WP/02/165
Revised: 10/17/02

IMF Working Paper

An Empirical Investigation of Exchange Rate Pass-Through in South Africa

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INTERNATIONAL MONETARY FUND

 WP/ 02/165

IMF Working Paper

African Department

An Empirical Investigation of Exchange Rate Pass-Through in South Africa

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Authorized for distribution by Michael Nowak

September 2002

Abstract

This paper analyzes the degree to which fluctuations in the nominal exchange rate passthrough to consumer prices in South Africa. While the average pass-through is found to be low, evidence from a structural vector autoregression suggests it is much higher for nominal (versus real) shocks. Historical decompositions suggest that the nominal exchange rate depreciation up to November 2001 is attributable primarily to negative real shocks, which explains why CPIX (consumer price index excluding interest on mortgage bonds) inflation did not increase significantly until December 2001, when positive nominal shocks began to contribute to the depreciation.

JEL Classification Numbers: E31, E37

Keywords: Pass-through, exchange rate, producer prices, structural VAR

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[1] The author would like to thank staff at the South African Reserve Bank and South African Treasury, seminar participants at the University of Witwatersrand (Johannesburg), the African Department at the IMF, and Jan Gottschalk for helpful comments on an earlier draft.

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I. Introduction

The South African authorities preannounced in 2000 their intention to target CPIX[2] inflation directly beginning in 2002.[3] The CPIX inflation target is set as a (annual average) range of 3-6 percent in 2002 and 2003, and 3-5 percent in 2004 and 2005. Large fluctuations in the external value of the rand in 2001 and 2002 have made the South African Reserve Bank (SARB)'s task of hitting the inflation target in 2002 considerably more difficult. After the rand depreciated by almost 40 percent in the last four months of 2001, CPIX inflation picked up significantly in 2002. Lags in monetary policy mean that it will be difficult for the SARB to meet its inflation target in 2002 without significantly increasing its policy interest rate, which would have undesirable consequences for output. To benefit discussion about the appropriate response of monetary policy to the rand weakness, this paper analyzes the link between rand depreciation and CPIX inflation, commonly known as exchange rate pass-through.

Currency depreciation can affect domestic prices directly by increasing the domestic currency price of tradables, and indirectly through changes in economic activity when the price of foreign goods increases relative to domestic goods. The extent to which currency fluctuations passthrough to domestic prices will depend on the weight of imported goods and services in the production process and many other factors, including the degree to which import prices are priced to market in the importing country's currency. Pass-through may also be endogenous to the monetary policy regime because policy credibility underpins agents' expectations about the willingness of the authorities to counteract the second-round effects of currency depreciation on inflation.

A number of theoretical and empirical studies have analyzed the transmission of exchange rate fluctuations to domestic prices for a variety of countries at different levels of aggregation.[4] Choudhri and Hakura (2001) find that the inflation regime is a significant determinant of the degree of pass-through for a cross section of countries. They focus on headline consumer prices and find a pass-through elasticity for South Africa of 7 percent after two years. The South African Reserve Bank, in its *Monetary Policy Review* of April 2002, reports a long-run pass-through elasticity of 78 percent for import prices—a 10 percent depreciation in the nominal effective exchange rate is reflected in a 7.8 percent increase in import prices in the long run.

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[2] CPIX is the consumer price index, excluding interest on mortgage bonds.

[3] The Minister of Finance announced the move in his Budget speech on 23 February, 2000. Additional information is contained in the appendix to the Monetary Policy Statement, 6 April 2000, South African Reserve Bank.

[4] See Krugman (1979) and Hooper and Mann (1989) for theoretical and empirical insights, and Menon (1995) for a survey of the empirical literature.

This paper focuses on CPIX inflation because it is the operational target of the SARB, while most attention is paid to the pass-through profile over two years, as this is the horizon over which monetary policy has the most impact on inflation (see the SARB's *Monetary Policy Review* for October 2001). The framework underpinning the analysis in Section II follows McCarthy (1999) and is based on the idea that prices are set along a distribution chain that comprises three stages in the following order: imports (import prices), production (production prices), and consumption (CPIX). The working definition of exchange rate pass-through used in this analysis is the *correlation between exchange rate fluctuations and quarterly CPIX inflation.*

The distribution chain is modeled as a six-variable recursive vector autoregression (VAR), and impulse responses are analyzed. Exchange rate shocks result in a gradual increase over time in the level of CPIX—on average, eight quarters after a 1 percent shock to the nominal effective exchange rate, the level of CPIX increases by 0.12 percent, giving a pass-through elasticity of 12 percent. However, the pass-through elasticity resulting from shocks to producer price inflation is high at about 72 percent after eight quarters, suggesting that favorable shocks to producer price inflation can help to bring CPIX inflation back to target.

The paper then distinguishes between real and nominal shocks, and investigates their impact on the exchange rate and prices. A bivariate VAR comprising the real exchange rate and relative prices (CPIX relative to trade-weighted foreign prices) is estimated, and long-run restrictions are used to identify structural nominal and real shocks, along the lines of the Blanchard and Quah (1989) structural VAR (SVAR) methodology. The impulse response functions for the nominal exchange rate and relative prices reveal how these variables respond to nominal versus real shocks.[5] Evidence from a historical decomposition of the nominal effective exchange rate (NEER) indicates that up to November 2001, negative real shocks were the primary driver of the rand depreciation, and that positive nominal shocks began to contribute to the depreciation from December 2001 onward, when CPIX inflation also began to increase. The incidence and timing of negative real shocks is consistent with the fact that in 2001 fiscal policy was one percentage point tighter than the target announced by the minister of finance, and the world economy was slowing. The incidence of positive nominal shocks is consistent with the lagged impact of a loosening in monetary policy from June and September 2001.

[5] The nominal exchange rate is calculated from the impulse response of the real exchange rate and relative prices.

II. The Distribution Chain: A Vector Autoregression (VAR) Analysis

An agnostic approach is taken to model the dynamic interrelationships between the price variables in the distribution chain.[6] A vector autoregression (VAR) is estimated, and following McCarthy (1999), a recursive Cholesky orthogonalization identifies the primitive shocks (see Appendix II for details). The VAR comprises six variables in the following order: oil price inflation, π^{oil}, which is a proxy for international supply shocks; output gap, y; the change in the nominal effective exchange rate, Δe; import price inflation, π^{m}; producer price inflation, π^{p}; and CPIX inflation, π^{c}. At time t, they are determined by the previous period's expectation and their respective shocks, or expectational error, ε_t. The variable ordering assumes that international supply and output gap shocks are exogenous to the exchange rate at time t, and that pricing decisions at the import and production stage can have a contemporaneous impact on consumer prices, but not vice versa.

$$\pi_t^{oil} = \underset{t-1}{E}(\pi_t^{oil}) + \varepsilon_t^{oil}$$

$$y_t = \underset{t-1}{E}(y_t) + a_1\varepsilon_t^{oil} + \varepsilon_t^{y}$$

$$\Delta e_t = \underset{t-1}{E}(\Delta e_t) + b_1\varepsilon_t^{oil} + b_2\varepsilon_t^{y} + \varepsilon_t^{\Delta e}$$

$$\pi_t^{m} = \underset{t-1}{E}(\pi_t^{m}) + c_1\varepsilon_t^{oil} + c_2\varepsilon_t^{y} + c_3\varepsilon_t^{\Delta e} + \varepsilon_t^{m}$$

$$\pi_t^{p} = \underset{t-1}{E}(\pi_t^{p}) + d_1\varepsilon_t^{oil} + d_2\varepsilon_t^{y} + d_3\varepsilon_t^{\Delta e} + d_4\varepsilon_t^{m} + \varepsilon_t^{p}$$

$$\pi_t^{c} = \underset{t-1}{E}(\pi_t^{c}) + f_1\varepsilon_t^{oil} + f_2\varepsilon_t^{y} + f_3\varepsilon_t^{\Delta e} + f_4\varepsilon_t^{m} + f_5\varepsilon_t^{p} + \varepsilon_t^{c}$$

The ordering and choice of variables is motivated by the idea that prices are set at each of three different stages—import, production and consumer—, which together make up a stylized distribution chain for goods and services. The VAR controls for oil price inflation (in U.S. dollars) and domestic demand pressures using an output gap equation.

Implicit in the variable ordering is the assumption that causality runs from the nominal effective exchange rates to prices,[7] and that the degree of endogeneity increases as you move down the order. This is a potential drawback of the recursive structure because prices can feedback to exchange rates within the period of one quarter, the frequency of the data set. Therefore, alternative orderings of the variables are estimated to check for the robustness of

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[6] Sims (1980) argues against "incredible identification restrictions" inherent in structural models. For this exercise, in the absence of a prior theory about the relationship between the price variables, a standard nonstructural Cholesky decomposition is used to identify the primitive innovations (see Appendix II for details).

[7] Results from pairwise Granger noncausality tests are inconclusive, finding little evidence of granger causality in either direction.

the preferred ordering. Several other modifications are made to the basic setup, including by trying different measures of the nominal exchange rate (bilateral versus nominal effective);[8] making different estimates of the output gap; including trade-weighted foreign consumer prices as an exogenous variable; using different measures of consumer prices (Appendix III). The basic model is robust to each of these modifications.

All the variables were found to be I(1), apart from the output gap, which was stationary (see appendix IV for the unit root test results). No cointegration was found between the variables with the output gap entering as an exogenous I(0) variable,[9] and so the VAR was estimated in first differences to avoid the spurious regression problem.[10] A time dummy beginning in 1994: Q1 is included in the VAR to capture structural change as the economy opened up under the post-apartheid government.

A. Results: The Impulse Response Analysis

Impulse response functions trace out the effect over time on prices of orthogonal shocks to the exchange rate equation. The cumulative impulse responses for import, producer and consumer prices to a shock to the exchange rate equation [11] is plotted in Figure 1—for comparability, the shock is one standard error (approximately 5.5 percent). The pass-through elasticity at time *t* is given by the following ratio:

$$\text{Pass-through elasticity at time } t = \frac{\text{percent change in price level } t \text{ quarters after shock}}{\text{initial percent change in the exchange rate at } t=0}$$

The numerator is the percentage change in the level of the CPIX between period 0, when the initial exchange rate shocks hits, and time *t*. The denominator is the percentage change in the nominal effective exchange at time 0 (or the initial shock).

[8] Athukorala and Menon (1994) point out that pass-through elasticities may be sensitive to how the nominal exchange rate is defined, and since a large share of South Africa's exports are commodities priced in U.S. dollars, the bilateral rand-U.S. dollar exchange may be more important for transmitting exchange rate shocks to prices.

[9]When I(1) data are cointegrated, a model is misspecified if it is estimated as a differenced VAR because this ignores the levels information from the error-correction process.

[10] The optimal lag length is chosen using Akaike information criterion.

[11] Since the model is estimated in first differences, the impulse responses are for quarterly CPIX inflation. It is necessary to plot the cumulative impulse responses to trace out the impulse response profile for the price level.

Figure 1. Pass-Through Elasticities for CPIX, Import Prices, and Producer Prices

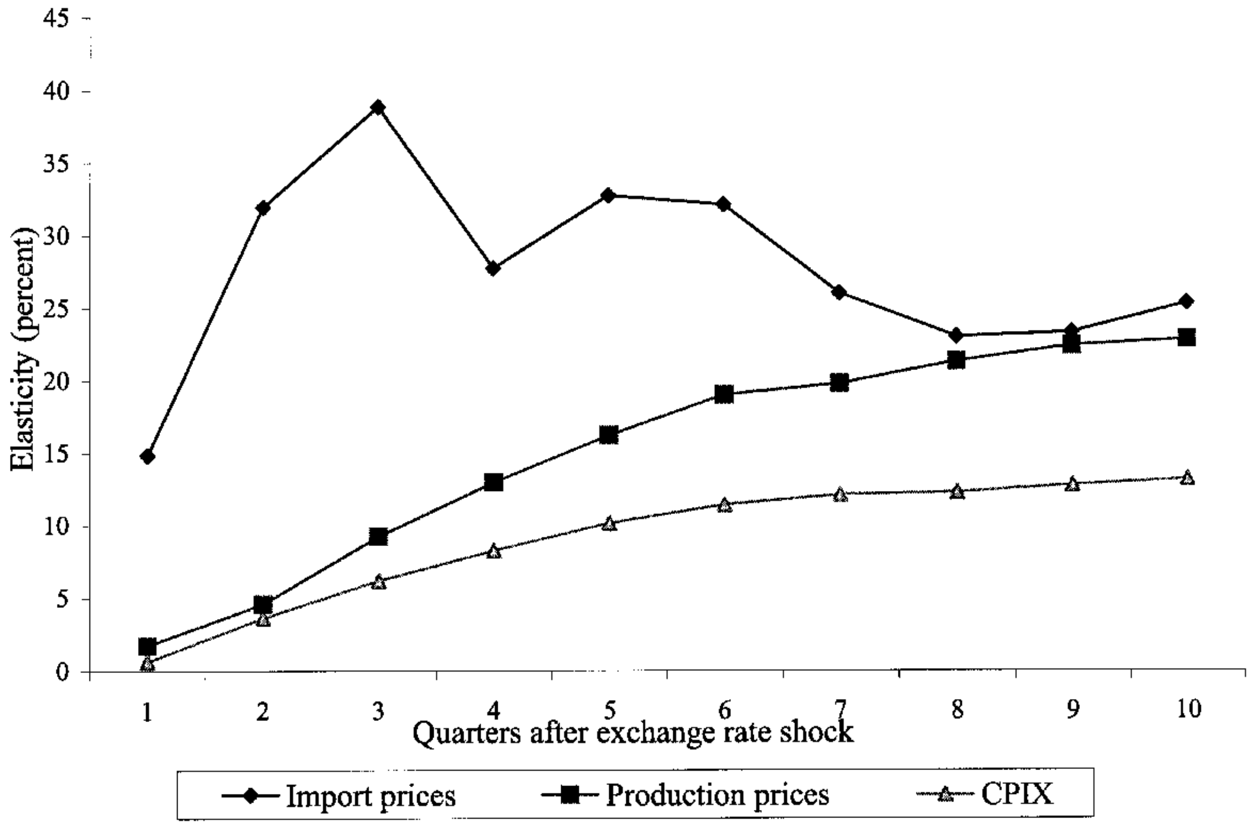


Table 1. Time Profile of the Pass-Through Elasticity for CPIX

	$t=4$	$t=8$	$t=10$
CPIX	8.3	12.3	13.2

The exchange rate shock feeds through to CPIX gradually, with the rate of increase slowing over time. This deceleration is also observed in the pass-through profiles for import and producer prices (Figure 1). The ranking of pass-through elasticities—it is highest for import prices, followed by producer prices and CPIX—suggests that shocks to the exchange rate have a successively smaller impact as you move down the distribution chain. This result is reinforced by the fact that the ranking does not change for different orderings of the variables.

Less than one-half of the long-run pass-through to CPIX feeds through by the first year. Choudhri and Hakura (2001) find a long-run pass-through of 14 percent for headline consumer prices in South Africa, but one of 7 percent after two years compared to an estimate of 12 percent for after two years for CPIX found in this study (Table 1). Both studies suggest that, on average, the pass-through in South Africa has been low. As discussed above, strategic behavior in the form of pricing-to-market may explain why exchange rate fluctuations are not fully reflected in domestic prices.[12] Frictions in price-setting behavior of the New Keynesian menu cost type may also explain why pass-through is low. Burstein, Eichenbaum and Rebelo (2002) present evidence for a wide range of countries that substitution by consumers away from imports to lower quality local goods is able to account for the absence of complete pass-through, even when there have been large currency devaluations.

B. Pass-Through to CPIX from Producer Price and Import Price Shocks

The CPIX cumulative impulse response functions are also used to analyze the pass-through to the CPIX from shocks to producer prices and shocks to imports prices. In contrast to the exchange rate results, pass-through from shocks to producer prices is high and close to complete; after only eight quarters, the pass-through elasticity is 75 percent—that is, on average, the level of CPIX increases by 7.5 percent following an increase of 10 percent in producer prices (Figure 2), and increases to approximately 85 percent in the long run. However, the impact of import price shocks on CPIX is small—the pass-through elasticity peaks at just over 3½ percent in the long run.

The very low pass-through from import price shocks seems a little puzzling, but may be explained by consumers substituting away from imported goods to domestically produced goods, or if distribution costs,[13] which may comprise a large share of non-traded inputs, are a major component of the final price of consumer goods (see Burstein, Eichenbaum and Rebelo, 2002, for a discussion). In the absence of disaggregated price data, it is not possible to verify these hypotheses, but is a possible avenue for future research.

[12] Krugman (1987) and Dornbusch (1987) show that under imperfect competition "pricing-to-market" may explain why fluctuations in the exchange rate are not reflected one-for-one in prices. But it would require a structural model to test alternative theories consistent with the low pass-through result.

[13] Distribution costs should be interpreted widely here to include wholesale and retail services that are nontraded.

Figure 2. Pass-Through Elasticities from Shocks to Producer Prices and Import Prices

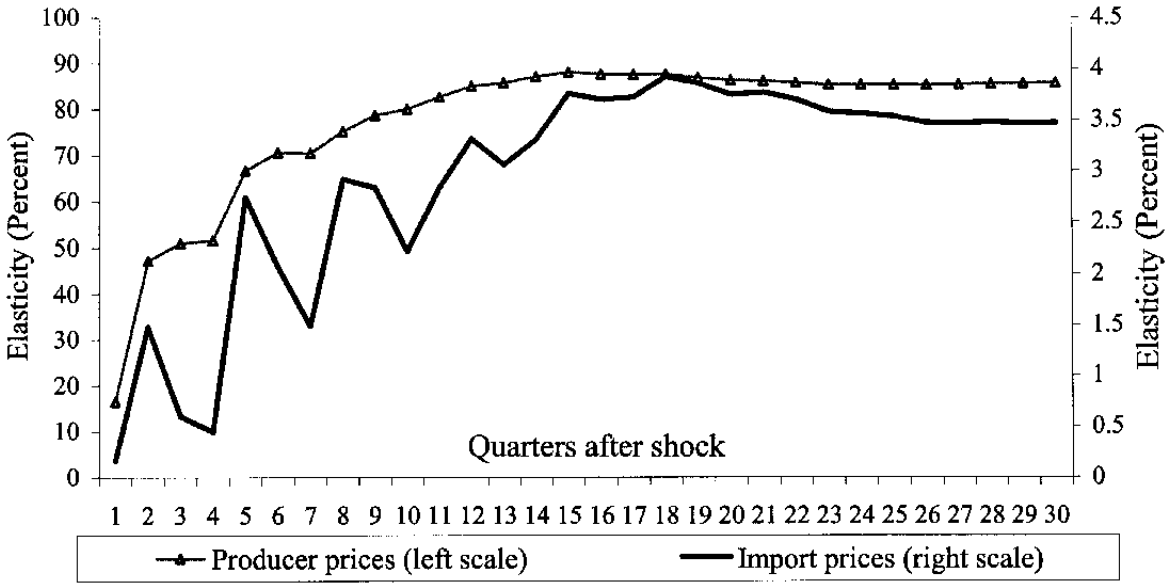
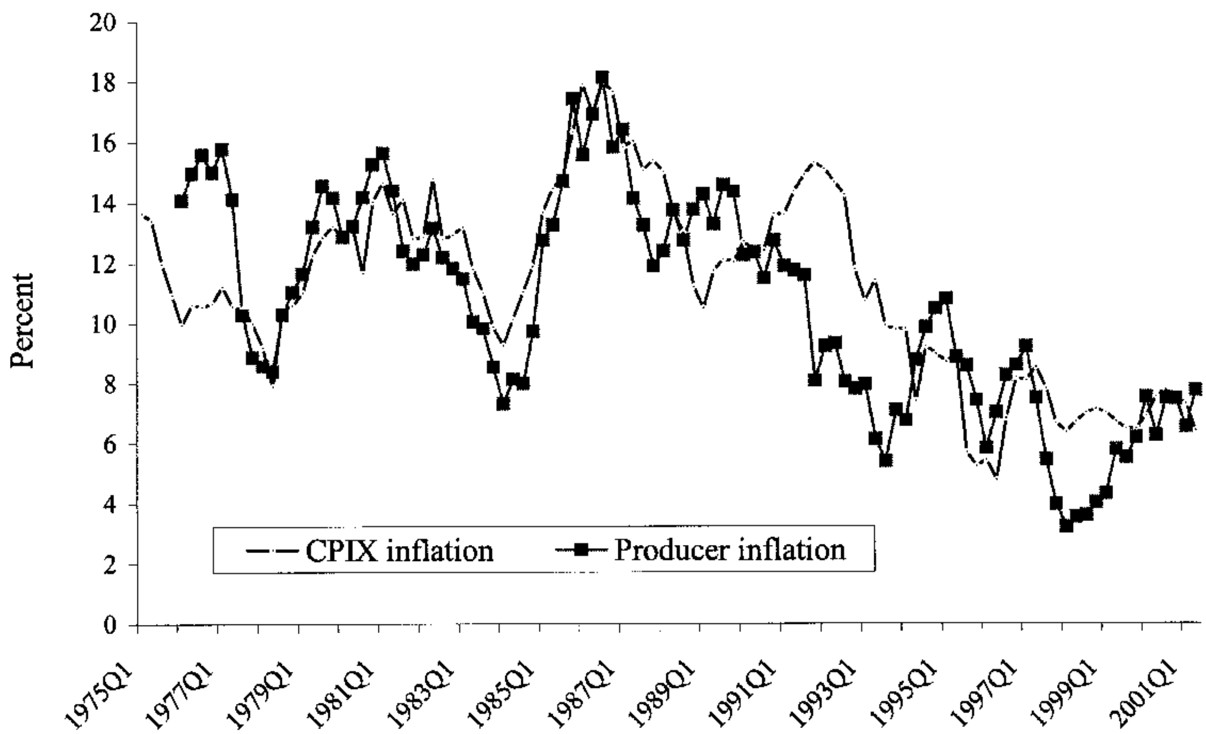
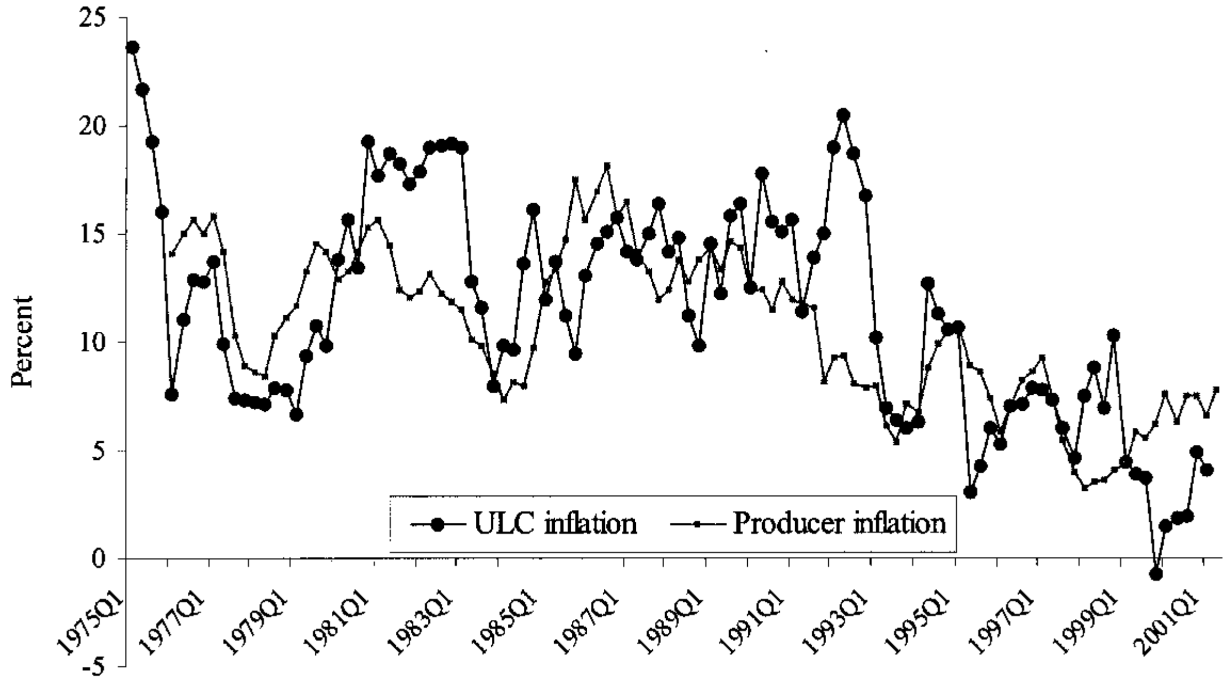


Figure 3. Twelve-Month CPIX Inflation and Producer Price Inflation



The evidence of high pass-through from producer price shocks to CPIX is reinforced by the strong correlation between producer price inflation and CPIX inflation (Figure 3). The fall in CPIX inflation beginning in the early 1990s was led by a fall in producer price inflation that began in 1989; however, the relationship seems to have weakened somewhat in the latter part of the 1990s. Nonetheless, these results suggest that structural reforms aimed at improving competitiveness, and which lower costs at the producer price level, are likely to provide a significant boost to CPIX disinflation. For example, growth in unit labor costs is highly correlated with producer price inflation (Figure 4), suggesting that labor reforms that moderate unit labor costs could help mitigate any inflationary pressures.

Figure 4. Twelve-Month Producer Price and Unit Labor Cost Inflation



III. Identifying the Source of Exchange Rate Shocks

While the previous evidence indicates that the average pass-through has been low in South Africa, it does not rule out the possibility that for specific shocks it may be higher or lower than the historical average. We know from economic theory that the dynamics of exchange rate pass-through also depend on the nature of the economic shock. As noted by Alberola, Ayuso, and Lopez-Salido (2000), the exchange rate and prices are jointly determined and their comovement may vary across different types of shocks. Consequently, identifying the source of the underlying shock to the economy, and its impact on the exchange rate, is important for assessing the possible implications for domestic inflation.

The analysis is based on the following (log) real exchange rate relationship:

$$q = e - p,$$

q is the real effective exchange rate, *e* is the nominal effective exchange rate, and *p* is domestic prices relative to trade-weighted foreign prices. This approach involves estimating a bivariate structural VAR (SVAR) comprising trade-weighted relative prices and the real effective exchange rate, and imposing theory-based long-run restrictions (along the lines of Blanchard and Quah, 1989) to identify nominal shocks and real shocks. The long-run restrictions are motivated by a model of the real exchange rate in which prices are sticky in the short run so that a domestic monetary expansion, for example, causes an initial overshooting (depreciation) of the nominal exchange rate; however, in the long run, as relative prices adjust, the real exchange returns to its unchanged long run level.[14] Table 2 notes the expected response of the real exchange rate (*q*), relative prices (*p*), and the nominal exchange rate (*e*) to a nominal and real shock.

Table 2. Expected Response To Nominal and Real Shocks

Type of shock	Variable					
	q		e		p	
	S	L	S	L	S	L
Nominal shock	+	0	+	+	+	+
Real shock	?	?	?	?	?	?

Note: S and L are the expected short run and long run responses, respectively.

A. The Impulse Response Results

The impulse response functions trace out the comovement of relative prices and the real exchange rate, including the implied nominal exchange rate, in response to nominal and real shocks. The response of each of the three variables to a real shock is ambiguous (Table 2) because the framework cannot distinguish between real demand and real supply shocks—each has different implications for the comovement of relative prices and the nominal exchange rate.[15] For example, a domestic real demand shock leads to an increase in domestic prices relative to foreign prices, and an appreciation in the nominal and real exchange rate in the short and long run, which relieves excess demand pressures in the economy, other things equal. However, in the case of a positive supply shock, domestic prices would fall relative to foreign prices, and the real exchange rate would depreciate in both the short and long run to reflect the improvement in supply. The impact on the nominal exchange rate is ambiguous, and depends on whether the fall in relative prices is greater than the depreciation in the real exchange rate.

[14] Consistent with economic theory, the long-run restrictions impose ensure that nominal shocks have no permanent impact on the level of the real exchange rate, but real shocks do.

[15] To identify real supply shocks separately from real demand shocks, additional information is needed, requiring an extension of this framework

The impulse responses (Figure 5) show that a positive real shock results in a permanent appreciation of the real effective exchange rate (REER) and the nominal effective exchange rate (NEER), and a modest increase in domestic prices relative to foreign prices. Without being able to distinguish between real demand and real supply shocks, we can conclude that, on average, a positive real shock does not induce strong pass-through dynamics.

The implications of a positive nominal shock are very different (Figure 6). The price response is much stronger, and the nominal exchange rate depreciates and overshoots, resulting in a temporary real exchange rate depreciation that eventually returns to its original level (consistent with the long-run restriction that nominal shocks have no long run impact on the real exchange). This corresponds to the typical pass-through scenario of exchange rate depreciation being associated with higher domestic inflation. Moreover, the impulse responses indicate that it takes approximately twelve months after a nominal shock for relative prices to fully adjust to the nominal exchange rate depreciation and bring the real exchange rate back to its original equilibrium (Figure 6).

Figure 5. The Impulse Responses for a Positive Real Shock

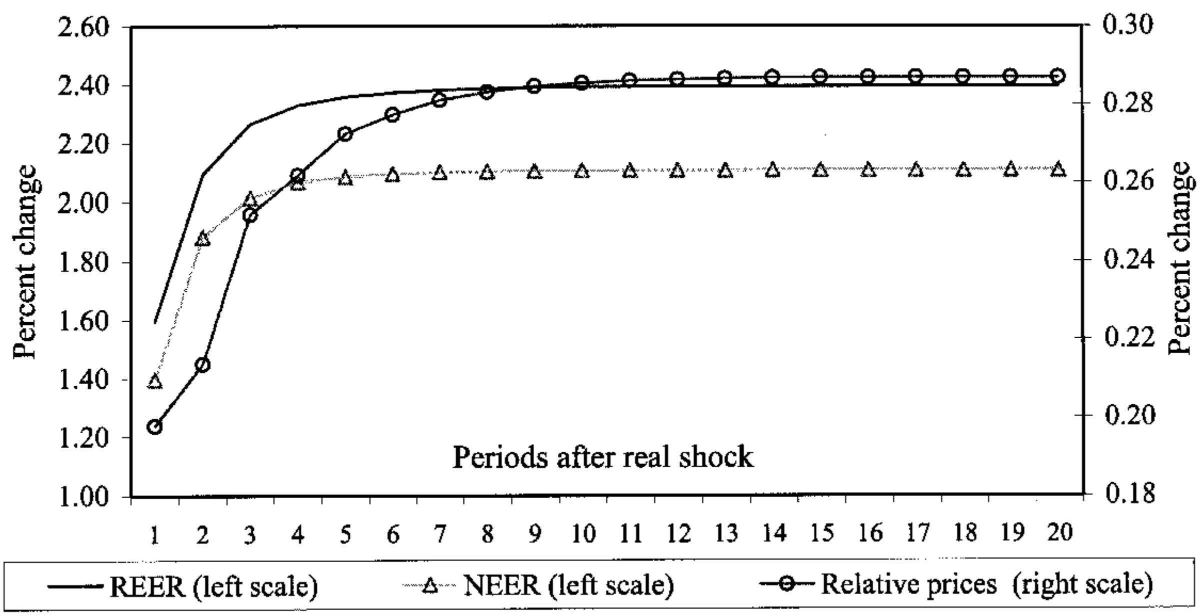
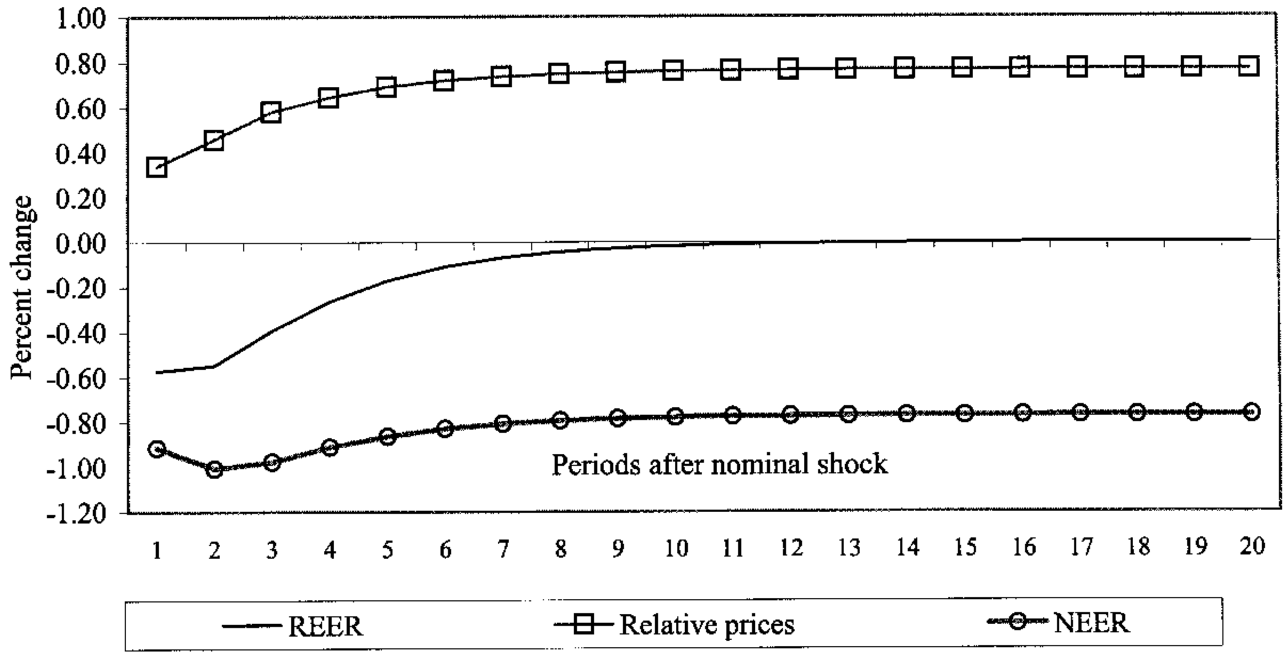


Figure 6. The Impulse Responses for a Positive Nominal Shock



B. Variance Decomposition Results

This section reports results from a variance decomposition of the forecast errors for the real exchange rate and relative prices that are generated by the bivariate VAR. These are used to determine which of the two shocks, nominal or real, have been more important in explaining the historical variation in the real exchange rate and relative prices (Table 3).

Table 3. Percent Variance Explained by Real Shocks

Horizon (months)	q	p
2	89	23
8	88	21
12	88	21
24	88	21

The results show that real shocks explain a greater proportion of the variance in real exchange rate forecast errors, and that nominal shocks (100 minus the percentage explained by real shocks) explain most of the variance in forecast errors for relative prices. These results suggest that nominal shocks have been more important for explaining fluctuations in relative prices.

C. Explaining the Nominal Exchange Rate Fluctuations in 2001: Q4

By combining the impulse response functions and the time series of the structural real and nominal shocks, the observed fluctuations in the nominal exchange rate and relative prices are decomposed into that part explained by the structural nominal shocks, and that part explained by the structural real shocks over the second half of 2001 and up to March 2002.[16] These historical decompositions reveal the relative importance of nominal and real shocks in explaining actual fluctuations in the nominal effective exchange rate (NEER) and relative prices over this period (Figures 7 and 8).

Figure 7. Cumulative Impact of (Structural) Nominal and Real Shocks on the NEER

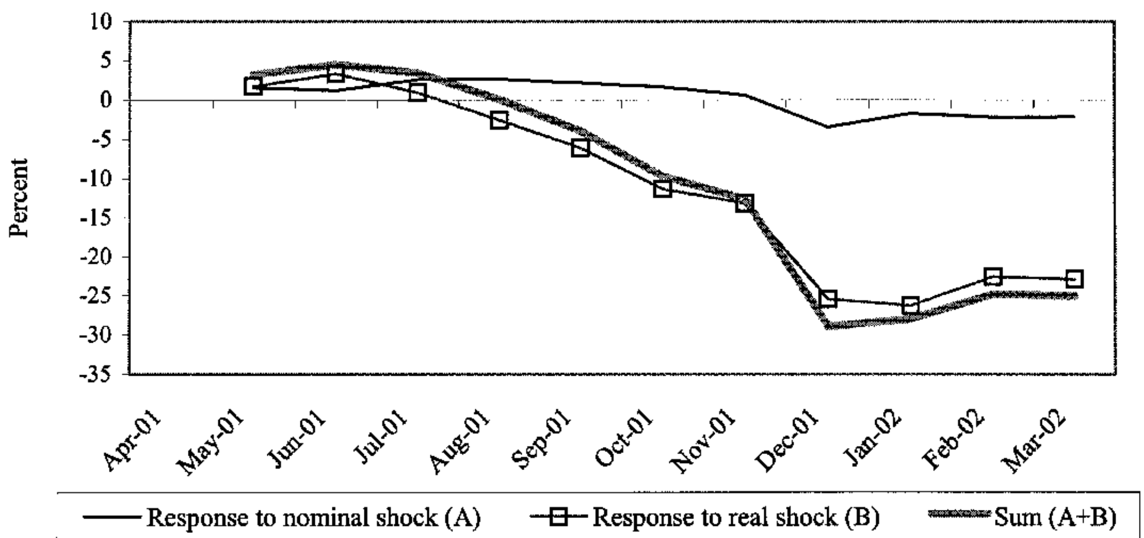


Figure 7 decomposes the response of the NEER into that part explained by nominal shocks and that part explained by real shocks. Negative real shocks account for almost all of the observed depreciation in the NEER up to November 2001. Nominal shocks began to contribute to the depreciation of the NEER only from November 2001 (Figure 7). This helps to explain why domestic inflation did not pick up during this time even though the nominal exchange rate had depreciated significantly (Figure 8). Nominal shocks began to put upward pressure on domestic prices vis-à-vis South Africa's trading partners from December 2001 onward, when they were also making a significant contribution to the currency depreciation. The positive impact of nominal shocks on domestic prices continued into 2002, with the cumulative impact growing more positive over time.

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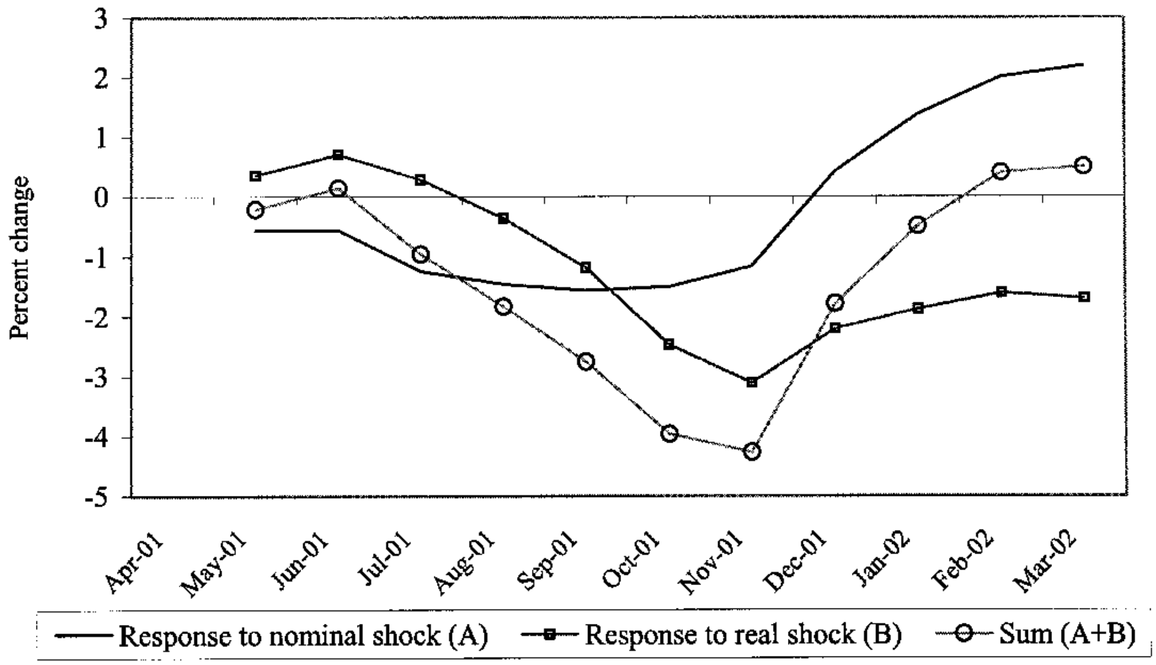
[16] The structural shocks are the identified nominal and real shocks. The respective impulse response functions govern how the real exchange rate, nominal exchange rate, and relative prices respond to these shocks.

Figure 8. Cumulative Impact of (Structural) Nominal and Real Shocks on Relative Prices



A number of factors may help to explain the contribution of nominal and real shocks to the exchange rate and price fluctuations in 2001 and 2002. The slowdown in world economic activity, and a tighter than targeted fiscal outturn probably contributed to the negative real shocks hitting South Africa in 2001. The outturn for the overall fiscal balance in 2001/02 is estimated to be one percentage point tighter than the announced target of 2½ percent of GDP.

The evolution of nominal shocks from May to November, 2001 can in part be explained by the relatively tight monetary policy stance from late 1999 through to June 2001. Ex-post real interest rates averaged 6½ percent in 2000, and were increasing steadily up to June 2001 as inflation continued to fall. Then the SARB made three cuts to its repurchase rate, from 12 percent in June to 9½ percent by September 2001, which resulted in higher money growth in late 2001. This acceleration in money growth is consistent with the positive nominal shocks identified in this paper as having contributed to the nominal depreciation and with the increase in CPIX inflation in 2002.

IV. Conclusions

Evidence has been presented in this paper that the inflationary impact of exchange rate depreciations in South Africa has been absorbed at intermediate stages of production. However, shocks to producer prices have tended to have a considerable impact on CPIX. Consequently, policies oriented toward mitigating inflationary pressures at the producer price level would help the SARB to bring CPIX inflation back to target and keep it there.

The paper also draws attention to the importance of identifying the nature of the underlying shock when assessing pass-through dynamics. Nominal shocks induce the standard exchange rate pass-through dynamics and are important for explaining relative price fluctuations in South Africa. However, when real shocks are responsible for nominal exchange rate depreciation the response of inflation is much smaller. The historical decompositions of the nominal exchange rate and relative prices show that the combination of the nominal exchange rate depreciation and the pickup in CPIX inflation in December 2001 was the result of significant positive nominal shocks hitting South Africa during this time. Future work could extend the analysis in this paper to include additional information that allows for the separate identification of real demand and real supply shocks.

Data Sources

All data is from the South African Reserve Bank unless otherwise stated.

Rand price of oil—IMF, with price converted to Rand using period average Rand-U.S. dollar exchange rate.

Output gap—this is the difference between actual GDP and potential GDP. Actual GDP is quarterly real GDP at market prices (1995=100), and potential GDP is estimated using a HP filter with a smoothing parameter of 1600. An alternative method used for calculating potential GDP was to fit a cubic polynomial time trend to actual real GDP.

Import prices—import price index.

Production prices—Production prices index of goods and services for domestic consumption; excludes imports

Consumer price index—includes food and other volatile items, and mortgage interest; 2000=100

Core consumer price index—provided by the SARB. Excludes the following items: food, interest on mortgage bonds, and VAT.

CPIX—consumer prices excluding interest on mortgage bonds; pre-1997 the data is a synthetic index constructed by the SARB.

Real effective exchange rate—SARB's calculation of trade-weighted real exchange rate.

P*—trade weighted foreign price level calculated by the SARB and consistent with their real effective exchange rate calculation.

Identification

The Recursive VAR and Long-Run Restrictions

Suppose that the expression below represents the underlying structural model, where X_t is the vector of the macroeconomic variables, matrix A_0 describes the contemporaneous relationships between the variables, A(L) is the finite-order lag polynomial matrix, ε_t is the (unobserved) vector of structural shocks, and matrix B governs how the structural shocks affect the different macroeconomic variables; nonzero off-diagonal elements in B indicate that the structural shocks affect more than one variable simultaneously:

$$A_0 X_t = A(L) X_{t-1} + B\varepsilon_t$$

This structural model is not directly observable, but instead a reduced form VAR can be estimated from which the structural model must be identified. In this paper, a six-variable VAR of the following form is estimated:

$$X_t = A_0^{-1} A(L) X_{t-1} + e_t$$

where e_t is the vector of observed residuals that are related to the structural shocks in the following way: $A_0 e_t = B u_t$ or equivalently:

$$e_t = A_0^{-1} B u_t$$

which is used to derive the relationship between the variance-covariance matrix of e_t (observed) and ε_t (unobserved):

$$E(e_t e_t') = A_0^{-1} B E(u_t u_t') B' A_0^{-1}$$

This variance-covariance matrix has n(n+1)/2 elements, which is also the number of elements in A_0 and B, and so a necessary condition for identification is that the number of parameters does not exceed the number of elements in A and B. Another condition is that no equation in A_0 or B should be a linear combination of the other equations. The cholesky decomposition restricts matrix A_0 to be lower triangular, and B to be diagonal. This imposes the correct number of restrictions for just identification and imposes a recursive structure on the system so that the most endogenous variable is ordered last i.e. it is affected by all contemporaneous "structural" shocks, ε_0.

Structural VAR: Long-Run Identification Restrictions

In Section III the Blanchard and Quah, 1989, identification scheme is employed to identify nominal and real shocks from a bivariate structural VAR (SVAR) of the real exchange rate and relative prices. Often long-run restrictions are acceptable across a wide range of economic models. In this paper, the long-run restriction is that nominal shocks have no long-run impact on the real exchange rate.

In the following generic model, matrix A is restricted to be the identity matrix:

$$y_t = \sum_{i=1}^{p} A_i y_{t-i} + B\varepsilon_t$$

Then the matrix that describes the long run impact of the structural shocks, ε, on the variables is the following:

$$\left(I - \sum_{i=1}^{p} A_i\right)^{-1} B\varepsilon_t = -\Pi^{-1} B\varepsilon_t$$

Coefficients in B are obtained from the reduced form, and therefore long-run restrictions can be imposed given the estimation of the reduced form. Note that the long-run restrictions are restrictions on the cumulative impulse response function.

The VAR Estimation Results and Robustness Tests

Several different models are estimated to test whether the principle result for the CPIX model is robust to alternative measures of consumer prices, the exchange rate or the inclusion of foreign trade-weighted prices as an exogenous variable. Qualitatively, the results are the same, while the empirical magnitudes of the pass-through elasticities are very similar, and not statistically different (see Table III.5).

Alternative Measures of Consumer Prices

The sample period for the core price model is 1976Q2 to 2000Q3, and for headline prices it is 1985Q1 to 2000Q3—evidence of a structural break in the differenced series for headline prices around 1985 meant that the sample period for headline prices had to be shortened to avoid biasing the results. Moreover, the impulse responses were not sensible when the model was estimated over the whole sample.

Table III.1. Summary Statistics for the Core Inflation VAR Model

Lag length of 4	Equations					
Sample 1980Q1:2001Q2	DLOIL	GAP	DLE	DLIMP	DLPRODP	DLCP
R-squared	0.43	0.91	0.42	0.53	0.64	0.63
Adj. *R*-squared	0.19	0.87	0.17	0.33	0.49	0.47
Sum sq. resids	0.92	0.00	0.20	0.04	0.00	0.01
S.E. equation	0.12	0.01	0.06	0.03	0.01	0.01
F-statistic	1.78	24.35	1.71	2.67	4.25	4.07
Log likelihood	73.10	328.54	139.17	207.02	307.28	289.40
Akaike AIC	-1.10	-7.04	-2.63	-4.21	-6.54	-6.13
Schwarz SC	-0.35	-6.29	-1.89	-3.47	-5.80	-5.38
Mean dependent	0.00	0.00	-0.02	0.03	0.03	0.03
S.D. dependent	0.14	0.02	0.06	0.03	0.01	0.01

Table III.2: Summary Statistics for the Headline Inflation VAR Model

Lag length of 2	Equations					
Sample 1985Q1:2001Q2	DLOIL	GAP	DLE	DLIMP	DLPRODP	DLP
R-squared	0.26	0.92	0.32	0.52	0.52	0.61
Adj. *R*-squared	0.08	0.90	0.15	0.41	0.40	0.51
Sum sq. resides	1.13	0.00	0.19	0.03	0.00	0.00
S.E. equation	0.15	0.00	0.06	0.03	0.01	0.01
F-statistic	1.41	45.07	1.87	4.41	4.29	6.30
Log likelihood	40.61	264.87	99.46	156.40	223.21	225.39
Akaike AIC	-0.81	-7.60	-2.59	-4.32	-6.34	-6.41
Schwarz SC	-0.34	-7.14	-2.13	-3.85	-5.88	-5.94
Mean dependent	0.00	0.00	-0.02	0.02	0.02	0.03
S.D. dependent	0.15	0.02	0.07	0.03	0.01	0.01

Table III.3: Summary Statistics for the CPIX inflation VAR model

Lag length 3	Equations					
Sample 1980Q1:2001Q2	DLOIL	GAP	DLE	DLIMP	DLPRODP	DLCPIX
R-squared	0.27	0.91	0.26	0.47	0.59	0.70
Adj. R-squared	0.07	0.88	0.04	0.32	0.47	0.61
Sum sq. resides	1.16	0.00	0.25	0.05	0.00	0.00
S.E. equation	0.13	0.01	0.06	0.03	0.01	0.01
F-statistic	1.32	33.46	1.20	3.07	4.99	8.00
Log likelihood	63.06	326.51	128.73	202.12	301.75	320.69
Akaike AIC	-1.00	-7.13	-2.53	-4.24	-6.55	-6.99
Schwarz SC	-0.43	-6.56	-1.96	-3.66	-5.98	-6.42
Mean dependent	0.00	0.00	-0.02	0.03	0.03	0.03
S.D. dependent	0.14	0.02	0.06	0.03	0.01	0.01

Table III.4. Residual Diagnostics (p-values are in parenthesis)

	Test statistics	
Model	Normality Jarque-Bera $\chi^2(2)$	ARCH $\chi^2(2)$
CPIX	222 (0.02)	1276 (0.69)
Core CPI	201 (0.15)	1112 (0.09)
Headline CPI	196 (0.21)	593 (0.08)

Table III.4 reports the residual diagnostic tests—specifically the test for (joint) residual normality (Jarque-Bera test) and the test for residual heteroskedasticity. The null hypotheses are, respectively, the residuals are normal and they are homoskedastic. While the residuals are borderline normal in the CPIX model, this is the only diagnostic test statistic that causes any problems. Even then, the evidence is borderline.

The impulse responses from the core CPI and headline CPI were very similar to the impulse responses for the CPIX model. The estimated pass-through coefficients were not statistically significantly different indicating the results are robust to alternative measures of the general level of prices.

Alternative Exchange Rate Measure

South Africa is a major exporter of commodities that are priced in U.S. dollars on international commodity exchanges. Consequently, it is important to check whether the impulse responses and estimated pass-through is robust to using an alternative measure of the exchange rate. The result for the bilateral rand-U.S. dollar exchange rate shows that the degree of pass-through is very similar to the model that uses the nominal effective exchange rate.

Including Foreign Price inflation, *dP**, as an exogenous variable

The paper also tests for the robustness of the pass-through results in the basic CPIX model when foreign prices are included in the VAR as an exogenous variable since South Africa is a price-taker in international markets. Again, the results were very similar to the basic pass-through results in the CPIX model.

Table III.5. Pass-Through Elasticities for the Different Models

VAR model			
	Percent Pass-through		
	$t = 4$	$t = 8$	$t = 10$
Model 1	8.3	12.3	13.2
Model 2	12.0	22.0	23.4
Model 3	10.7	11.7	11.7
Model 4	5.3	10.4	11.6
Model 5	7.7	10.4	10.5

The models listed in table III.5 includes the following variables in the order indicated:

Model 1 – *Dloil, gap, dle, dlmprice, dlproddp, dlcpix*
Model 2 - *Dloil, gap, dle, dlmprice, dlproddp, dlcp*
Model 3 - *Dloil, gap, dle, dlmprice, dlproddp, dlp*
Model 4 - *Dloil, gap, dlusrand, dlmprice, dlproddp, dlcpix*
Model 5 - *Dloil, cubicgap, dle, dlmprice, dlproddp, dlcpix*

Dl prefix indicates the first difference of the log of the level.
oil is the US dollar price of oil.
gap is the output gap as a percentage of potential output
e is the nominal effective exchange rate
mprice is the import price index (1995=100)
cpix is the CPIX
cubic gap is the output gap calculated by fitting a cubic time trend to real GDP
usrand is the bilateral rand-U.S. dollar exchange rate.

Unit Root Tests

An analysis of the time series properties of the variables reveals that they are I(1). With South Africa having undertaken significant policy reforms in the 1990s, especially in the post-apartheid era, there is potential for structural change that may affect the statistical properties of the data, including whether the data possess unit roots. When there are structural breaks, the various Dickey-Fuller test statistics are biased toward nonrejection of a unit root (see Enders, p. 243). As a first step, I test for a unit root using the Zivot-Andrews (ZA) test, which explicitly takes into account the possibility of a deterministic structural break, by augmenting the standard ADF regression with intercept dummy variables (see Zivot and Andrews (1992)).[17] The results are reported in table D1, which indicate that all the variables (except the output gap) are I(1) even after allowing for the possibility of a deterministic structural break in the series.

Table IV.1: ZA Test for Non-Stationarity

Variable	t-test statistic (max)
Rand price of oil – *Lrandoil*	-1.4
Nominal effective index – *Le*	-4.1
Output gap – *gap*	-10.2*
Import price index – *Limp*	-4.1
Production price index - *Lproddp*	-1.7
Core consumer price index - *Lcp*	-1.4
Headline consume prices – *Lp*	-3.5
CPIX – LCPIX	-3.2
ADF Tests	Test statistic (lags in parentheses)
Dloil	-5.2*
Output gap – *gap*	-4.8*
Dle	-4.6*
Dlimp	-4.3*
Dlprod	-3.2*
DLcp	-3.1 *
DLp	-3.7 *
Dlcpix	-3.2*

* indicates rejection of the null hypothesis of a unit root (5% level of significance)
D - this prefix indicates the variable has been differenced once (all variables in logs)

[17] The results for slope dummies failed to reject the null hypothesis of a unit root.

Residual Covariance Matrices

The covariance matrices for the different models provide an indication of how robust the impulse responses are to different orderings of the variables. If off-diagonal elements indicate significant cross-correlation between the residuals from the different autoregressions, then it suggests the impulse responses are highly dependent on the order in which the variables enter the VAR.

As a rule of thumb, Enders (1997) suggests that a value greater than 0.2 constitutes significant cross-correlation rendering the impulse response profile sensitive to variable ordering. There were no significant problems in this regard, with cross correlations low for most pairs of residuals. This is confirmed by comparing impulse responses from different variable orderings.

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