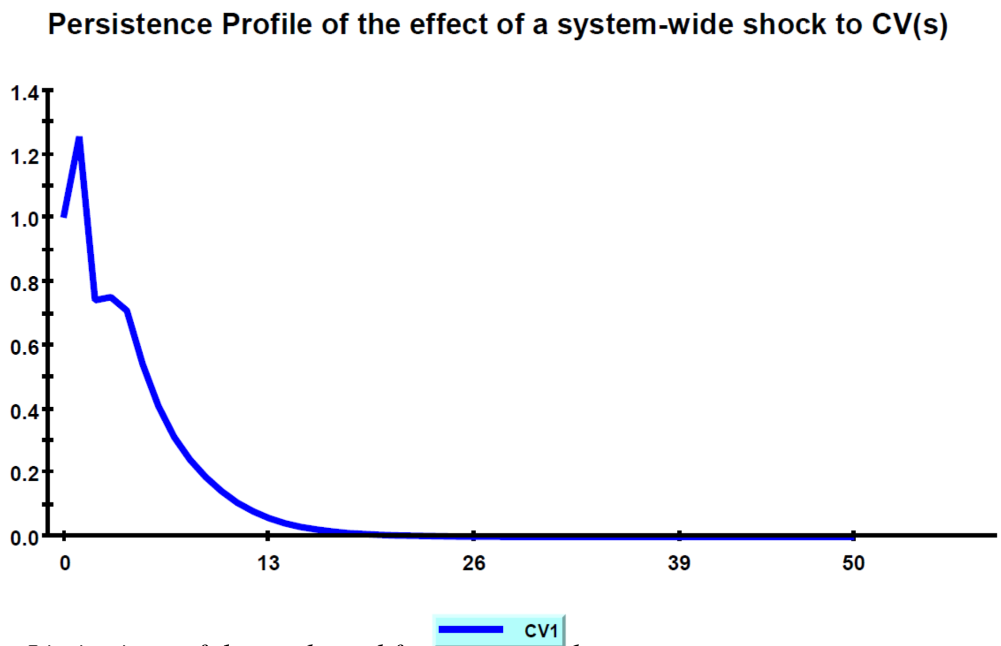




We can clearly observe that shocks on Oil price had strong negative effect on the exchange rate, inflation and unemployment rate in Russia.

vii. Persistence profile (PP)

The persistence profile (PP) illustrates the scenario when entire cointegrating equation is shocked and indicates the time horizon it will take for the relationship to get back to the equilibrium. Here the effect of a system-wide shock on the long-run relations is the focus. The chart below shows the persistence profile for the cointegrating equation of this study.



viii. Limitations of the study and future research.

This study has some limitations that can be subject to expansion in the future related researches. This is a single country research focused on Russia. More inclusive research may be of more substance as many other economies in the region are heavily dependent on oil export (e.g Ukrain). Additionally, sufficient annual data was not available, and this study was carried out using quarterly data. Finally, impact of economic sanctions was not studied exclusively. Future research can look into the effects of political sanction and implication on oil price.

5. Concluding remarks and policy implications

This study attempts to study the Granger-causality between the oil price, exchange rate, inflation rate and other economic variables such as gross domestic product and inflation rates in Russia as an oil exporting nation. We chose to employ The Auto-Regressive Distributive Lag (ARDL) technique due to the nature of our variables and limitations of other time-series techniques.

We found that there is a strong long-run relationship between mentioned the variables. Based on the exogeneity tests, we found that exchange rate is heavily influenced by oil price and inflation rate. VDC test results were in conformity with the ARDL test results where Oil price was the most exogenous variable of the bunch. The study also found that value of ruble is in contrast with the inflation rate in Russia. This is in line with the PPP theory which states that exchange rate and inflation move in the opposite direction proportionately. However, our results support the PPP theory partially as 1% change in inflation depreciates Russian ruble by 2.24%. One counter intuitive result of the Long-run coefficient test was the significant relationship between unemployment rate and exchange rate volatility. There is a negative relationship between the exchange rate movement and rate of unemployment. It can be attributed to the competitive advantage businesses aim to get when ruble depreciates.

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