

# THE COMMODITY-CONSUMER PRICE CONNECTION: EVIDENCE FROM SOUTH AFRICA

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*Abstract: Price stability constitutes the primary objective of monetary policy in South Africa. To achieve price stability, the SARB monitors various indicators of inflationary pressure. This paper considers the importance of commodity prices as one such indicator. Commodity price changes may affect the downstream production cost of manufactured goods and hence cause inflation. In addition, increases in commodity prices may increase the earnings of commodity exporters and through the income thus generated cause aggregate demand to increase. This, in turn, may also put upward pressure on the price level. Thus, in countries where commodities constitute a predominant share of imports and exports, the question for their central banks would be whether or not commodity prices lead inflation and as such, can be used as an early warning mechanism to the appearance of inflationary pressure in the economy. Against this backdrop, the paper explores the relationship between commodity- and consumer prices in South Africa (together with possible exchange rate effects) by making use of cointegration and causality tests.*

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Price stability constitutes the primary objective of monetary policy in several countries. South Africa is no exception to this with its system of official inflation targeting. To achieve price stability, the South African Reserve Bank monitors various indicators of inflationary pressure such as credit extension and aggregate demand pressure. This paper considers the importance of commodity prices as one such indicator for the South African Reserve Bank to monitor. Given that commodity prices are determined in auction-type markets they are sensitive to supply and demand conditions affecting the commodity markets. As such, commodity prices are quick to respond to changing conditions, which, in turn, may affect the downstream production cost of manufactured goods and hence cause inflation. In addition, increases in commodity prices may increase the earnings of commodity exporters and thereby add to aggregate demand in the economy. This, in turn, may also put upward pressure on the price level. Therefore, commodities may represent upstream variables in a transmission mechanism that runs from a change in commodity prices, via changes in input costs and aggregate demand, to the domestic price level. Thus, in countries where commodities constitute a predominant share of imports and exports, the question for its central bank would be whether or not commodity prices lead inflation and as such, can be used as an early warning mechanism to the appearance of inflationary pressure in the economy.

Against this backdrop, the paper explores the relationship between commodity- and consumer prices in South Africa. The paper uses three commodity prices – gold, oil and platinum – and two commodity price indices – food and metal (excluding gold and platinum). Gold and platinum are the two main commodity exports of South Africa, with the country being the number one international producer of both. Oil constitutes the main commodity import of South Africa. Together with countries such as Australia and

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Canada, South Africa is a commodity-rich economy in which the production and export of commodities play a significant role (Bloch *et al* 2006:S98). This paper examines the relationship between commodity prices and inflation in South Africa by making use of cointegration, causality and stability tests. Section 1 presents an overview of the literature, while subsequent sections contain the empirical analysis and findings.

## 1. LITERATURE REVIEW

Malliaris (2006:269-70) draws attention to the fact that in the case of anticipated inflation, there is no general framework or definite transmission mechanism between commodity- and consumer prices, and even less so in the case of unanticipated inflation. In particular, commodity- and consumer price cycles do not need to have the same frequency or chronology, thereby obfuscating the empirical relationship between the two. Moosa (1998:202) concurs with this by stating that even though there is similarity in the cycles for commodity and consumer prices, the amplitudes of these cycles may differ. As a result, it is no surprise to find that empirical studies produce mixed results. The results are ambiguous even in those cases where studies focus on the same country (usually the US), and in particular, sensitive to changes in sample periods and methods used to explore the data.

Table 1 contains a summary of the recent literature on the relationship between commodity- and consumer prices. What is notable from these studies is that they differ (and display ambiguity) in their findings about the univariate properties of consumer prices. While a number of studies covering the US, the OECD and some East Asian countries find it to be an I(1) variable (Mahdavi and Zhou 1997; Moosa 1998; Cunado and de Gracia 2004; Cutler *et al* 2005), others find some or even conclusive evidence that consumer prices in, among other, the US, Japan, Canada and Australia may be an I(2) variable (Blomberg and Harris 1995; Furlong and Ingenito 1996; Stock and Watson 2003; Rapach and Weber 2004; Cunado and de Gracia 2004; Bloch *et al* 2006). In addition, given the sometimes ambiguous univariate features of consumer prices, it is also not surprising to find mixed results with respect to the existence of cointegrating and causal relationships between commodity and consumer prices.

Most of the studies investigate whether or not a cointegrating relationship exists between commodity prices and the domestic price level (or inflation) (Furlong and Ingenito, 1996; Mahdavi and Zhou, 1997; Moosa, 1998; Stock and Watson 2003; Cunado and de Gracia, 2004; Kyrtsov and Labys, 2006), while many also use some form of a (bivariate) VAR representation of the relationship between commodity prices and CPI (Blomberg and Harris, 1995; Furlong and Ingenito, 1996; Moosa, 1998; Cunado and de Gracia, 2004; Cutler *et al.*, 2005; Kyrtsov and Labys, 2006). Control variables such as M2, the trade-weighted dollar, the real GDP and interest rates are also included in the VAR specification (Blomberg and Harris, 1995; Furlong and Ingenito, 1996; Mahdavi and Zhou, 1997; Cutler *et al.*, 2005). What is notable about these studies is the absence of domestic demand-pull and cost-push control variables such as unit labour cost. The only exception might be Furlong and Ingenito (1996:36) who include an unemployment gap as measure of the tightness of the labour market. The absence of such control variables might be explained *a priori* in two ways. First, in the case where commodities are a major export of a country, it is an upstream variable in a transmission mechanism where an increase in commodity prices might cause an increase in the earnings of commodity

exporters, which in turn may put upward pressure on profits and wages. This increase in profits and wages, in turn, causes an increase in aggregate demand that puts upward pressure on domestic prices. Thus, their relationship within the transmission mechanism obviates the need to include commodities as well as wages and profits.<sup>2</sup> Secondly, many of these studies are mainly interested in whether or not commodity prices can be used to predict inflation and therefore do not focus on a regression that describes inflationary behaviour in all its facets.

The various papers contained in the literature and summarised in Table 1 used several empirical methods to explore and analyse the data. Thus, following the literature, this paper also does not rely on any single method of analysis, but includes a range of methods. These include cointegration tests, VECM analysis, causality as well as stability tests. The paper uses cointegration analysis to consider whether or not a long-run relationship exists between commodity- and consumer prices in South Africa. Following this, the variables are modelled as VECM to see whether or not commodity- and consumer prices in South Africa share the same long run properties. To establish whether or not commodity prices are leading indicators of inflation in South Africa, the paper investigates the short-run causality between commodity prices and inflation by conducting Granger causality tests. Finally, the paper carries out impulse response analyses and variance decompositions.

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<sup>2</sup> Note that this approach is similar to Taylor, who, in effect also argues that there is no need to include both upstream and downstream variables (where downstream variables have a direct effect and upstream variables have an indirect effect) in the same regression. In Taylor's case, he argues that there is no need to include an exchange rate (an upstream variable) in the Taylor rule, given that exchange rate effect is already there (given its influence on inflation – the downstream variable) (Taylor 2001:266-7).

Table 1. Review of the Literature

	Blomberg and Harris (1995)	Furlong and Ingenito (1996)	Mahdavi and Zhou (1997)	Moosa (1998)	Cunado and de Gracia (2004)	Cutler, Chan and Li (2005)	Kyrtsov and Labys (2006)	Bloch, Dockery and Sapsford (2006)
<b>Country / countries</b>	USA	USA	USA	OECD countries	6 Asian countries	USA, Hong Kong, Mainland China	USA	Australia and Canada
<b>Sample period</b>	1970M1-1994M4	1947M1-1995M12	1958Q1-1994Q4; 1970Q1-1994Q4	1972M1-1993M12	1975Q1-2002Q2	Depending on the country, from 1981M01/1983M11/1988M09 to 2004M11	1970M1-2002M12	1960Q1-2001Q4
<b>Variables</b>	Core CPI, five commodity indices, three sub-groups of commodities	CPI, all-commodity index, raw materials index	CPI, price of gold, the Journal of Commerce index (JOCI) of industrial material prices	OECD CPI, all commodity index, metals index, raw materials index, food index	CPI, oil prices (both dollar and local currency denominated), economic activity measures	Headline CPI, core CPI, as well as energy, non-fuel, metals and food indices	CPI, comprehensive commodity price index	CPI, IMF index of primary commodity prices
<b>Method</b>								
<b>Unit root tests</b>	Dickey-Fuller (DF) tests	Augmented Dickey-Fuller (ADF) test	ADF tests, Phillips-Perron (PP) tests, KPSS tests	Seasonal unit root tests, ADF tests, Z-statistic proposed by Phillips, as well as Phillips and Ouliaris	PP tests	ADF test	-	DF tests, ADF tests
<b>Cointegration tests</b>	-	Johansen's cointegration test	Johansen's cointegration test	Engle-Granger cointegration test on the residual series, Johansen's cointegration test	Phillips-Ouliaris test, Gregory-Hansen test (both residual based cointegration tests)	Not explicitly included in the paper – authors note that none of the variables are cointegrated	Johansen's cointegration test, Bieren's cointegration test	-
<b>Granger Causality</b>	Bivariate VAR between commodity prices and inflation; VECM estimation included as well	Bivariate VAR between commodity indices and CPI (both in first differences)	-	Bivariate VAR between commodity indices and CPI (both in first differences)	Bivariate VAR between commodity indices and CPI (both in first differences)	Bivariate VAR between commodity indices and CPI (both in first differences)	Test for non-Linear Granger Causality	-

Table 1. (continued) Review of the Literature

	Blomberg and Harris (1995)	Furlong and Ingenito (1996)	Mahdavi and Zhou (1997)	Moosa (1998)	Cunado and de Gracia (2004)	Cutler, Chan and Li (2005)	Kyrtsov and Labys (2006)	Bloch, Dockery and Sapsford (2006)
<b>Multivariate VAR</b>	M2 and trade-weighted dollar added to test whether monetary policy may have offset inflation	Labour market measures, trade-weighted dollar, spot price of oil, foreign exchange rate and federal funds interest rate are also included	Different multivariate VAR specifications that include variables such as price of gold, 3-month Treasury Bill rate and the real GDP	-	-	Additional variables included in the VAR such as changes in global output, domestic interest rates and nominal effective exchange rate	-	Use structural equations to model commodity prices, the exchange rate and domestic prices for Australia and Canada; also use generalised instrumental variable estimation (GIVE) to control for possible endogeneity
<b>Rolling regressions</b>	-	Plot the sum of the lagged commodity price index coefficients over time	-	-	-	Rolling regressions using a five year period window	-	-
<b>Predictive performance / out of sample forecasts</b>	Predictive errors in a model that controls for monetary policy	Univariate CPI equations, bivariate VAR	Dynamic OLS	-	-	-	-	-
<b>Splitting of the sample period</b>	Mid-1980s	1983	-	-	-	-	-	Only in exchange rate equations to control for different exchange rate regimes
<b>Testing for asymmetries / non-linearities</b>	-	-	-	-	Method proposed by Mork (1989) and Mork <i>et al</i> (1994)	Non-linear Granger causality specification	Multivariate Noisy Mackey-Glass Process	-

Table 1. (continued) Review of the Literature

	Blomberg and Harris (1995)	Furlong and Ingenito (1996)	Mahdavi and Zhou (1997)	Moosa (1998)	Cunado and de Gracia (2004)	Cutler, Chan and Li (2005)	Kyrtsou and Labys (2006)	Bloch, Dockery and Sapsford (2006)
<b>Order of integration of the CPI (domestic price level) series</b>	Commodity indices and the core CPI cannot be cointegrated at the same degree of differencing (i.e. commodity indices $\sim I(1)$ and CPI $\sim I(2)$ )	Some evidence that log of CPI $\sim I(2)$ ; authors conclude that the second difference of the log of the CPI indicates “over-differencing” and proceed by assuming that log of the CPI $\sim I(1)$	Authors refer to the other studies that have found the CPI series to be $I(2)$ ; however, ADF, PP and the KPSS tests reveal conclusively that CPI $\sim I(1)$ for the sample under consideration	CPI $\sim I(1)$	Some evidence that Japanese CPI $\sim I(2)$ ; authors argue that Japanese CPI $\sim I(1)$ based on the temporal evolution of the series, the significance of the time trend included in the model, as well as the results of the correlogram	Authors argue that other studies find CPI to be $I(2)$ ; however, unit root tests suggest that CPI in USA, Hong Kong and Mainland China are $I(1)$	Not discussed – the authors work with the first difference of the log of the CPI series	The authors argue that the CPI is $I(1)$ for both Australia and Canada and conclude “intuitively” that the price series is $I(1)$ ; however, authors note that their results are flawed
<b>General Findings</b>	For the total period, commodity indices are useful predictors of inflation; for the latter period almost all commodity indices were found to have “perverse” negative relationship to the CPI inflation; gold price found to be negatively related to the inflation irrespective of the period under consideration.	Commodity price indices and CPI not cointegrated; empirical link between commodity prices and inflation has changed dramatically over time – commodities are poor stand alone indicators of inflation since the early 1980s; using commodity prices to forecast inflation results in a sizeable over-prediction of inflation towards the end of the sample period.	Some evidence of cointegration between commodity prices and the CPI; index of commodity prices performs better than gold as a predictor of the inflation rate – thus, emphasis on the price of gold as a guide to monetary policy is perhaps misplaced.	No evidence of a long-run relationship between the commodity prices and the CPI; there is evidence of a short-run dynamic relationship with strong support for causality running from the commodity prices to the CPI.	No cointegration between oil prices and the CPI; evidence of causality from oil prices to CPI (especially if the oil price is denominated in local currency); evidence of an asymmetric relationship between inflation and oil price changes (in four out of the six countries).	Commodity price indices and CPI not cointegrated; changes in non-fuel commodity prices are significant in predicting headline CPI inflation in Hong Kong and China but not in the USA; energy prices are not significant in predicting headline CPI for Hong Kong and Mainland China but are significant for the USA.	Evidence of a cointegrating relationship between the commodity prices and the CPI – linear dependence in the long-run; non-linear Granger Causality indicates a non-linear relationship between inflation and commodity price inflation; Mackey-Glass model indicates the existence of a chaotic non-linear inter-dependence between commodity prices and the CPI.	Rate of change in commodity prices is directly related to domestic inflation in both Australia and Canada (however, the magnitude of this relationship is grater for Canada than Australia); offsetting impact of exchange rates may eliminate the inflationary impact of a commodity price boom in the case of Australia.

## 2. DATA

To consider the relationship between South African consumer- and commodity prices, the paper selected the consumer price index (CPI), the prices of oil, gold and platinum, as well as the Commodity Food Price Index and Commodity Metals Price Index. The latter index excludes gold and platinum. (For more detail on the CPI as well as the commodity-prices and price indices used in this study, see Appendix I). Oil is the main commodity imported, while gold and platinum are the two main commodities exported. The two chosen indices form part of the IMF Nonfuel Commodities Price Index and are selected for the purpose of completeness.<sup>3</sup> The data frequency is monthly, while the period under review is 1970M01 to 2007M04 (i.e. 448 observations). Figure 1 presents the natural logarithms<sup>4</sup> of CPI (CPI), exchange rate<sup>5</sup> (EXCHR), oil (OIL), gold (GOLD), platinum (PLATINUM), food price index (FOOD) and the metals price index (METAL) series. Following international studies such as Blomberg and Harris (1995), Furlong and Ingenito (1996) and Stock and Watson (2003) who found a structural break in commodity prices in the mid-1980s, this paper also imposes a structural break in the mid-1980s. This decision is further supported by the behaviour of inflation, which also experienced a structural change in the mid-1980s (see Figure 2 that presents a 12- month moving average of the South African inflation series). For South Africa, Nel (2000:16-17) found evidence of this structural break when he studied inflation dynamics in South Africa – he identifies two distinct periods: the accelerating inflation period (1971Q1-1985Q4) and the deflationary period (1986Q1-1997Q2). Thus, following international literature and Nell (2000), this study imposes a structural break in 1986M1,<sup>6</sup> with the first sub-period spanning 1970M1-1985M12 (i.e. 192 observations) and the second sub-period spanning 1986M1-2007M4 (i.e. 256 observations). Imposing such a structural break can assist in addressing the question of whether or not commodity prices have become less important as signals of inflation in South Africa.

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<sup>3</sup> Other studies such as Moosa (1998) and Cutler *et al.* (2005) also used these indices in their estimation.

<sup>4</sup> From this point forward, all analysis will be performed on the natural logarithms of the CPI, EXCHR, FOOD, GOLD, OIL, METAL and PLATINUM.

<sup>5</sup> The exchange rate variable is included in VAR/VECM analysis (section 3) to control for the exchange rate movements as all of the commodity prices are denominated in Dollar terms and the commodity indices are indices of goods priced in Dollars. The paper considered, but decided against the inclusion of a labour cost variable such as unit labour cost. The decision not to include it is based on *a priori* and practical grounds. The *a priori* grounds entail the upstream/downstream argument discussed earlier in the paper and follow the example of the vast majority of studies discussed above. The practical grounds entail problems with labour cost data in South Africa. There were several changes in the surveys collecting South African labour data (1998, 2002 and 2004), so that no consistent time-series in levels exist that covers the entire period under review. Furthermore, the labour cost data that is available is available on a quarterly basis, while commodity and price data has a monthly frequency. Thus, a decision to include labour variables will imply a significant cut in information and will limit the period under review to the late 1990s.

<sup>6</sup> Preliminary tests showed significant structural breaks between the commodity prices (indices) and the CPI series in 1986M1. Experimenting with alternative dates for splitting the sample leads to a deterioration in the commodity variable coefficients as they move through the 1980s.

Figure 1 – South African CPI, the \$/R Exchange Rate, Commodity Prices and Commodity Price Indices

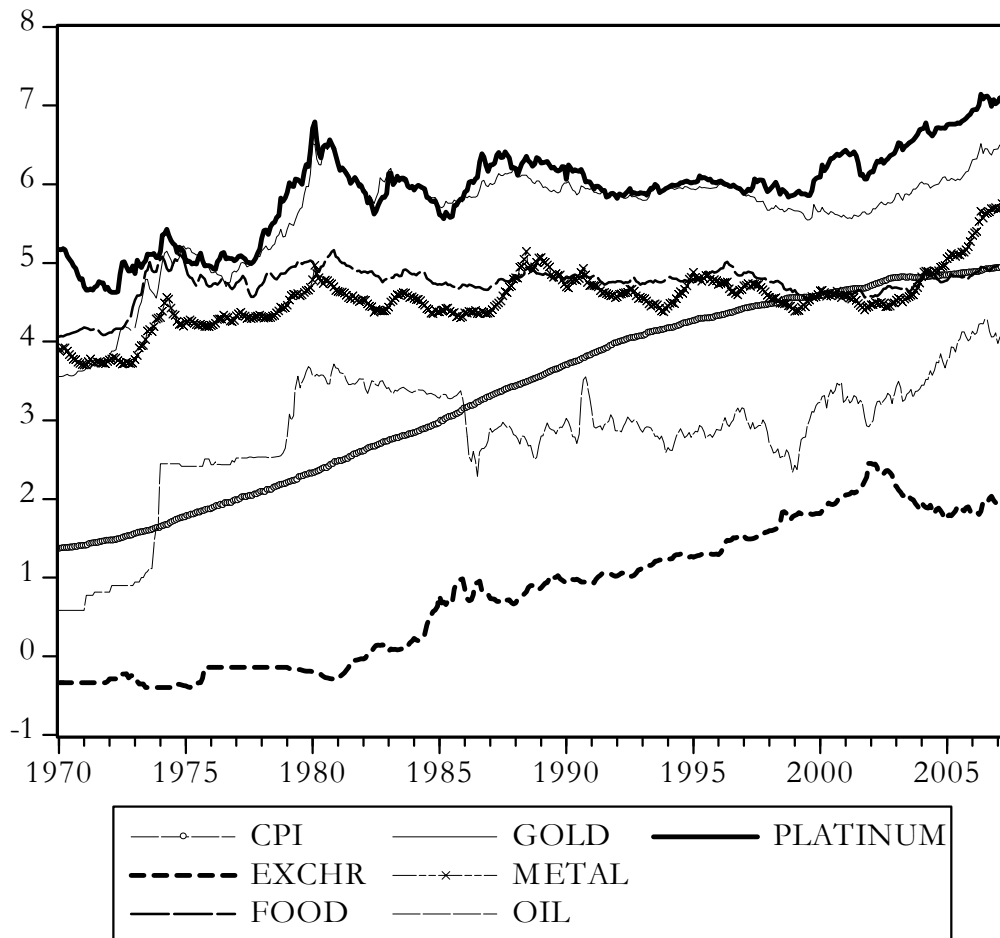
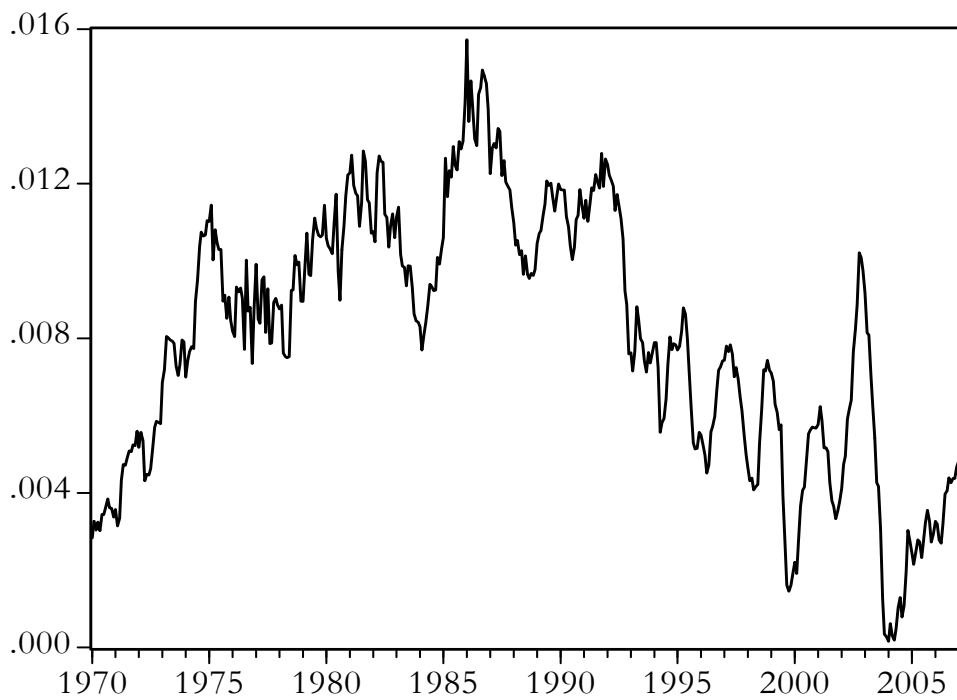


Figure 2 – South African Inflation Rate (12-month Moving Average)



As can be seen from Figure 1, GOLD and PLATINUM moved quite closely together after the abandonment of the Bretton Woods system, though this co-movement seems to be less tight since the late 1990s (confirmed by correlation analysis, Table 2 below – 0.86 for the total sample period, 0.90 and 0.64 in the first and second sub-periods). The OIL series shows significant increases in the mid- and late 1970s, as well as a steady increase since 1999. OIL also moves quite closely with the GOLD, METAL and PLATINUM series (again confirmed by the correlation analysis, Table 2 below). CPI shows an increase throughout the period, though the pace of this increase has slowed down towards the end of the sample period. EXCHR series seems to move most closely with the PLATINUM series – the estimated correlation coefficient between these two series is 0.70. The two commodity indices (i.e. FOOD and METAL) also move closely together over the sample period and especially so during the 1990s. However, metal prices have risen sharply since 2002, while the food index has risen by much less.

Further inspection of the estimated correlations (Table 2) reveals that for the first sample period, all commodities display a high correlation with the CPI series. FOOD also displays relatively lower correlations (although still high) with GOLD, METAL, OIL and PLATINUM, which all correlate highly (above 0.8) among each other. The second sub-period reveals perverse correlations for the FOOD and GOLD variables given their negative correlation with the CPI. The correlation of METAL, OIL and PLATINUM with the CPI is also considerably smaller than in the first period. In general, the correlations among the commodity prices (indices) are smaller in the second period.

Table 2. The Correlation Matrix

		1970M1-1985M12					
	CPI	EXCHR	FOOD	GOLD	METAL	OIL	
EXCHR	0.823	1	-	-	-	-	
FOOD	0.563	0.153	1	-	-	-	
GOLD	0.869	0.479	0.834	1	-	-	
METAL	0.737	0.310	0.875	0.932	1	-	
OIL	0.880	0.528	0.812	0.966	0.932	1	
PLATINUM	0.770	0.373	0.676	0.898	0.876	0.839	
		1986M1-2007M4					
	CPI	EXCHR	FOOD	GOLD	METAL	OIL	
EXCHR	0.926	1	-	-	-	-	
FOOD	-0.106	-0.336	1	-	-	-	
GOLD	-0.072	-0.239	0.762	1	-	-	
METAL	0.284	0.115	0.673	0.787	1	-	
OIL	0.636	0.545	0.221	0.484	0.698	1	
PLATINUM	0.443	0.421	0.276	0.635	0.739	0.841	

### 3. METHOD AND RESULTS

Most of the empirical literature outlined in section 1 have analysed the relationship between commodity prices and consumer prices using some type of a VAR framework. The central feature characterising the VAR technique is that it poses a less restrictive structural modelling as it does not impose *a priori* division of variables into endogenous or exogenous variables. When accompanied with cointegration analysis, the VAR technique can be used to model the long-run relationship between non-stationary variables (Johansen, 1988). Cointegration techniques are used to establish whether or not a long-run equilibrium (i.e. stationary) relationship exists between non-stationary variables in a single or system of equation(s). Such long-run relationships are normally hypothesised by economic theory, where the theory postulates the existence of an equilibrium relationship

that links the variables in question.<sup>7</sup> The dependent variable may depend not only on the level of the explanatory variables but also on the extent of the deviation of the explanatory variables from the equilibrium relationship with the dependent variable. This sort of behaviour is captured by the error correction models that describe the interaction between short-term and long-term impacts in a given relationship. The method employed in this paper combines cointegration analysis with the VECM technique to account for the problems of non-stationarity and endogeneity and to estimate relevant coefficients and parameters that describe the long-run and the short-run interactions between South African CPI, the \$/R exchange rate and the commodity prices (indices).

*(a) Univariate properties of the data*

Prior to establishing whether or not there is a relationship between commodity prices (indices) and consumer prices, the univariate properties of the data must be investigated. For this purpose, the analysis conducts the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron test,<sup>8</sup> as well as the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. Because of the low power associated with finite samples when applying the ADF test, the stationarity properties of the data is further explored using the KPSS test (for more on the KPSS test, see Appendix II). Note that the null hypotheses of the ADF and KPSS tests differ – the null hypothesis of the ADF test postulates non-stationarity, while that of the KPSS test postulates stationarity. Ideally, if a series is stationary, the ADF test should reject the non-stationarity null hypothesis, whereas the KPSS test should not reject its null hypothesis postulating stationarity. Such a finding by both tests is considered as consistent evidence favouring stationarity (Mahdavi and Zhou 1997:479; Lütkepohl and Krätzig, 2004:63).

*Table 3. Unit Root Tests*

Sample	CPI	EXCHR	GOLD	OIL	FOOD	METALS	PLATINUM
1970M1-1985M12	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
1986M1-2007M4	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)

Note: 1. Comprehensive unit root test results are provided in Appendix II, Tables IIA, B and C (together with a discussion on the KPSS test).

Table 3 summarises the results of the unit root tests for the total sample period as well as for the two sub-periods. The results, reported in Table 3 as well as Appendix II, indicate that the majority of the variables are I(1) irrespective of the period under consideration. Some variables (EXCHR, FOOD and METAL for the total period, PLATINUM in the first sub-period, as well as EXCHR and FOOD in the second sub-period) appear to indicate stationarity in levels, but the evidence is not robust to alternative testing procedures, with the majority of the unit root tests employed indicating that these variables are I(1). The results for the CPI variable are also a bit ambiguous as some tests indicate that CPI may be an I(2) variable (Tables IIA and B, Appendix II). This finding corresponds to that of Woglom (2005:304) and Burger and Marinkov (2006:177) for South Africa, as well as Blomberg and Harris (1995:21-3; 36n5) for the US, Stock and

<sup>7</sup> The concept of cointegration is in essence a statistical characterisation of a situation where the variables in the hypothesised relationship should not diverge from each other in the long run, or if they should diverge in the short run, this divergence must be stochastically bounded and diminishing over time (Banerjee *et al.*, 1993:136).

<sup>8</sup> For more on the ADF and the PP tests, see Gujarati (2003:817-8).

Watson (2003:802) for the G7 countries, Rapach and Weber (2004:409) for 16 OECD countries, with Mahdavi and Zhou (1997:477n4) citing several older studies that have a similar finding. If CPI is assumed to be I(2), the implication is that one should not so much consider the relationship between CPI and the logarithms of the commodity prices (indices), but the relationship between the *change* in the logarithm of CPI, i.e. the inflation rate, and the logarithms of the commodity prices. This may be considered counterintuitive given that it implies that a one-time increase in the price of a commodity input will cause a permanent increase in the rate of growth of output prices (Blomberg and Harris 1995:34). With this in mind, and given that the majority of the unit root tests performed on the CPI series indicate stationarity in first differences, this paper reports the results of the relationship between commodity prices (indices) and the CPI.<sup>9</sup>

(b) *Cointegration tests*

Following the investigation of the univariate characteristics of the data, the next step is to test whether or not a long-run cointegrating relationship exists between inflation and the individual commodity prices. Adopting a VAR system of equations is justified given that all of the variables are non-stationary in level (Table 3 above). The unrestricted VAR model is given by:

$$Z_t = A_0 + A_1 Z_{t-1} + \dots + A_k Z_{t-k} + E_t \quad (1)$$

while the error correction representation of Equation (1) is:

$$\Delta Z_t = A_0 D_t + \Pi Z_{t-1} + \Gamma_1 \Delta Z_{t-1} + \dots + \Gamma_{k-1} \Delta Z_{t-k+1} + V_t \quad (2)$$

where  $Z$  is an  $(n \times 1)$  vector containing all variables in the system ( $n$ ),  $D$  is a vector holding deterministic terms,  $E$  is an  $n$  dimensional vector of multivariate random errors with a mean of zero and a covariance matrix  $\Sigma$ .

Cointegration entails determining the rank of the long run matrix  $\Pi$  (i.e. the maximum number of linearly independent columns in  $\Pi$ ). The testable hypothesis under cointegration is  $H_0: \text{rank}(\Pi) \leq r$  where  $r$  is the rank of the long-run matrix (maximum =  $n$ , minimum = 0). In addition, matrix  $\Pi$  can be decomposed as:

$$\Pi = a\beta' \quad (3)$$

where  $a$  is an  $(n \times r)$  matrix containing adjustment coefficients (ECMs) and  $\beta$  is an  $(n \times r)$  matrix containing long-run parameters. The determination of rank of  $\Pi$  is supplemented by exogeneity and causality analysis to provide economically valid linear relations. The vector  $Z$  consists of three variables: CPI, EXCHR and each one of the commodity prices (indices), i.e. GOLD, FOOD, METAL, OIL and PLATINUM.

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<sup>9</sup> The paper also investigated the relationship between commodity prices (indices) and CPI inflation (as opposed to the CPI). However, no statistically significant or meaningful results were found. These results can be obtained from the authors on request.

Table 4 summarises the results of the Johansen cointegration test.<sup>10</sup> The test results are very sensitive to the lags selected. To establish the optimal amount of lags, several criteria such as the AIC, SIC and HQ were employed. Using these criteria did not yield an amount of lags that rendered the VARs free of serial correlation. Hence, the number of lags was increased systematically (one at a time) with a maximum permitted amount of twelve lags (given the use of monthly data; cf. Blomberg and Harris (1995), as well as Furlong and Ingenito (1996)). The results of these tests are reported for each VAR in Appendix III (Table IIIA).

Table 4. *Johansen's Cointegration Test*

Variables	$H_0$	$\lambda_{TRACE}$		$H_0$	$\lambda_{MAX}$	
		1970M1-1985M12	1986M1-2007M4		1970M1-1985M12	1986M1-2007M4
FOOD, CPI, EXCHR	$r = 0$	35.841	32.144	$r = 0$	27.273	17.939
	$r = 1$	8.568	14.205	$r \leq 1$	7.888	15.575
	$r = 2$	0.679	1.631	$r = 2$	0.679	1.631
Conclusion		$r = 1$	$r = 1$		$r = 1$	$r = 0$
GOLD, CPI, EXCHR	$r = 0$	37.844	39.914	$r = 0$	30.390	27.441
	$r = 1$	7.454	12.473	$r \leq 1$	6.739	12.471
	$r = 2$	0.715	0.003	$r = 2$	0.715	0.003
Conclusion		$r = 1$	$r = 1$		$r = 1$	$r = 1$
METAL, CPI, EXCHR	$r = 0$	36.091	45.702	$r = 0$	26.133	37.929
	$r = 1$	9.958	7.773	$r \leq 1$	9.885	7.031
	$r = 2$	0.074	0.742	$r = 2$	0.074	0.742
Conclusion		$r = 1$	$r = 1$		$r = 1$	$r = 1$
OIL, CPI, EXCHR	$r = 0$	31.415	36.174	$r = 0$	22.695	25.191
	$r = 1$	8.720	10.983	$r \leq 1$	8.694	8.394
	$r = 2$	0.025	2.589	$r = 2$	0.025	2.589
Conclusion		$r = 1$	$r = 1$		$r = 1$	$r = 1$
PLATINUM, CPI, EXCHR	$r = 0$	28.844	34.733	$r = 0$	15.004	25.182
	$r = 1$	13.840	9.551	$r \leq 1$	13.496	8.599
	$r = 2$	0.345	0.953	$r = 2$	0.345	0.953
Conclusion		$r = 0$	$r = 1$		$r = 0$	$r = 1$

- Note: 1.  $\lambda_{TRACE}$  and  $\lambda_{MAX}$  denote the trace and maximal eigenvalue statistics of Johansen's cointegration test;  $r$  denotes the number of cointegrating vectors.  
2. No trends were included in the cointegration test specification except in the case of FOOD, CPI and EXCHR VAR for the period 1970M1-2007M4 (as the FOOD variable was found to be trend stationary for the period 1970M1-2007M4). For the other VARs an intercept in the cointegrating equation as well as in the VAR were included in cointegration test specification.  
3. When an intercept is included in the cointegrating equation and the VAR: 5% critical values for  $\lambda_{TRACE}$  test are 29.797, 15.495 and 3.842; 5% critical values for  $\lambda_{MAX}$  test are 21.131, 14.265 and 3.842. When a linear trend is included in the VAR: 5% critical values for  $\lambda_{TRACE}$  test are 42.91525, 25.872 and 12.518; 5% critical values for  $\lambda_{MAX}$  test are 25.823, 19.387 and 12.518.

For the first sub-period Johansen cointegration tests show one cointegrating vector for FOOD, METAL, GOLD and OIL and no cointegration for PLATINUM. In the second period there is some ambiguity regarding FOOD, with the trace test showing one cointegrating vector and the maximum eigenvalue indicating no cointegration. GOLD, METAL, OIL and PLATINUM each displayed one cointegrating vector.

### (c) *VECM estimation*

Since one cointegrating vector was found for FOOD, METAL, GOLD and OIL in the first sample period, the paper estimated an unrestricted VECM, where after restrictions were imposed based on which variables were found to be exogenous to the cointegrating vector. The results are reported in Table 5 below. In addition to VECM estimation, VAR Granger causality tests (block exogeneity/Wald tests) were performed on a first

<sup>10</sup> For more on the Johansen cointegration approach, see Hamilton (1994:635-8), as well as Mahdavi and Zhou (1997:481) and Kyrtsou and Labys (2006:258-60).

difference VAR <sup>11</sup> for each of the variables under consideration, the results of which are reported in Table 6.

Table 5. Unrestricted and Restricted Standardised Eigenvector ( $\beta$ ) and Standardised Adjustment Coefficients ( $\alpha$ )

Variables	Unrestricted VECM		Test for long-run weak exogeneity		Restricted VECM		
	Unrestricted $\beta$	Unrestricted $\alpha$	$\chi^2$	Conclusion	Restricted $\beta$	Restricted $\alpha$	
1970M1-1985M12	CPI	1	-0.0012* (-4.87)	19.646 (0.000)	Endogenous	1	-0.0016* (-4.98)
	EXCHR	-5.5529* (-3.03)	-0.0006 (-0.50)	0.224 (0.636)	Exogenous	-4.7565* (-3.33)	0
	FOOD	-10.487* (-5.33)	0.0016 (1.13)	1.258 (0.262)	Exogenous	-8.0443* (-5.25)	0
	Constant	46.9960	-	-	-	35.5004	-
	CPI	1	-0.0209* (-4.99)	23.613 (0.000)	Endogenous	1	-0.0208* (-5.01)
	EXCHR	-0.9998* (-9.62)	0.0016 (0.09)	0.007 (0.932)	Exogenous	-1.0038* (-9.62)	0
	GOLD	-0.581* (-14.46)	0.0795 (1.95)	4.135 (0.042)	Endogenous	-0.581* (-14.42)	0.0798* (2.00)
	Constant	0.8055	-	-	-	0.8083	-
	CPI	1	-0.0079* (-4.48)	16.244 (0.000)	Endogenous	1	-0.0082* (-4.52)
	EXCHR	-1.4356* (-5.52)	-0.0020 (-0.25)	0.048 (0.827)	Exogenous	-1.3949* (-5.59)	0
	METAL	-2.0249* (-8.20)	0.0216* (2.24)	5.352 (0.021)	Endogenous	-1.9790* (-8.35)	0.0225* (2.25)
	Constant	6.4296	-	-	-	6.2359	-
	CPI	1	-0.0062* (-4.17)	16.198 (0.000)	Endogenous	1	-0.0062* (-4.24)
	EXCHR	-1.2328* (-3.41)	-0.0055 (-0.81)	0.505 (0.477)	Exogenous	-1.2131* (-3.06)	0
OIL	-0.8039* (-6.94)	0.0312 (1.58)	2.511 (0.113)	Exogenous	-0.8127* (-3.46)	0	
Constant	-0.2142	-	-	-	-0.1897	-	
1986M1-2007M4	CPI	1	-0.0014* (-2.31)	2.581 (0.118)	Exogenous	-	-
	EXCHR	0.4111 (1.22)	-0.0146* (-2.79)	3.068 (0.080)	Endogenous	-	-
	FOOD	0.2030 (0.18)	-0.0032 (-0.88)	0.687 (0.408)	Exogenous	-	-
	Constant	-5.8170	-	-	-	-	-
	CPI	1	-0.0061* (-5.18)	18.979 (0.000)	Endogenous	1	-0.0060* (-5.17)
	EXCHR	-0.4958* (-4.41)	-0.0017 (-0.17)	0.017 (0.895)	Exogenous	-0.4791* (-4.14)	0
	GOLD	-0.3073 (-1.42)	-0.0073 (-0.70)	0.384 (0.536)	Exogenous	-0.2941 (-1.32)	0
	Constant	-1.707	-	-	-	-1.8091	-
	CPI	1	-0.0061* (-6.02)	28.922 (0.000)	Endogenous	1	-0.0068* (-6.18)
	EXCHR	-0.3975* (-4.27)	-0.0103 (-1.16)	1.147 (0.284)	Exogenous	-0.4612* (-5.26)	0
	METAL	-0.2288 (-1.75)	-0.0043 (-0.39)	0.157 (0.692)	Exogenous	-0.2065 (-1.68)	0
	Constant	-2.5869	-	-	-	-2.5992	-
	CPI	1	-0.0064* (-4.90)	16.336 (0.000)	Endogenous	1	-0.0061* (-4.90)
	EXCHR	-0.4346* (-4.07)	0.0097 (0.83)	0.538 (0.463)	Exogenous	-0.3899* (-3.43)	0
OIL	-0.2670* (-2.61)	0.0164 (0.54)	0.260 (0.610)	Exogenous	-0.2361* (-2.17)	0	
Constant	-2.7855	-	-	-	-2.9465	-	
CPI	1	-0.0042* (-4.79)	16.887 (0.000)	Endogenous	1	-0.0048* (-4.89)	
EXCHR	-0.2633 (-1.81)	-0.0097 (-1.24)	1.159 (0.282)	Exogenous	-0.3530* (-2.64)	0	
PLATINUM	-0.0282 (-0.16)	-0.0030 (-0.26)	0.057 (0.811)	Exogenous	-0.0744 (-0.45)	0	
Constant	-3.6869	-	-	-	-3.2685	-	

Note: 1. Columns containing estimates of restricted and unrestricted  $\beta$  and  $\alpha$  coefficients include t-statistics in parentheses. Significance at the 5% level is denoted by \*.  
2. The null hypothesis for the test for long-run weak exogeneity is  $H_0$ : Variable is weakly exogenous to cointegrating vector. Probabilities are included in parentheses.

The VAR analysis for FOOD indicates that the exchange rate and FOOD are exogenous to the cointegrating vector, with the long-run elasticity coefficient for the FOOD index being 8.04. Though this coefficient is statistically significant, its size is much larger than expected on *a priori* grounds, raising doubts on its validity. However, in the short-run,

<sup>11</sup> Employing the VAR analysis in levels may present ambiguous results since it contains I(1) variables (though adequate parameterisation of the autoregressive process and the introduction of correct deterministic components may solve this problem). Again, the test results are very sensitive to the lags selected. To establish the optimal amount of lags, the AIC, SIC and HQ were once again employed. As with the cointegration tests, using these criteria did not yield an amount of lags that rendered the first difference VARs free of serial correlation. Hence, the number of lags was increased systematically with a maximum permitted amount of twelve lags. The results of these tests are reported for each VAR in Appendix III (Table IIIB).

FOOD Granger causes the CPI jointly with the exchange rate for the period 1970M1-1985M12. The VARs for GOLD and METAL indicate that the exchange rate is exogenous, while CPI and these two commodities are endogenous. Given that GOLD and METAL prices are internationally determined prices, their endogeneity in this setting does not make sense on *a priori* grounds. In addition, the ECMs of both GOLD and METAL have the wrong sign, indicating that they do not adjust to the long-run relationship as specified by the cointegrating vectors. In contrast to the findings on GOLD and METAL, the VECM of OIL yields *a priori* consistent results. Both the exchange rate and the oil price are exogenous to the cointegrating vector, while the CPI is endogenous. The long-run elasticity coefficient for OIL has an economically plausible and statistically significant magnitude of 0.81 (which implies that a 1% increase in the oil price results in a 0.81% increase in the South African CPI). Its CPI ECM has the correct sign and is statistically significant, indicating short run adjustment to the long-run equilibrium. Furthermore, in the short-run, OIL Granger causes the CPI jointly with the exchange rate for the period 1970M1-1985M12. Since no cointegrating vector was found for PLATINUM in the first sub-period, a VAR Granger causality test was performed in the form of a first difference VAR. No causality could be detected.

Table 6. Granger Causality Tests Based on Stationary VARs

Direction of causality		Commodity				
		FOOD	GOLD	METAL	OIL	PLATINUM
1970M1-1985M12	EXCHR → CPI	7.252 (0.027)	6.861 (0.032)	10.304 (0.067)	6.876 (0.009)	6.943 (0.090)
	Commodity → CPI	2.275 (0.321)	0.126 (0.939)	6.878 (0.230)	0.727 (0.394)	1.771 (0.621)
	ALL → CPI	8.775 (0.067)	7.430 (0.115)	14.690 (0.144)	7.365 (0.025)	8.500 (0.204)
	CPI → EXCHR	0.399 (0.819)	0.259 (0.879)	4.268 (0.512)	0.041 (0.840)	3.654 (0.301)
	Commodity → EXCHR	4.179 (0.124)	3.114 (0.211)	5.207 (0.391)	0.872 (0.350)	1.741 (0.628)
	ALL → EXCHR	4.432 (0.351)	3.297 (0.510)	10.030 (0.438)	0.882 (0.643)	5.520 (0.479)
	CPI → Commodity	0.731 (0.694)	0.273 (0.872)	2.041 (0.844)	0.151 (0.698)	0.411 (0.938)
	EXCHR → Commodity	2.935 (0.231)	1.491 (0.475)	3.863 (0.569)	0.035 (0.851)	2.121 (0.548)
	ALL → Commodity	3.433 (0.488)	1.771 (0.778)	5.453 (0.859)	0.189 (0.910)	2.696 (0.846)
1986M1-2007M12	EXCHR → CPI	24.231 (0.000)	34.965 (0.000)	34.986 (0.000)	35.481 (0.000)	32.301 (0.000)
	Commodity → CPI	2.906 (0.234)	6.751 (0.455)	5.201 (0.635)	19.268 (0.007)	3.740 (0.809)
	ALL → CPI	25.711 (0.000)	37.723 (0.001)	35.975 (0.001)	51.851 (0.000)	43.325 (0.002)
	CPI → EXCHR	4.196 (0.123)	6.657 (0.465)	6.795 (0.451)	6.502 (0.483)	6.356 (0.499)
	Commodity → EXCHR	0.104 (0.949)	8.841 (0.264)	4.651 (0.702)	9.699 (0.206)	9.892 (0.195)
	ALL → EXCHR	4.321 (0.364)	15.365 (0.354)	11.063 (0.681)	16.246 (0.299)	16.444 (0.287)
	CPI → Commodity	0.326 (0.850)	5.620 (0.585)	7.178 (0.411)	9.769 (0.202)	4.384 (0.735)
	EXCHR → Commodity	4.057 (0.132)	7.746 (0.356)	6.818 (0.448)	6.747 (0.455)	7.312 (0.397)
	ALL → Commodity	4.901 (0.928)	15.016 (0.327)	12.888 (0.535)	17.982 (0.208)	14.317 (0.426)

Note: 1. Second column presents the direction of causality where the first variable denotes the lagged endogenous variables and the second variable denotes the dependent variable. ALL refers to the joint significance of all the lagged endogenous variables in the dependent variable equation.  $\chi^2$  statistics are reported in each instance with the probabilities in parentheses.

In the second sub-period the VAR analysis for FOOD indicates that FOOD, CPI and the exchange rate are all exogenous to the cointegrating vector. Given that there was some ambiguity regarding the number of cointegrating relationships for FOOD, the paper conducted a Granger causality test on a first difference VAR. The Granger causality test indicates that the exchange rate individually and jointly with FOOD Granger causes the CPI in the short run, while FOOD does not individually Granger cause CPI. This indicates that FOOD explains short-run movements in CPI, after one controls for the exchange rate. The results are identical when short-run VARs for GOLD, METAL and PLATINUM are considered. Furthermore, GOLD, METAL and PLATINUM display similar results when their VECM specifications are considered. Each indicates that the exchange rate and each of these commodities are exogenous to the cointegrating vector, while the CPI is endogenous. This finding accords with *a priori* expectations. In addition,

GOLD, METAL and PLATINUM have valid ECMs. Lastly, the OIL VAR analysis indicates that OIL and the exchange rate are exogenous to the long-run equilibrium, while CPI is endogenous. The long-run coefficient for OIL is 0.24 and is statistically significant. This is about a quarter of what it was in the first sub-period, which can be expected given that since the 1980s economies in general are better at absorbing oil price changes than in the 1970s. Furthermore, the short-run VAR (in first differences) for oil indicates that oil individually Granger causes CPI – the only commodity to do so.

*(d) Impulse response functions*

Impulse response functions can be used to analyse the dynamic behaviour of a variable due to a random shock or innovation in other variables. The impulse responses are normalised such that zero represents the steady-state value of the response variable. To identify orthogonalised innovations in each of the variables, the paper factorises the variance-covariance matrix of the VAR using the Cholesky decomposition.<sup>12</sup> Appendix IV contains the impulse response functions for the three significant VECM summarised in Table 5. Figure IVA illustrates the dynamic response of EXCHR, FOOD and CPI variables using the data from the sample period 1970M1-1985M12. The variable of interest is the CPI, particularly the response of the CPI variable to a Cholesky one standard deviation innovation in the FOOD variable. Figure IVA indicates consistently positive but moderate effects of the shocks on the exogenous variables to the CPI equation. The same is true for the impulse responses displayed in figures IVB and IVC, where the shocks in the OIL variable have a persistently positive effect on the CPI variable, both in the first and the second sub-samples.

*(e) Variance decompositions*

Impulse response functions indicate the qualitative response of the endogenous variables in the system to shocks in the exogenous variables. To indicate the relative importance of these shocks requires variance decomposition. Variance decompositions can provide an indication of the relative causal strength of variables by partitioning the variance of the forecast error of a dependent variable into what is attributable to shocks in each variable in the system, including its own. Appendix IV, Table IVA contains the results of variance decomposition analysis.<sup>13</sup> For the first sub-period estimation, a shock to the FOOD variable becomes more important to the CPI variable in later months (24.7% after 12 months). On the other hand, the impact of the OIL variable on the CPI differs according to the sub-period considered. In the first sub-period, a shock in the OIL variable becomes more important to the CPI in later months (26.8% after 12 months), with this effect being considerably smaller in the second sub-period (6.4% after 12 months). This indicates that OIL price is a less important source of variations in the South African CPI since the mid-1980s.

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<sup>12</sup> Cholesky decomposition method imposes an ordering of the variables in the VAR and attributes all of the effect of any common component to the variable that comes first in the VAR system. The responses can change if ordering of the variables in the VAR is changed – the ordering in this paper is endogenous variable last with the most exogenous variable first.

<sup>13</sup> The ordering of the variables in the variance decomposition analysis is the same as that used in the impulse response analysis.

#### 4. CONCLUSION

The above analyses for the overall as well as the two sub-periods indicate that oil is consistently an explanatory variable for movements in the CPI. This is borne out by both the short and long-run analyses. In addition to oil, food in the overall period and the second sub-period (after controlling for the exchange rate) appears to explain short run movements in CPI. Furthermore, for the total period metal Granger causes CPI in the short run, whereas for the second sub-period metal displays a long-run relationship with CPI.

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#### APPENDIX I: DATA DESCRIPTION AND SOUTH AFRICAN INFLATION

- CPI: South African Consumer Price Index (2000 = 100); total consumer prices of goods (metropolitan areas), seasonally unadjusted. Source: Statistics South Africa (STATSSA), [www.statssa.gov.za](http://www.statssa.gov.za).
- GOLD: London gold price in USA dollar. Source: South African Reserve Bank (SARB), [www.kitco.com](http://www.kitco.com).
- OIL: Crude Oil (petroleum), simple average of three spot prices; Dated Brent, West Texas Intermediate, and the Dubai Fateh, US\$ per barrel. Source: International Monetary Fund (IMF), [www.imf.org](http://www.imf.org).
- PLATINUM: Price of platinum, monthly average of the London PM fix price. Source: Kitco Bullion Dealers, [www.kitco.com](http://www.kitco.com).
- FOOD: Commodity Food Price Index (2000 = 100); includes cereal, vegetable oils, meat, seafood, sugar, bananas and orange price indices. Source: International Monetary Fund (IMF), [www.imf.org](http://www.imf.org).
- METAL: Commodity Metals Price Index (2000 = 100); includes copper, aluminium, iron ore, tin, nickel, zinc, lead and uranium price indices. Source: International Monetary Fund (IMF), [www.imf.org](http://www.imf.org).
- EXCHR: South African foreign exchange rate (US Dollar per Rand). Source: Quantec, [www.quantec.co.za](http://www.quantec.co.za).

## APPENDIX II: THE KPSS TEST AND UNIT ROOT TEST RESULTS

Kwiatkowski, Phillips, Schmidt and Shin (1992) have developed a test (i.e. the KPSS test) to test the null hypothesis that the series is stationary against the alternative that the series is non-stationary. The specified data generating process (assuming there is no linear trend) is as follows:

$$y_t = x_t + z_t \tag{IIa}$$

where  $x_t$  is a random walk,  $x_t = x_{t-1} + v_t$ ,  $v_t \sim \text{iid}(0, \sigma_v^2)$ , and  $z_t$  is a stationary process (Lütkepohl and Krätzig, 2004:63)<sup>14</sup>. It should be noted that the null hypothesis of stationarity is equivalent to  $H_0 : \sigma_v^2 = 0$  - if this null hypothesis holds, then  $y_t$  in equation (2) is composed of a constant and a stationary process, thus,  $y_t$  is also stationary. The KPSS statistic is given by:

$$KPSS = \frac{1}{T^2} \frac{\sum_{t=1}^T S_t^2}{\hat{\sigma}_\infty^2} \tag{IIb}$$

where  $S_t^2 = \sum_{j=t}^T \hat{\omega}_j$  with  $\hat{\omega}_j = y_t - \bar{y}$  and  $\hat{\sigma}_\infty^2$  is an estimator of the long-run variance of the process  $z_t$ . If  $y_t$  is a stationary process,  $S_t$  is I(1) and the quantity in the numerator of the KPSS statistic is an estimator of its variance which has a stochastic limit (note that the term in the denominator ensures that the limiting distribution is free of unknown nuisance parameters). On the other hand, if  $y_t$  is I(1) the numerator will grow without bounds causing the statistic to become large for large samples (Lütkepohl and Krätzig, 2004:63-4).

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<sup>14</sup> If a deterministic trend is suspected in the series, equation (2) becomes  $y_t = \mu_1 t + x_t + z_t$  where  $t$  is a deterministic trend (Lütkepohl and Krätzig, 2004:64). Critical values for both cases can be found in Kwiatkowski *et al* (1992:166, Table 1).

Table IIA. Unit Root Tests (1970M1-1985M12)

Test	Series	CPI	EXCHR	FOOD	GOLD	METALS	OIL	PLATINUM
ADF <sub>NC</sub>	Level	14.293	1.662	0.636	1.406	0.408	1.458	0.366
	1 <sup>st</sup> diff.	0.110	-6.877***	-8.401***	-9.555***	-9.460***	-5.680***	-10.941***
	2 <sup>nd</sup> diff.	-10.063***						
ADF <sub>C</sub>	Level	4.924	4.156	-2.394	-1.606	-1.490	-1.780	-1.158
	1 <sup>st</sup> diff.	-15.832***	-10.749***	-8.429***	-9.472***	-9.456***	-12.649***	-10.930***
ADF <sub>CT</sub>	Level	-2.928	1.836	-2.047	-1.211	-1.458	-0.689	-1.959
	1 <sup>st</sup> diff.	-17.689***	-11.389***	-8.535***	-9.597***	-9.472***	-12.784***	-10.902***
PP <sub>NC</sub>	Level	23.860	1.318	0.875	1.556	0.450	0.959	0.408
	1 <sup>st</sup> diff.	-8.716***	-10.968***	-8.231***	-9.458***	-9.503***	-12.917***	-10.846***
PP <sub>C</sub>	Level	-5.016	3.211	-2.313	-1.836	-1.493	-1.666	-1.084
	1 <sup>st</sup> diff.	-15.812***	-11.207***	-8.212***	-9.507***	-9.500***	-13.063***	-10.832***
PP <sub>CT</sub>	Level	-2.900	1.102	-1.501	-0.927	-1.332	-1.166	-1.859
	1 <sup>st</sup> diff.	-17.858***	-11.641***	-8.192***	-9.576***	-9.519***	-13.118***	-10.803***
KPSS <sub>C</sub>	Level	1.700	1.291	0.814	1.436	1.170	1.472	1.201
	1 <sup>st</sup> diff.	1.392	0.696 <sup>#</sup>	0.369 <sup>#</sup>	0.320 <sup>#</sup>	0.158 <sup>#</sup>	0.235 <sup>#</sup>	0.121 <sup>#</sup>
	2 <sup>nd</sup> diff.	0.119 <sup>#</sup>						
KPSS <sub>CT</sub>	Level	0.407	0.287	0.264	0.229	0.283	0.296	0.170 <sup>#</sup>
	1 <sup>st</sup> diff.	0.115 <sup>#</sup>	0.157 <sup>#</sup>	0.049 <sup>#</sup>	0.076 <sup>#</sup>	0.073 <sup>#</sup>	0.056 <sup>#</sup>	

Note: 1. ADF denotes the Augmented Dickey-Fuller unit root test, PP denotes the Phillips-Perron unit root test and KPSS denotes the Kwiatkowski-Phillips-Schmidt-Shin unit root test. Subscripts NC, C and CT denote, respectively, that there is no constant, a constant, and a constant and a trend in the unit root test equation.  
 2. The null hypothesis for the ADF and the PP tests is given by  $H_0$ : non-stationary series. Significance at the 1% and 5% levels is denoted by \*\*\* and \*\*, respectively.  
 3. The null hypothesis for the KPSS test is given by  $H_0$ : stationary series. Failure to reject the null hypothesis at the 1% level is denoted by #.

Table IIB. Unit Root Tests (1986M1-2007M4)

Test	Series	CPI	EXCHR	FOOD	GOLD	METALS	OIL	PLATINUM
ADF <sub>NC</sub>	Level	3.169	0.846	0.487	1.512	1.983	0.318	1.719
	1 <sup>st</sup> diff.	-1.946**	-10.962***	-12.806***	-12.683***	-12.535***	-12.186***	-15.050***
ADF <sub>C</sub>	Level	-6.890***	-0.824	-1.733	0.593	1.157	-1.380	0.141
	1 <sup>st</sup> diff.		-11.032***	-12.798***	-12.801***	-12.744***	-12.178***	-15.184***
ADF <sub>CT</sub>	Level	-2.182	-2.218	-1.674	0.601	0.600	-3.309	-0.662
	1 <sup>st</sup> diff.	-11.429***	-11.010***	-12.802***	-12.957***	-12.890***	-12.246***	-15.227***
PP <sub>NC</sub>	Level	7.323	1.217	0.594	1.393	1.900	0.402	1.678
	1 <sup>st</sup> diff.	-4.274***	-10.762***	-12.822***	-14.186***	-12.570***	-11.884***	-15.035***
PP <sub>C</sub>	Level	-8.330***	-0.542	-1.519	0.318	1.115	-0.986	0.084
	1 <sup>st</sup> diff.		-10.682***	-12.814***	-14.259***	-12.717***	-11.810***	-15.184***
PP <sub>CT</sub>	Level	-2.145	-1.919	-1.457	0.272	0.557	-2.942	-0.715
	1 <sup>st</sup> diff.	-11.587***	-10.657***	-12.816***	-14.368***	-12.900***	-11.877***	-15.228***
KPSS <sub>C</sub>	Level	2.002	1.896	0.215 <sup>#</sup>	0.306 <sup>#</sup>	0.450 <sup>#</sup>	1.290	1.040
	1 <sup>st</sup> diff.	1.756	0.200 <sup>#</sup>				0.191 <sup>#</sup>	0.268 <sup>#</sup>
	2 <sup>nd</sup> diff.	0.305 <sup>#</sup>						
KPSS <sub>CT</sub>	Level	0.499	0.207 <sup>#</sup>	0.178 <sup>#</sup>	0.314	0.253	0.363	0.450
	1 <sup>st</sup> diff.	0.109 <sup>#</sup>			0.233	0.249	0.023 <sup>#</sup>	0.109 <sup>#</sup>
	2 <sup>nd</sup> diff.				0.018 <sup>#</sup>	0.075 <sup>#</sup>		

Refer to the notes of Table IIA above.

## APPENDIX III: LAG LENGTH CRITERIA AND TESTS

*Table IIIA. Lag Selection for the VECM Estimation*

Variable		Lag Selection Criteria			Serial Correlation LM test
		AIC	SC	HQ	
1970M1- 2007M4	CPI, EXCHR, FOOD	2 lags	2 lags	2 lags	6 lags
	CPI, EXCHR, GOLD	2 lags	1 lag	2 lags	6 lags
	CPI, EXCHR, METAL	2 lags	2 lags	2 lags	6 lags
	CPI, EXCHR, OIL	2 lags	1 lag	1 lag	7 lags
	CPI, EXCHR, PLATINUM	2 lags	1 lag	2 lags	6 lags
1970M1- 2007M4	CPI, EXCHR, FOOD	2 lags	2 lags	2 lags	9 lags
	CPI, EXCHR, GOLD	3 lags	2 lags	3 lags	4 lags
	CPI, EXCHR, METAL	2 lags	2 lags	2 lags	2 lags
	CPI, EXCHR, OIL	4 lags	2 lags	2 lags	5 lags
	CPI, EXCHR, PLATINUM	3 lags	2 lags	2 lags	3 lags

Note: 1. AIC, SC and HQ denote Akaike Information criterion, Schwartz criterion and Hannan-Quinn criterion, respectively.  
 2. Lags selected on the basis of the serial correlation LM test resulted in the residuals that are normally distributed and free from heteroscedasticity at conventional significance levels.

*Table IIIB. Lag Selection for the Stationary VARs*

Variable		Lag Selection Criteria			Serial Correlation LM test
		AIC	SC	HQ	
1970M1- 2007M4	CPI, EXCHR, FOOD	1 lag	1 lag	1 lag	2 lags
	CPI, EXCHR, GOLD	1 lag	0 lags	1 lag	2 lags
	CPI, EXCHR, METAL	1 lag	1 lag	1 lag	5 lags
	CPI, EXCHR, OIL	1 lag	0 lags	0 lags	1 lag
	CPI, EXCHR, PLATINUM	1 lag	0 lags	1 lag	3 lags
1970M1- 2007M4	CPI, EXCHR, FOOD	3 lags	1 lag	2 lags	2 lags
	CPI, EXCHR, GOLD	3 lags	1 lag	2 lags	7 lags
	CPI, EXCHR, METAL	3 lags	1 lag	2 lags	7 lags
	CPI, EXCHR, OIL	4 lags	1 lag	2 lags	7 lags
	CPI, EXCHR, PLATINUM	3 lags	1 lag	2 lags	7 lags

Refer to the notes of Table IIIA above.

## APPENDIX IV: IMPULSE RESPONSES AND VARIANCE DECOMPOSITIONS

*Figure IVA. 1970M1-1985M12*

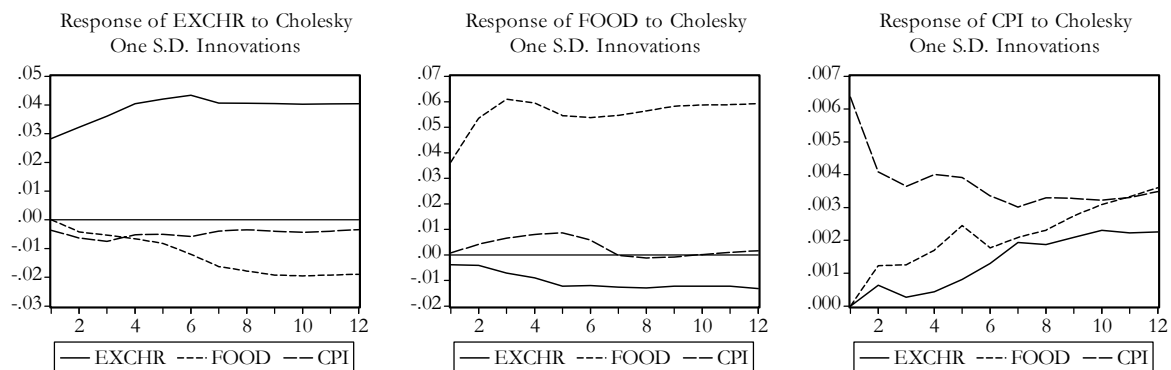


Figure IVB. 1970M1-1985M12

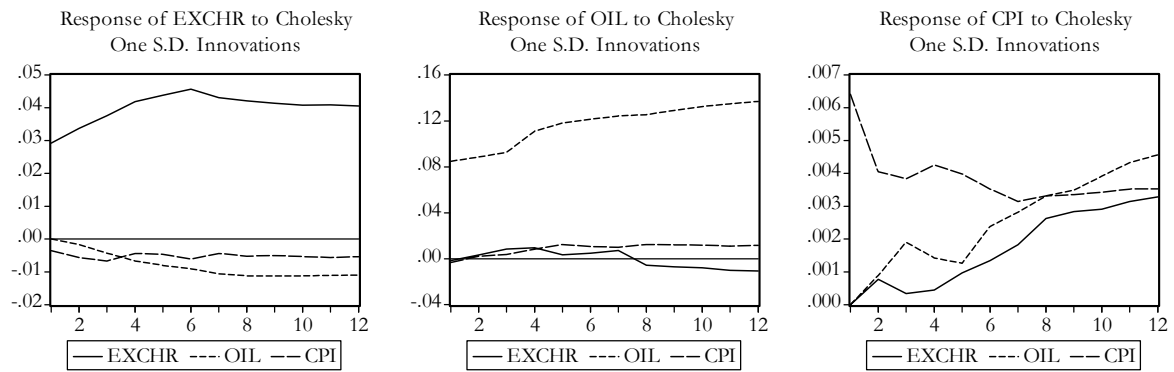


Figure IVC. 1986M1-2007M4

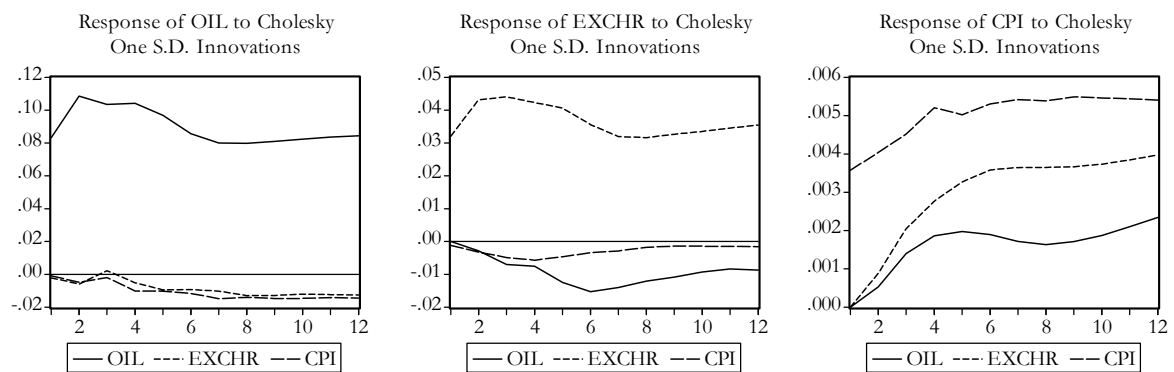


Table IVA. Variance Decompositions

1970M1-1985M12					
Variance decomposition	Period	S.E.	EXCHR	OIL	CPI
EXCHR	3	0.0088	99.1794	0.5951	0.2255
	6	0.0117	97.6630	2.2418	0.0952
	9	0.0147	96.1513	3.7853	0.0635
	12	0.0184	95.3730	4.5660	0.0590
OIL	3	0.0592	0.3065	99.2321	0.4614
	6	0.0977	0.2480	98.4269	1.3251
	9	0.1237	0.2804	98.2665	1.4531
	12	0.1440	0.4043	98.1798	1.4159
CPI	3	0.1539	0.9059	4.6840	94.4102
	6	0.2552	1.2858	8.3525	90.3617
	9	0.3368	6.6568	18.2492	75.0939
	12	0.4105	10.5984	26.8033	62.5984
1986M1-2007M4					
Variance decomposition	Period	S.E.	OIL	EXCHR	CPI
OIL	3	0.0075	99.8314	0.1133	0.0553
	6	0.0134	99.2483	0.2103	0.5415
	9	0.0178	98.3402	0.4981	1.1617
	12	0.0215	97.8392	0.6661	1.4946
EXCHR	3	0.0702	1.6792	98.0341	0.2867
	6	0.1007	5.9485	93.5817	0.4698
	9	0.1170	8.2426	91.3795	0.3779
	12	0.1323	8.0637	91.6390	0.2973
CPI	3	0.1718	3.3447	7.4389	89.2164
	6	0.2401	6.2979	18.1609	75.5412
	9	0.2794	5.7882	21.8211	72.3907
	12	0.3163	6.4306	23.7566	69.8128