ANALYSIS OF THE NON-LINEAR EFFECT OF PETROL PRICE CHANGES ON INFLATION IN SOUTH AFRICA

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─Abstract─

In the South African economy, the phenomenon of high levels of inflation coupled with low levels of economic growth has been experienced over the last decade. In addition to this, the relatively high levels of inflation could be related to rising costs (cost-push inflation) rather than consumer demand (demand-push inflation). One of the factors that contributes to costs and rising inflation in South Africa is fuel or petrol costs. The objective of this study is therefore to determine the non-linear effect of changes in petrol prices on inflation by means of a threshold analysis. The econometric equation included inflation as the dependent variable with the petrol price as the independent variable and GDP as the control variable for the period 2001 to 2018. The Johansen cointegration model was utilised to determine both the long- and short-run relationships between the variables. The methodology also included a threshold analysis to determine at what level of the petrol price inflation is affected to increase significantly over time. The results indicated a cointegration equation with long-run relationships between the variables, while the VECM analysis showed that the effect of petrol price changes was non-linear. Furthermore, excessive increases in petrol prices aggravate inflation levels. A threshold petrol price level was also determined. In the short run, price increases had no significant impact on inflation and economic

growth. In conclusion, the continuing increases in petrol prices over the last decade have had a significant and negative impact on inflation and economic growth in the long run in South Africa. In order to keep inflation under control, cost-push factors, including petrol and energy prices, need to be kept at moderate levels or even below the threshold level as determined in this study.

Key Words: Inflation; non-linear effect; petrol price; South Africa; threshold analysis

JEL Classification: E3, O4

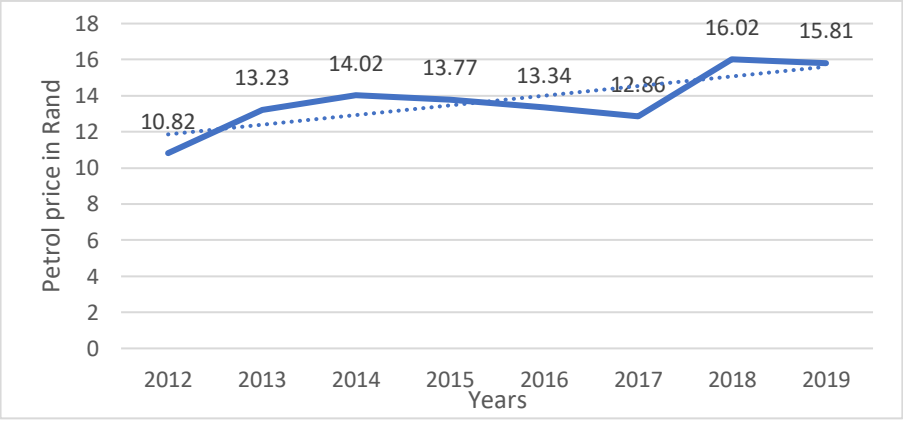
1. INTRODUCTION

Since the beginning of the 1970s, the global economy has experienced a number of fuel price increases, mostly due to supply shocks, leading to economic crises. In 1973, with the start of the Yom Kippur War, the first major oil crises started, leading to stagnant economic growth accompanied by inflation. This led to the formulation of the term stagflation (Barsky & Kilian, 2001). In 1979, the Iranian Revolution disrupted oil supply in the Middle East, which led to the next economic crisis (Painter, 2012). Economies in both developed and developing countries and regions are significantly negatively affected by rapid increases in fuel prices, known as price shocks (Cunado & Perez de Gracia, 2005). Although renewable energy sources have come to the fore over the last decade, fuel (including petrol and diesel) remains a dominating energy source. On a global scale, energy prices still significantly affect the global economy and markets (Katircioglu, Sertoglu, Candemir & Mercan, 2015). The importance of the phenomenon of rapid fuel price increases has been one of the major causes of global recessions, excepts for one since the end of World War II (Brown & Yucel, 2002).

When global fuel prices are analysed, high levels of volatility are evident. From 2008 to 2019, since the financial crises, the price of Brent crude oil showed extreme changes and shocks. In the midst of the financial crises, in December 2008, the price of oil was $40 per barrel, and reached $126 per barrel at the end of the first quarter of 2012. Towards 2016, however, the prices dropped to a record low of only $30.5 per barrel. In October 2018, the price once again peaked at $86, but reached a low again at the end of 2018 of $50 per barrel. Due to factors such as global political instability and supply and demand fluctuations, the price again spiked in April 2019 to $74 per barrel and the current price in July 2019 is $64 per barrel (Macrotrends, 2018). Because South Africa is a fuel importing country, the volatility and fluctuations also affect fuel prices. Figure 1 depicts petrol prices

changes for 95-octane in Gauteng in South Africa since 2012. The increases in the petrol price in South Africa have been dramatic, and since 2012 to July 2019, the price has increased by 46.1% with an average annual increase of 7.7%. Of major significance are the petrol price increases over the last two years of 22.9% (SAPIA, 2018). The rapid petrol price increases, and other factors such as rising electricity costs, have resulted in increases in inflation, but with economic growth well below 1 percent, leading to a situation of stagflation. South Africa is also experiencing supply-cost inflation and not cost-push inflation (Kabundi, Schaling & Some, 2015). The objective of this study is therefore to determine the non-linear effect of changes in petrol prices on inflation by means of a cointegration and threshold analysis.

Figure-1: Petrol price fluctuations in South Africa



Source: SAPIA, 2019

2. LITERATURE REVIEW

From a theoretical point of view, the relationship between energy or specifically petrol prices and economic indicators relates in most cases to a non-linear relationship (Lee & Chang, 2007). This interesting relationship is realised in the event of rapid and unexpected petrol price increases having a negative impact on aggregate demand as a result of overall increases in prices. This then leads to inflation and a diminishing effect on real income and demand. Both demand and supply are affected by petrol price increases and supply is affected via higher production costs with less output (Cunado & Perez de Garcia, 2005). Brown and Yücel (2002) state that petrol price increases have many negative impacts on the economy, such as adverse impacts on spending by consumers; increasing production costs; contributing to negative trade surplus; changes in demand for

money and resulting monetary policy; and lastly market volatility and an unstable economic environment. Changes in the petrol price have an impact on inflation, but empirical results from other studies indicate mixed results on the significance of the impact (Lescaroux & Mignon, 2008; Barsky & Kilian, 2004; LeBlanc & Chinn, 2004). Literature, as analysed, mostly concludes that petrol price shocks adversely affect economic growth. Brown and Yucel (2002) even go as far as to indicate that ongoing rapid petrol price increases are in some cases a leading indicator of a possible recession due to increases in production cost and subsequent outputs (Huang, Hwang & Peng, 2005; Cologni & Manera, 2008).

Within an Asian context, Cunado and Perez de Gracia (2005) investigated the relationship between increases in the petrol price on economic output and inflation from 1975 to 2002. Results indicate negative impacts on economic growth and inflation, but mostly in the short run. As could be expected, granger causality flows from petrol price increases to the other two variables. Cunado, Jo and Perez de Gracia (2015) did a similar study for the period 1997 to 2014 in Japan, Korea, India and Indonesia. The final results surprisingly indicate that petrol price increases did not significantly impact on the economies of these countries. In a further study in 17 Asian countries, Chang, Jha, Fernandez and Jam'an (2011) also tested the impact of petrol price shocks on selected economic variables, including GDP, inflation and unemployment in 17 Asian countries. They also found a negative impact only in the short run. Tang, Wu and Zhang (2010) analysed the relationship between the variables in China from 1998 to 2008, while Wei (2010) completed a similar study from 1995 to 2008. Results from the studies are interesting and indicate a negative impact of petrol increases on economic growth in both the long- and short run, and a positive relationship with inflation. Results also show that output is negatively affected by petrol price increases and inflation. Their results even indicate that a one percent increase in the petrol price could have a 0.38 percent negative impact on economic output. Other findings from these studies are that petrol price changes have a non-linear relationship with growth and inflation, and causality runs from petrol price (Popp, Oláh, Fekete, Lakner & Máté, 2018).

In developed countries, interesting empirical results were also found. In a study including 26 OECD countries, by Katircioglu, Sertoglu, Candemir and Mercan (2015), the impact of changes of petrol prices on the economic performance of the mostly developed countries from 1980 to 2011 was analysed. Results confirmed a long-run relationship between the petrol price, GDP, inflation and employment. Papapetrou (2011) found similar results in Greece, while Lardic and Mignon (2006) and Roeger (2005) analysed a number of European countries and also

found that petrol prices negatively impacted on GDP in both the long- and short run. The studies found that the impact on GDP was mostly negative with a coefficient of -0.5 percent in the short run, and even a -1.0 percent impact over the long-run.

More empirical studies by Cavalcanti and Jalles (2013) in the US, and Cologni and Manera (2008) in the G-7 countries from 1980 to 2003 found that, for these countries, petrol price increases had a negative impact on GDP and a positive impact on inflation. Peersman and Van Robays (2012) did a similar study from 1986 to 2010 for industrialised countries, and found that if the rise in petrol prices is due to economic growth on a global scale, it could lead to a decline in GDP and an increase in inflation. The results for oil exporting countries are different, and such countries are not affected in the same way by such increases.

In different types of analyses, Korhonen and Ledyaeva (2010) studied both petrol exporting and importing countries to determine the difference in the impact of price increases. For a country such as Russia, which exports fuel, the increase has a positive impact on GDP. However, for countries that predominantly import fuel, such as Japan, China, Finland, Germany and the UK, increases had a mostly negative impact on GDP. In other similar studies, Lescaroux and Mignon (2008) analysed the impact of increases in 36 countries, which included both fuel importing and exporting countries and found similar results. Iwayemi and Fowowe (2011) studied the impact of fuel price increases on the Nigerian economy from 1985 to 2007, which economy is dominated by the exports of oil and concluded for this country that price shocks do not negatively impact on the local economy.

Lastly, Nkomo (2009) completed a study in South Africa to determine the impact of petrol price increases on the economy. The country is dependent on the import of crude oil and is also affected by exchange rate fluctuations affecting prices. It was found that increasing petrol prices had a negative impact on economic activities with external factor resulting in continuous volatility and price uncertainty. In conclusion, and from the above analysis, different countries are affected differently by rising oil prices. Factors such as currency stability, export or import focus are causing different scenarios. The focus of this study is, however, on the impact in a petrol importing developing country and the relationships between the selected variables.

3. METHODOLOGY

In order to capture the non-linear effect of petrol price on inflation, we begin by specifying a standard quadratic equation as follows:

$$lcpi_t = \alpha_0 + \alpha_1 lpet_t + \alpha_2 lpet_t^2 + \alpha_3 lgdp_t + \epsilon_t \quad (1)$$

In the model, $lcpi$ is log of consumer price index, $lpet$ is log of petrol price, $lpet^2$ is the non-linear term, $lgdp$ is log of GDP, $\alpha(\alpha_0, \alpha_1, \alpha_2, \alpha_3)$ is a vector of parameters to be estimated and ϵ is the error term. The non-linear hypothesis in this specification centres around coefficients α_1 and α_2, in that for the effect of petrol price on inflation to be deemed non-linear, the two coefficients must be significant and carry opposite signs. If α_1 and α_2 are negative and positive, respectively, and both are statistically significant, it indicates a U-shaped relation between petrol price and inflation; therefore, petrol prices at moderate levels help in reducing inflation, while high petrol prices cause inflation to soar. On the other hand, if α_1 and α_2 are positive and negative, respectively, and both are statistically significant, then an inverted U-shaped relation between petrol price and inflation is evident; therefore, petrol prices at moderate or low levels cause inflation to rise, while high petrol prices help in reducing it. If, however, both α_1 and α_2 bear the same sign, or if the non-linear term is not statistically significant, then it indicates that the relationship between petrol price and inflation is linear. Within this specification, the threshold of petrol price beyond which it aggravates (or mitigates) inflation is determined by finding the first order partial derivative of equation (1) with respect to petrol prices. Therefore,

$$\frac{\partial lcpi_t}{\partial lpet_t} = \alpha_1 + 2\alpha_2 lpet_t \quad (2)$$

By setting equation (2) equal to zero and solving for petrol price, we get a candidate for an optimum:

$$lpet^* = e^{\frac{-\alpha_1}{2\alpha_2}} \quad (3)$$

Equation (3) is the threshold petrol price that represents the minimum (or maximum) price beyond which inflation rate increases (or is mitigated) if the second-order partial derivative of equation (1) is positive (or negative). To determine whether the variables in the model have long-run relationships, the cointegration technique of Johansen (1988) and Johansen and Juselius (1990) was employed. This technique is applicable only if all the variables in the model are

integrated of order one; therefore, it was preceded by unit root tests. Based on this, the following error correction model (ECM) is formulated:

$$\Delta Z_t = \Pi_k Z_{t-k} + \sum_{i=1}^{k-1} \phi_i \Delta Z_{t-i} + \epsilon_t \qquad (4)$$

Where Δ is the difference operator, Π and ϕ are (p x p) matrices of unknown parameters, k is lag order and ϵ_t is the error term. The long-run parameters that are represented in the model by vector Π are defined as multiples of two vectors α and β', such that $\Pi = \alpha\beta'$, where α represents the speed of adjustment from disequilibrium, while β' indicates a vector of long-run coefficients such that $\beta' Z_{t-1}$ in equation (4) represents up to $(p-1)$ cointegrating relationships in the model. Johansen and Juselius (1990) developed two likelihood ratio tests, which are based, respectively, on the maximal eigenvalue and the trace test. The former is based on the null hypothesis of 'r' cointegrating vectors against the alternative of '$r+1$' cointegrating vectors, while the latter is based on the null hypothesis of at most 'r' cointegrating vector(s) against the alternative of more than 'r' cointegrating vectors. For this study, quarterly data for South Africa from the first quarter of 2001 to the third quarter of 2018 were used. All the data are sourced from the South African Reserve Bank (SARB).

4. ESTIMATION AND RESULTS

The descriptive statistics of the variables in the model are presented in Table 1. The number of observation for each series is 71, representing the number of quarters in the data. The highest and the lowest values of CPI were 108.9 and 41.47. The petrol price peaked at 1 708 cents per litre in the third quarter of 2018, while it was at its lowest (357 cents) in the fourth quarter of 2001. Moreover, the variance is quite large for all the series, as shown by the substantial differences between the maximum and the minimum values of the variables. This is further reinforced by the high standard deviation value for all the series, which implies that the data points are quite spread out around their means.

Table 1: Descriptive statistics

	Mean	Std. dev	Min	Max	Obs
cpi	70.1760	20.1856	41.47	108.9	71
pet	888.4837	382.9713	357	1708	71
gdp	2672797	370158.4	1994180	3157231	71

The results of the unit root tests conducted on the variables are reported in Table 2. The tests were conducted based on the automatic lag selection by the Akaike information criterion (AIC), with the inclusion of intercept in each equation. The tests were conducted on both the level and first differences of the lagged series. As reported in the table, both the ADF and PP unit root tests agree that all the three variables are integrated of order one (I(1)).

Table 2: Unit root tests

	Level		First difference	
Variable	ADF	PP	ADF	PP
lcpi	0.423	-0.239	-3.105**	-4.945***
lpet	-0.865	-0.611	-8.261***	-10.069***
$lpet^2$	-0.691	-0.387	-8.207***	-9.842***
lgdp	-2.575	-2.815	-4.651***	-4.586***

Note: *** and ** indicate significance at 1% and 5%, respectively.

The selection of optimal lag length for our model was based on the outcome of the Akaike information criterion (AIC). As shown in Table 3, the AIC recommends optimal lag length as lag 3; therefore, we adopt it for our estimations.

Table 3: Lag order selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	255.7549	NA	6.40e-09	-7.5150	-7.3834	-7.4629
1	674.8368	775.6142	3.81e-14	-19.5473	-18.8895*	-19.2869*
2	694.7532	34.4821	3.41e-14	-19.6642	-18.4796	-19.1955
3	716.3666	34.8394*	2.9e-14*	-19.8318*	-18.1207	-19.1547
4	729.6895	19.8849	3.25e-14	-19.7519	-17.5143	-18.8665

Note: * denotes lag order selected by the criterion; LR = sequential modified LR test statistic; FPE = final prediction error; AIC = Akaike information criterion; SC = Schwarz information criterion; HQ = Hannan-Quinn information criterion

4.1. Cointegration test

Table 4 presents the result of the cointegration test based on Johansen (1988) and Johansen and Juselius (1990). From the results, both the trace statistic and Max-Eigen statistic are unanimous in their respective positions that there exists one cointegrating equation among the variables. This conclusion is reflected in the values of the trace statistics and Max-Eigen statistics being greater than their respective critical values at the 1% level of significance. This result confirms a cointegrating relationship between the variables and similar results were observed by Papapetrou (2001).

Table 4: Johansen cointegration test

Hypothesised no. of CE(s)	Trace statistic	Critical value (5%)	Max-Eigen statistic	Critical value (5%)
None	58.0906***	47.8561	34.9042***	27.5843
At most 1	23.1864	29.7970	15.2914	21.1316
At most 2	7.8950	15.4947	6.9268	14.2646
At most 3	0.9682	3.84146	0.9682	3.8414

The result of the estimated VECM with CPI as the dependent variable is presented in Table 5. The coefficient of petrol price is significant and negative, while the coefficient of the non-linear term is positive and significant. This result confirms that the effect of petrol price on inflation is non-linear over the study period, and

as indicated by the signs of the respective coefficients of the petrol variables, increases in petrol price reduce inflation when the petrol price is still at moderate levels. However, increases in petrol price lead to an increase in inflation when the petrol price is rising rapidly. This implies that excessive increases in petrol price aggravate inflation. This finding corroborates the position that empirical research is undecided on the level of the impact of fuel price increases on inflation (Barsky & Kilian, 2004; Lescaroux & Mignon, 2008). It also supports the conclusion of Du, Yanah and Wei (2010) that economic growth and inflation are significantly affected by petrol price changes and that the effect is non-linear. The double impact of the petrol price on inflation points to the existence of an optimum threshold needed to ensure that inflation is kept at lower levels. This indicates a turning point between the two petrol price coefficients beyond which the petrol price begins to affect inflation positively. This threshold of the petrol price is given by equation (3), and is computed to be 1,214.64 ($e^{\frac{(6.422682)}{2(0.452161)}}$). This result implies that at any petrol price above 1 214.64 cents per litre, inflation significantly increases. Specifically, the results indicate that at any price beyond the threshold, a 1% increase in the price of petrol leads to about 0.45% increase in inflation in the long run. In order to keep inflation at moderate levels, the petrol price should be kept constant or below the threshold price. The result also shows that the coefficient of GDP is positive and statistically significant, indicating that improvement in economic growth leads to higher inflation. Specifically, the result implies that, ceteris paribus, a 1% rise in economic growth is accompanied by a 3.06% increase in inflation, and *vice versa*.

Table 5: VECM cointegrating result (lcpi as dependent variable)

Variable	Coefficient	Std. error	t-Statistic
lpet (-1)	-6.4226	1.1147	5.7618
$lpet^2$ (-1)	0.4521	0.0750	6.0280
lgdp (-1)	3.0604	0.5446	5.6192

Turning to the short-run results as shown in Table 6, the error correction term (ECT) is shown to have a negative, less than one, and significant coefficient. This indicates that there is a tendency for any past disequilibrium to be corrected in the current period, with the speed of adjustment very low at about 1.9%. As for the petrol price variables, though the coefficients of the joint lags of both petroleum

prices and the non-linear term carry opposite signs, with the former and the latter being negative and positive, respectively, neither of the two coefficients is significant. This indicates that, in the short run, changes in petrol price have limited impact on inflation. This result contradicts the finding of Cunado and Perez de Gracia (2005), who claim that the impact of the petrol price on economic growth and inflation is mainly in the short run. The coefficient of the joint lag of GDP is positive, but statistically insignificant, implying that, in the short run, economic growth has no significant impact on inflation. These short-run results show that over the study period, the short-run dynamics of petroleum prices and economic growth do not matter as far as inflation is concerned.

Table 6: VECM short-run dynamics (lcpi **as dependent variable)**

Variable	Coefficient	Std. error	t-Statistics
ect_{t-1}	-0.0187	0.0179	-2.0453
$\Delta(lpet(-1))$	0.0774	0.2062	0.3753
$\Delta(lpet(-2))$	-0.0934	0.1978	-0.4722
$\Delta(lpet(-3))$	-0.2624	0.1776	-1.4772
$\Delta(lpet^2(-1))$	-0.0071	0.0151	-0.4690
$\Delta(lpet^2(-2))$	0.0044	0.0146	0.3059
$\Delta(lpet^2(-3))$	0.0215	0.0133	1.6191
$\Delta(lgdp(-1))$	0.1019	0.2042	0.4992
$\Delta(lgdp(-2))$	0.0211	0.2167	0.0977
$\Delta(lgdp(-3))$	0.0031	0.2026	0.0155

The results of the granger-causality test conducted to ascertain the direction of causality among the variables are presented in Table 7. To measure the direction of causality among the variables, the study employed F-Statistics constructed under the null hypothesis of no causality. As shown in the table, the null hypotheses that petrol price (or the nonlinear term) does not granger cause inflation, and *vice versa*, are both rejected, indicating a bi-directional causal relationship between petrol price variables and inflation. Similar findings were estimated by Nkomo (2009) and LeBlanc *et al*. (2004). On the other hand, the null hypotheses that economic growth does not granger cause inflation and *vice versa*

are both accepted, implying no causal relationship between economic growth and inflation, thereby confirming the short-run result discussed earlier. Furthermore, the null hypothesis that economic growth does not granger cause petrol price variables is rejected, while the null hypothesis that petrol price variables do not granger cause economic growth cannot be rejected, indicating that the causality between petrol price variables and economic growth is unidirectional, with causality moving from economic growth to petrol price variables. Similar results were obtained by Peersman and Van Robays (2012).

Table 7: Granger causality test

Null hypothesis	F-Stat	Probability	Decision
lpet does not Granger cause lcpi	5.37	0.003**	Reject
lcpi does not Granger cause lpet	4.99	0.005**	Reject
$lpet^2$ does not Granger cause lcpi	5.43	0.004**	Reject
lcpi does not Granger cause $lpet^2$	4.77	0.007**	Reject
lgdp does not Granger cause lcpi	1.33	0.2731	Do not reject
lcpi does not Granger cause lgdp	1.88	0.1467	Do not reject
lgdp does not Granger cause lpet	3.63	0.023**	Reject
lpet does not Granger cause lgdp	1.19	0.328	Do not reject
lgdp does not Granger cause $lpet^2$	3.02	0.0415**	Reject
$lpet^2$ does not Granger cause lgdp	1.08	0.365	Do not reject

Note: ** indicate significance at 5%.

Finally, the results of the diagnostic tests are listed in Table 8. The null hypothesis of no serial correlation cannot be rejected for all the three lags in the model. It can, therefore, be concluded that the model is free from the problem of serial correlation. The result of the normality test shows that the four variables in the model exhibit normal distribution, as we cannot reject the null hypothesis that each of the residuals of each of the variables is distributed normally. Finally, we cannot reject the null hypothesis that our model suffers from heteroskedasticity, with the insignificance of the chi-square coefficient.

Table 8: Diagnostic tests

Type of test	Prob.
Serial correlation LM test	0.1072
Normality test	0.2490
Residual heteroskedasticity test	0.2174

5. CONCLUSIONS

Rapidly rising general fuel and petrol prices constitute shocks on economies, leading to cost-push inflation, particularly in oil-importing countries and this includes South Africa. This study had the objective to analyse and determine the non-linear effect of changes in petrol prices on inflation by means of a cointegration and threshold analysis. The objective was successfully achieved via both a literature review and by means of an econometric time series data analysis of the relationships between the variables included in the study in South Africa, which is an oil-importing country. Results from the empirical section of the literature review confirmed that the energy sector is still dominated by the oil/fuel market and that this energy source continues to significantly impact economies, although the market share of the renewable energy sources is increasing steadily (Popp, Lakner, Harangi-Rákos & Fári, 2014).

The study found interesting results indicating that a non-linear relationship existed among the variables, namely inflation (listed as CPI), petrol price and economic growth. It also supports the conclusion of Du, Yanah and Wei (2010) that economic growth and inflation are significantly affected by petrol price changes and that the effect is non-linear in the long run. It was also determined that an optimal threshold exists for the petrol price and its relationship with inflation. Rising petrol prices have a significant impact on inflation and the economy in the long run, but not in the short run. Economic growth also does not have a short-run impact on inflation.

Limitations in the study include the availability of data and that only a limited number of variables could be included. This research topic is interesting and future studies will include comparisons between developed and developing countries, as well as panels or grouping of countries. Other variables could also be added to the model such as the exchange rate and the producer price index (PPI). Other options for future studies are to also compare countries with different

sectoral compositions and the effect of the fuel price (Máté, Oláh, Laknern & Popp, 2017).

The implications of the study are that the petrol price significantly affects inflation and economic growth in South Africa, and that the petrol price should as far as possible be kept at relatively stable and low levels. This is because, as shown from our results, if the price surpasses a specific level, the impact on inflation escalates. The results of this study could be used to re-evaluate the current economic policy that requires urgent amendments due to structural problems and the low-growth trap the country is in. Shocks from fuel prices have significant impacts on the economy, but also on monetary and fiscal policy, and directly affect government income and consumer spending. South Africa, as an oil-importing country, urgently needs to investigate and implement the increased use of renewable energy sources to reduce the dependency on fuel imports.

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