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Do Oil Price Shocks Affect Exchange Rates in Oil-Importing Countries: A Case of the Zambian Economy using the SVAR Approach

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Abstract

Oil price shocks have been argued to impact Real Effective Exchange Rates (REERs) in net oil importing countries, mostly through the wealth-transfer effect, which involves the transfer of wealth from net oil-importers to net oil-exporters, and the Terms of Trade Channel. Since this analysis had not been done for the Zambian case by decomposing oil price shocks, a Structural Vector Autoregressive Model (SVAR) was used to measure the contemporaneous impact of oil price shocks on REERs, and was complemented by Impulse Response Functions (IRFs), Granger Causality Tests and Forecast Error Variance Decomposition (FEVD). The long-run impact was analyzed by the Vector Error Correction Model (VECM) after satisfaction of cointegration requirements.

The findings revealed that decomposed oil price shocks had no short-run contemporaneous impact on REERs at the 5% level. Similarly, it was found that decomposed oil price shocks and the combined effect of all the variables in the system did not granger-cause Zambia's REERs, while FEVD results showed that oil price shocks were attributed for a minute proportion of the variation in REERs. These findings were attributed to Zambia's profile as a predominantly copper and cobalt exporter, historic exchange rate controls, fuel subsidies, and price controls. Johansen's cointegration test revealed the existence of at least one cointegrated equation in the system, so the subsequent VECM which was constructed revealed that decomposed oil price shocks had no long-run impact on REERs in Zambia, but that the Error Correction Term (ECT) which measures the speed to adjustment back to equilibrium after a short-run disturbance, was significant.

Keywords: Oil Price Shocks, Structural Vector Autoregressive Model, Real Effective Exchange Rates, Vector Error Correction Model, Zambia

1. Introduction

Over time, there has been a large amount of research done on the nexus between oil prices and Real Effective Exchange Rates (REERs) since the seminal work of Trehan & General (1986), who explained the necessity of appreciating the fundamentals which influence the movement of REERs. The authors provided the initial impetus for further investigation by pointing out that oil price shocks which impacted the United States (U.S.) economy were likely to be exaggerated since oil prices are quoted in U.S. dollars. The literature largely shows that there are two transmission mechanisms at work when crude oil prices and currency rates are considered. Firstly, Amano & Van Norden (1998) asserted that the Terms of Trade (ToTs) channel was a crucial mode of transmission. According to the authors, if the non-trading sector is more reliant on crude oil than the tradable sector, higher oil prices result in real currency appreciation. Meanwhile, if the tradeable sector consumes more oil than the non-tradeable sector, rising oil prices will result in a considerable devaluation of the domestic currency due to increased production costs which cause loss in competitiveness and subsequently worsen the trade balance of oil-importing countries. The second is referred to as the "wealth transmission channel", which Krugman (1983) popularized. It explains that, as oil prices rise, wealth is transferred from oil-consumers to oil-exporters. Thus, when oil prices rise, importers must pay more, which causes their currencies to depreciate. The authors argued that as a result of portfolio reallocation and current account surpluses, real appreciation of exchange rates in oil-exporting countries increases.

Therefore, since a country-specific study focused on determining the impact of oil price shocks on REERs had not been conducted for the Zambian case by decomposing oil price shocks, it was not known whether they affected REERs in Zambia, which is a small open economy which imports all the oil which it uses. Studies such as Nkomo (2006) which partially presented the Zambian case using an elasticity approach to determine oil-vulnerabilities, did not consider the impact on REERs. Moreover, Kilian & Park (2009) showed the inadequacy of the methods which they used by proving that different sources of oil price shocks, such as aggregate demand, supply, and oil-specific demand shocks, affected macroeconomic variables in different ways since they were qualitatively and quantitatively different. In addition to their homogenous treatment of oil price shocks, earlier studies used models which treated oil prices as exogenously determined and did not distinguish between short and long-run effects. For this reason, a Structural Vector Autoregressive Model (SVAR) was used to measure the short-run impact of decomposed oil price shocks on REERs and was complemented by Impulse Response Functions (IRFs), Granger Causality Tests, and Forecast Error Variance Decomposition (FEVD). The long-run impact was analyzed using the Vector Error Correction Model (VECM) after satisfaction of cointegration requirements.

2. Literature Review

The bulk of empirical literature on the impact of oil prices on exchange rates has mainly focused on net oil-exporters and developed countries. For instance, Ji et al. (2020) studied the impact of oil price shocks on REERs and discovered that oil supply shocks devalue REERs more in oil-producing countries than in oil-importing countries. Furthermore, using a Markov-switching model, Beckmann et al. (2017) discovered a statistically significant association between higher real oil prices and a real appreciation of the U.S. dollar, where a depreciation in the real value of the U.S. dollar resulted in a rise in real oil prices. Similarly, the relationship between crude oil prices and the Euro/US dollar exchange rate was investigated by Jawadi et al. (2016) using a Generalized Autoregressive Conditional Heteroscedastic (GARCH) jump model. They discovered that a weakening of the U.S. dollar against the euro resulted in lower oil prices, demonstrating the importance of volatility transmission from currency exchange rates to the crude oil market. Moreover, despite increased crude oil production, the currencies of oil-importing countries depreciated against the U.S. dollar, whilst the currencies of oil-exporting countries strengthened. As espoused by economic theory, cheaper inputs from reduced oil prices are expected to raise output and increase ToTs, thus leading to a currency appreciation for net oil-importers.

Using various copula-based models and CoVaR measurements, Wu (2012) studied the nonlinear link between oil prices and REERs in oil-importing and exporting countries, but since Wu differentiate between different types of oil price shocks, the study was unable to conclusively provide statistical evidence of the influence of specific oil shocks on a country's REERs. In addition to the purchasing power channel on the supply side, Austvik (1987) proposed that there also exists a local pricing channel on the demand side, where fluctuations in the value of the U.S. dollar are argued to cause disequilibrium in the oil market since worldwide oil prices are quoted in U.S. dollars, which fluctuate in value like any other currency. Frankel (2006) added that tying oil export prices to the dollar aggravates volatility, while Mundell (2002) recommended invoicing in special drawing rights (SDR) as a solution to this problem.

Notably, Alhajji (2004) reported that the devaluation of the U.S. dollar had a negative impact on drilling activity in Europe and the Middle-East. Thus, consumers in non-U.S. dollar denominated regions benefit from the depreciation by making gasoline less expensive in their local currencies. The author discovered a statistically significant negative correlation (–0.81) between European demand for oil products and the U.S. Dollar/Euro exchange rate, thus revealing the presence of an asset channel. This channel was argued to be activated when the U.S. currency weakens, thus lowering the returns on U.S. dollar-denominated financial assets in the rest of the world, which consequently increases the appeal of oil as a financial asset. The author argued that the desirability of oil as an inflation-hedge increases due to the devaluation of the U.S. dollar, which raises the likelihood of inflationary pressure on the U.S. economy. Chen & Chen (2007) suggested that a currency market channel may be at work, since foreign exchange markets are claimed to be more efficient than crude oil markets, and hence better predict changes in the real economy which affects demand and supply of oil. The authors argued that this channel connects the U.S. Dollar to oil prices, although it reflects an inverse relationship.

Volkov & Yuhn (2016) claimed that equilibrium exchange rates are determined by fundamental macroeconomic variables such as inflation, output, and interest rates. Nevertheless, it is widely believed that empirical models based on market fundamentals have poor success in explaining exchange rate fluctuations (Meese & Rogoff, 1983). The argument supporting this viewpoint is that; because floating exchange rates between countries follow a random walk, basic variables do not aid in predicting potential changes in exchange rates (Engel & West, 2005). Several studies, however, have discovered that market-fundamental models, with commodity prices included, outperform their counterparts. For example, Golub (1983) built a stock/flow model of the impact of rises in oil prices on REERs. His model was concerned with the wealth-transfer effects which occur from rises in oil prices and the implications of these transfers on the maintenance of portfolio equilibrium. Lizardo & Mollick (2010) enhanced the fundamental monetary model for determining REERs by integrating oil prices. They discovered that swings in oil prices had a significant effect on the U.S. dollar's value in relation to other currencies, and that an increase in real oil prices resulted in a significant devaluation of the U.S. dollar. With regards to the long-run nexus, Ahmed & Moran (2013) evaluated the long-run link and asymmetry between real oil prices and the value of the real exchange rate in 12 oil-exporting countries using the Granger causality test, and discovered that cointegration existed in 6 of the 12 countries which were studied.

Numerous researchers such as Akram (2004) have examined the effects of oil prices on the REERs of currencies other than the U.S. dollar. According to Chen & Chen (2007), “In the case of freely floating commodity currencies, there appears to be more evidence that commodities are influenced by currencies than the other way around". Conversely, using an SVAR model, Cashin et al. (2004) found that a more comprehensive sample of commodity currencies, showed an inverse relationship. Importantly, Basher et al. (2016), and Akram (2004), discovered a negative association between oil price shocks and REERs for net oil-importing countries, a finding which was consistent with economic theory. In the case of net-exporters, Fratzcher et al. (2014) discovered a bi-directional causality, whereas Buetzer et al. (2016) discovered that oil prices had no observable effect on REERs. Notably, Coleman et al. (2011) showed that oil prices were cointegrated with REERs in some African countries but not in others. These discrepancies in the findings of previous studies necessitated a country-specific study to add to the body of available knowledge on the dynamics of the Zambian Kwacha's exchange rate. The literature generally indicates a positive relationship between oil prices and REERs in oil-exporting countries, while the converse is true for oil-importing countries.

3. Methodology

3.1. Sample

This study utilized quarterly data from 1985-2019. This period was sampled due to the data-availability and the importance of the post-1983 period which was identified by researchers such as Hamilton (2003) as having witnessed changes in the global oil market.

3.2. Description of Variables and Sources of Data

3.2.1. Global Oil Production (woilp): Global oil production data was obtained from the U.S. Energy Information Administration (EIA) and used to proxy global supply.

3.2.2. Global Oil Prices (boilp): Real Brent Crude Oil prices were used to proxy oil-specific demand since Brent Crude is the blend which is used by the Organization of Petroleum Exporting Countries (OPEC), and is the leading global price benchmark used to set the price of two-thirds of the world's internationally traded crude oil supplies. The data series was obtained from the World Bank and following Barsky & Kilian (2002), the nominal price of oil was deflated by the U.S. Consumer Price Index (CPI) available from the U.S. Bureau of Labor Statistics.

3.2.3. Global Economic Activity (bdi): The Baltic Dry Index was used to proxy global economic activity. The rationale of using this index was that increases in dry cargo ocean shipping rates, given a largely inelastic supply of suitable ships, was indicative of higher demand for shipping services arising from increases in global economic activity. Klovland (2009) also reported that the total shipping freight volumes operates at near full capacity, so the supply curve of shipping becomes virtually vertical. In other words, as economic activity increases relative to shipping volumes, freight rates tend to increase. As shown by Kilian & Zhou (2018), this index is superior to other measures of global economic activity since measures such as the Organization of Economic Cooperation and Development (OECD) industrial production index exclude real economic activity from China, Brazil, India and other countries, who singularly and collectively account for a significant proportion of global demand.

3.2.4. Real Effective Exchange Rate (reer): Historical data for Zambia was collected from the World Bank. Monthly data was converted into quarterly frequency using simple averaging.

3.3. Specification of Short-Run Model: SVAR

In accordance with by Kilian & Park (2009), data analysis was done by the application of a recursively identified SVAR which measured the contemporaneous impact of disaggregated oil price shocks on REERs. Therefore, to estimate the SVAR and develop IRFs and FEVDs, the equation below was identified by imposing restrictions on the elements in matrix A.

$$A z_t = \phi_0 + \sum_{i=1}^{p} \phi_i z_{t-i} + e_t \qquad (1)$$

Where A is a (4×4) matrix of contemporaneous relations among the endogenous variables and ϕ_i is a matrix of constants; e_t represents white noise, i.e. serially and mutually uncorrelated structural innovations that are independent and identically distributed (iid) with mean 0 and variance $\sum_p$, z_{t-i} are lagged variables.

Kilian & Park (2009) explained that imposing restrictions to matrix A also means imposing restrictions on the inverse of matrix A. Multiplying the right and left hand sides of the unrestricted VAR model by A^{-1}, resulting in the reduced form VAR such that:

$$X_t = A^{-1} A Z_t \qquad (2)$$

$$e_t = A^{-1} v_t \qquad (3)$$

Of which, the later explains the relationship between structural shocks and FEVD.

This model was selected because it allows for the treatment of oil prices as an endogenous variable, thus relaxing the pervasive assumption of exogeniety, and facilitates the structural decomposition of oil prices. Following the approach developed by Kilian & Park, the recursively identified block design SVAR used the cholesky decomposition where $\frac{n^2-n}{2}$ exclusion restrictions were imposed, resulting in the following matrix representation:

$$e_{\bar{t}} = \begin{bmatrix} e_{1t}^{\Delta global\ oil\ production} \\ e_{2t}^{\Delta\ global real\ economic\ activity} \\ e_{3t}^{\Delta real\ price\ of\ oil} \\ e_{4t}^{\Delta \in REER} \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t}^{oil\ supply\ shock} \\ \varepsilon_{2t}^{aggregate\ demand\ shock} \\ \varepsilon_{3t}^{oil\ specific\ demand\ shock} \\ \varepsilon_{4t}^{REER\ shock} \end{bmatrix} \qquad (4)$$

The ordering of variables when constructing a SVAR is critical since different orderings may affect the results. For this reason, it is important to assume an ordering such that a potential impulse to the system affects the variables in a direction which is consistent with economic theory and logic. Therefore, the Cholesky decomposition or ordering of the variables in the system was motivated by economic theory and an understanding that demand from the Zambian economy has an infinitesimal contribution to global aggregate demand.

The first identifying assumption was that significant changes in global oil production represent oil supply shocks and that oil supply does not contemporaneously respond to changes in demand within the same period (contemporaneously exogenous), in accordance with Kilian & Park (2009. This argument was motivated by technological limitations and costs associated with unplanned increases in production, since oil supply is widely accepted to be inelastic in the short-run. Secondly, it was assumed that changes in dry cargo ocean shipping rates represent global real economic activity changes. Therefore, significant changes in these freight rates represent aggregate demand shocks as explained by Kilian & Park (2009) and Klovland (2009). Thirdly, it is assumed that changes in the price of oil which are not caused by oil supply and global aggregate demand factors are caused by oil-specific (precautionary) demand factors. Therefore, the following equations describe the contemporaneous impact of decomposed oil price shocks on REERs:

$$woilp_t = \text{Ɏ} + \sum_{i=1}^{k} \beta_i woilp_{t-i} + \varepsilon_{1t} \tag{5}$$

$$bdi_t = \alpha + \sum_{i=1}^{k} \beta_i woilp_{t-i} + \sum_{l=1}^{k} \psi_l bdi_{t-l} + \varepsilon_{2t} \tag{6}$$

$$boilp_t = \text{ɚ} + \sum_{i=1}^{k} \beta_i woilp_{t-i} + \sum_{l=1}^{k} \psi_l bdi_{t-l} + \sum_{m=1}^{k} \phi_m boilp_{t-m} + \varepsilon_{3t} \tag{7}$$

$$reer_t = q + \sum_{i=1}^{k} \beta_i woilp_{t-i} + \sum_{l=1}^{k} \psi_l bdi_{t-l} + \sum_{m=1}^{k} \phi_m boilp_{t-m} + \sum_{n=1}^{k} \sigma_n reer_{t-n} + \varepsilon_{4t} \tag{8}$$

where k is the optimal lag length; Ɏ, α, ɚ, and q are constants; $\beta_{i,}$, ψ_l, ϕ_m and σ_n are short-run dynamic coefficients; ε_{4t} are residuals; *woilp* is the global oil production; *bdi* is the Baltic dry index; *boilp* is brent oil prices; and *reer* is the Real Effective Exchange Rate.

4. Empirical Results

4.1. Short-run Impact of Oil Price Shocks on REERs: SVAR

The significance of the contemporaneous impact of decomposed oil price shocks on consumption are reported in Table 1 below.

Table 1: Results of SVAR

Response- Impulse	Coef.	Std. Err.	z	P>z	95% Conf.	Interval
Global Economic Activity – Oil Supply	-1.407142	1.892545	-0.74	0.457	-5.116461	2.302177
Oil-specific Demand – Oil Supply	2.368644	.8631635	2.74	0.006	.6768743	4.060413

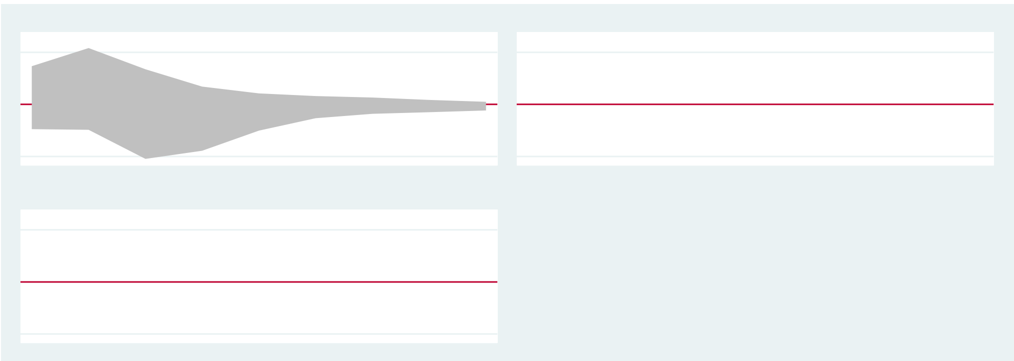
Real Effective Exchange Rates – Oil Supply	-.0529531	.1204935	-0.44	0.660	-.2891159	.1832098
Oil-specific Demand – Global Aggregate Demand	-.1727322	.0388877	-4.44	0.000	-.2489507	-.0965137
Real Effective Exchange Rates – Global Aggregate Demand	.0001591	.005653	0.03	0.978	-.0109206	.0112387
Real Effective Exchange Rates – Oil-Specific Demand	-.0137776	.0116116	-1.19	0.235	-.0365359	.0089806

The findings revealed that decomposed oil price shocks have no contemporaneous impact on REERs at the 5% level. This finding is further discussed below using IRFs, Granger Causality, and FEVDs.

4.2. Impulse Response Functions (IRF)

IRFs describe the evolution of REERs in response to shocks in oil supply, precautionary demand and aggregate global demand shocks, over a specified time horizon. As explained by Verbeek (2008) and other literature on VAR models, model coefficients provide limited information on the response of a variable to a shock from other variables. Therefore, IRFs are generated to fill the information gap by measuring the transmission of a one standard deviation innovation in one or more explanatory variables on the system. IRFs of decomposed oil price shocks on REERs are reported in Figure 2 below.

Figure 2: Impulse Response Functions



Where *D_Inbdi1* is global aggregate demand; *D_Inboilp1* is Oil-Specific Demand Shocks; *D_Woilp1* is supply Shocks; and *D_Inreerqtr* is the real effective exchange rate.

Notably, a unit shock in oil-specific demand appeared to show to that it positively affects REERs, although this result was insignificant at the 5% level, as shown in Table 1. The impact of a shock appeared to reduce REERs by 0.5% points until after 3 months when the effects of the shock diminish before completely dissipating after 12 months. The contemporaneous non-significance of the oil price-REERs nexus is logical since Zambia is predominantly an exporter of copper, cobalt, and does not export oil. Therefore, it was not expected that Zambian exports would be sensitive to oil price shocks, although economic theory suggests that oil price shocks increase costs of production for domestic goods and services, which in turn may reduce the competitiveness of Zambian exports. Notably, Rankin &

Simumba (2016) argued that Zambian exports were highly concentrated on mining products, thus export revenue is heavily dependent on the price of primary products such as copper and cobalt. They explained that since the Zambian Kwacha is affected by copper prices and exchange rate volatility, this may in turn curtail the development of Non-Traditional Exports (NTEs).

Although seemingly counter-intuitive since oil price shocks increase the import-bill of net-oil importing countries due to inelasticity of oil demand, the non-significance of the contemporaneous impact of decomposed oil price shocks on imports, the demand-side of REERs, can be explained by Zambia's historic exchange rate controls and introduction of a fixed exchange rate regime in response to the commodity price shocks of the 1970s (Chipili, 2009). Similarly, fuel subsidies and price controls which were introduced due to major commodity shortages which plagued the Zambian economy from 1966 to 1992, also cushioned economic agents such as firms from the inflationary effects of oil price shocks (Cheelo & Masenke, 2018).

4.3. Granger Causality

Granger Causality tests were conducted to determine whether decomposed oil price shocks granger-cause REERs where the former contains information that helps to predict the latter. The results of the Granger Causality Test are reported in Table 2 below.

Table 2: Results of Granger Causality Test

Equation		**Excluded**	**chi2**	**df**	**Prob > chi2**
Real Effective Exchange Rates	←	Oil Supply	2.2325	2	0.327
Real Effective Exchange Rates	←	Global Aggregate Demand	2.502	2	0.286
Real Effective Exchange Rates	←	Oil-specific Demand	1.2992	2	0.522
Real Effective Exchange Rates	←	ALL	6.4063	6	0.379

The findings in Table 2 shows that decomposed oil prices do not granger-cause REERs at the 5% level. This means oil prices do not contain information which can be used to forecast Zambia's REERs.

4.4. Forecast Error Variance Decomposition

FEVD determined the proportion of variation in REERs that was attributed to decomposed oil price shocks. The key results of the FEVD after 24 months of the initial shock are presented in Table 3 below.

Table 3: Results of Forecast Error Variance Decomposition

Horizon	**Oil Supply Shock (%)**	**Aggregate Demand Shock (%)**	**Oil Specific Demand Shock (%)**	**Other Shocks (%)**
1	0	0.1	1	98.9
2	0.98	0.4	0.56	98.06
3	0.88	0.5	0.55	98.07
4	0.8	0.6	0.57	98.03

5	0.8	0.7	0.57	97.93
6	0.81	0.7	0.56	97.93
7	0.81	0.7	0.55	97.94
8	0.8	0.7	0.56	97.94

FEVD results in Table 3 showed that decomposed oil price shocks were attributed for a minute proportion of the variation in REERs. In particular, oil supply shocks were attributed for only 0.8% of the variation in REERs, while global aggregate demand shocks were attributed for 0.7%, while oil-specific demand shocks were attributed for 0.56%. The revelation is consistent with the findings of the SVAR and Granger Causality Tests which showed that there was no significant nexus between decomposed oil price shocks and REERs.

4.5. Test for the Long-run Impact of Decomposed Oil Price Shocks on Household Consumption

Two time series are cointegrated when their linear combination creates a stationary time series. This study adapted the approach used by Johansen & Juselius (1990), from which the number of cointegrating vectors was determined and used to establish the presence of long-run relationships, with a view to create a VECM if cointegration requirements were satisfied (Brooks, 2008). When testing the null hypothesis of ‘r’ cointegrating vectors against an alternative of ‘n’ cointegrating vectors, the trace test is used, but when testing the null hypothesis of ‘r’ cointegrating vectors against an alternative of ‘r + 1’ cointegrating vectors, the maximum eigenvalue test is used. The results of the Johansen Cointegration Test are in Table 4 below.

Table 4: Results of Johansen’s Cointegration Test

Maximum Rank	Parms	LL	Eigen Value	Trace Statistic	Critical Value
0	20	800.02222	.	49.8130	47.21
1	27	812.74354	0.16837	24.3704*	29.68
2	32	820.55011	0.10697	8.7572	15.41
3	35	824.48319	0.05541	0.8911	3.76
4	36	824.92872	0.00644		

Results in Table 4 revealed that there is at least one cointegrating equation in the system. Therefore, a VECM was constructed since the cointegration requirement was satisfied. Selected results of the VECM are reported in Table 5 below.

Table 5: Results of Vector Error Correction Model

Impulse	Response	Coef.	Std. Err.	z	P > z	95% Conf.	Interval
ECT	Real Effective Exchange Rates	.0204561	.008109	2.52	0.012	.0045628	.0363494
Oil Supply	Real Effective Exchange Rates	.0356494	.1116064	0.32	0.749	-.1830952	.2543939

Aggregate Demand	Real Effective Exchange Rates	.0050654	.0054992	0.92	0.357	-.0057128	.0158435
Oil-specific Demand	Real Effective Exchange Rates	-.0179899	.0112375	-1.60	0.109	-.0400149	.0040351

Results in Table 5 shows that decomposed oil price shocks had no long-run impact on Zambia's REERs, but that the Error Correction Term (ECT), which measures the speed of adjustment back to equilibrium after a short-run disturbance, was significant with a coefficient of 0.02.

5. Conclusion

This study contributed to the literature on the impact of oil price shocks on REERs of net-oil importing countries by structurally decomposing oil price shocks and distinguishing between short and long-run effects on the case of the Zambian economy.

The findings revealed that decomposed oil price shocks had no short-run contemporaneous impact on REERs at the 5% level. Similarly, it was found that decomposed oil price shocks and the combined effect of all the variables in the system did not significantly granger-cause Zambia's REERs, while FEVD results showed that oil price shocks were attributed for a minute proportion of the variation in REERs. These findings were attributed to Zambia's profile as a copper and cobalt exporter, historic exchange rate controls, fuel subsidies, and price controls. Johansen's cointegration tests revealed that there was at least one cointegrated equation in the system, to the subsequent VECM which was constructed revealed that decomposed oil price shocks had no long-run impact on REERs in Zambia, but that the ECT which measures the speed to adjustment back to equilibrium after a short-run disturbance, was significant.

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