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A Structural Model of the Inflation Process in South Africa

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Abstract: *We build a 4-equation model of the inflation process in South Africa (which has recently adopted inflation targeting), including the exchange rate, consumer prices, producer price, and import prices. This provides useful information on the speed and extent of exchange rate pass-through, and illuminates the various channels through which monetary policy influences inflation. The model is in the tradition of central bank models of the inflation process, but carefully tests for asymmetries, structural breaks and expectations effects, and applies a range of econometric tests and methods to refute the charge that such models necessarily impose 'incredible' restrictions, Sims (1980).*

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1. Introduction

This paper is a comprehensive empirical study of the inflation process in South Africa. The adoption of inflation targeting in South Africa in 2000 has increased the clarity and transparency of monetary policy[1], and it also requires good empirical models toward understanding monetary policy transmission. Volatile capital flows and large exchange rate fluctuations pose challenges for inflation targeting in South Africa. For instance, the currency depreciation of over 30 percent at the end of 2001, compounded by higher grain prices, led in 2002 to an inflation surge reaching a level almost twice the upper bound of the inflation target, even after the downward revision of the data announced in April 2003. The evolution of the annual change in headline or overall consumer price index (*CPI*) is shown in Figure 1, as well as our constructed measure of CPI excluding mortgage interest costs, or *CPIX.* [2]

Apart from good forecasting models, and models that clarify the speed and extent of exchange rate pass-through into inflation and the interest rate transmission mechanism, there is a need for more complete models, within which questions of the optimal design of monetary policy rules can be investigated. For example, it is important to have estimates of the output cost of reducing inflation, and one can ask whether inflation targeting can cope well with exchange rate shocks of the magnitude experienced by South Africa, and whether the target chosen is appropriate. The four-equation model we present here, will ultimately be part of a larger model with just such a purpose.

There is a large literature on multi-sectoral models of inflation which include prices, wages, the exchange rate, the output gap and other variables (see Bank of England (2000)[3] for a review, and Bårdsen and Fisher (1999) and Bårdsen, Jansen and Nymoen (2002) for examples). Our model contributes to this literature, and may be contrasted with models based on simple theory, such as the closed economy New Keynesian Phillips curve of Gali and Gertler (1999) or the open economy version (e.g. see Razin and Yuen, 2002). However, it shares with these, and with the Federal Reserve Bank's U.S. model (Brayton et al, 1997), a concern for the role of expectations. We test for a range of expectations effects using instrumental variable methods, and also test for structural breaks and asymmetries. More generally, we begin with very general specifications, testing these down to parsimonious ones, being careful to impose economic priors, to ensure that the restrictions we impose are not 'incredible' - in the words of Sims (1980).

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[1] For a history of monetary policy regimes in South Africa, see Aron and Muellbauer (2002b).

[2] To be precise, we show the data for CPIX ("metropolitan areas") back to 1970, constructed from CPI ("metropolitan"), see Aron and Muellbauer (2004a). The variable targeted by monetary policy is CPIX ("metropolitan and urban areas"), which uses a broader expenditure coverage, but where data is published only from 1997.

[3] The South African Reserve Bank (SARB) model remains confidential.

In the next section we consider some methodological issues, following which South African regime shifts are discussed in section 3 and some shift indicators are estimated. In section 4, we present the equilibrium correction model to be used in estimating four price equations. These equations are motivated, estimated and discussed in separate sub-sections of section 4, and the results from estimation of the simultaneous system of the four equations are assessed. Section 5 provides conclusions and policy implications.

2. Methodological Issues

Sims (1980) has criticised standard macro-econometric policy models for embodying 'incredible restrictions', particularly in the light of the rational expectations hypothesis. The hypothesis suggests that agents use information about the economy as a whole to generate expectations, which influence variables such as wages, prices or consumption. In principle, this would imply that any one sectoral equation could embody variables from the system as a whole. But standard macro-models use relatively restrictive specifications of sectoral equations. As an alternative, Sims called for the use of Vector Autoregressive Models (VARs), now among the most widely-used tools in academic and central bank macro-econometrics e.g., for studying the transmission mechanism of monetary policy. However, there are substantial difficulties in interpreting and using VARs for policy and forecasting, arising from omitted variables (a restriction in another form), omitted structural breaks and relevant lags, omitted non-linearities, and the use of sometimes doubtful identifying restrictions to give economic interpretations to shocks.

The approach in this paper uses practical ways of bridging the gap between the two approaches. We begin with richly parameterised equations for a range of prices and wages, comprising a wage-price-exchange rate sector for the South African economy. Economic principles imply a strong set of sign priors on the effects of variables in the long-run, and often also in the dynamics. Using a general-to-specific model selection strategy, these equations are reduced to parsimonious forms on a single equation basis, instrumenting where endogeneity is likely to be important, and guided by the sign priors. We check for asymmetries, for example, that in the short-run, oil price increases are passed on more quickly than price decreases. Our preference is to leave checks for co-integration to last, giving primacy to the economics of the long-run solution, the economics of the adjustment processes, and checks for structural breaks.

Extending the analysis, richer specifications are investigated which incorporate potentially important expectations effects, for growth, producer price inflation and exchange rate expectations. We also test for another form of the 'incredible restrictions' hypothesis, by generating principal components from a wider set of variables, plausibly relevant in a larger model. This technique of overcoming the 'curse of dimensionality' has been used by Stock and Watson (2001) in the forecasting context, but seems at least as useful in our testing context.

Finally, we handle the endogeneity issue by using full information maximum likelihood (FIML) to estimate the simultaneous part of the system. In the current model, this involves the four-equation subsystem for producer, consumer, and import prices and for the exchange rate. The systems approach generates an important specification test since the over-identifying restrictions can be tested against the unrestricted reduced form. Tests of three further equations, for unit labour costs, food prices and house prices, detected no contemporaneous feedbacks, and the simultaneous part of the system can therefore be estimated separately.

Recent literature on 'general to specific' model selection procedures, see Hoover and Perez (1999), Hendry (2001), Krolzig and Hendry (2001), and Hendry and Krolzig (1999), suggests that sensible model selection procedures can select parsimonious reductions using a variety of criteria - including fit, lack of residual autocorrelation and parameter stability - which are surprisingly free of 'pre-test bias' problems[4]. The PCGETS software, developed by Hendry and Krolzig (2001), is a powerful tool for such model selection strategies, which automates search over many alternative reduction strategies. However, PCGETS tests and imposes zero-type parameter restrictions, when moving average and other restrictions may be more economically intuitive. It is important to allow for such possibilities in the general formulation of each equation. It also does not embody sign restrictions.

To illustrate the key issues of our broadly 'Bayesian' approach, but without the formal Bayesian apparatus, consider the following equilibrium correction form of a log price equation, a simplified form of equation (4.1) below:

$$\Delta Y_t = \gamma(\alpha_0 + \alpha X_{t-1} - Y_{t-1}) + \sum_{j=0}^{k} \beta_j \Delta X_{t-j} + \sum_{i=1}^{k} \lambda_i \Delta Y_{t-i} \qquad (2.1)$$

Suppose the sign prior is that *X* has a non-negative short-term and long-term effect on *Y* – for instance, let *Y* be log *(CPI)* and let *X* be log *(WPI)*. We would then expect β_0 to be non-negative, and could impose $\beta_0 \geq 0$ as a constraint, if relevant. If $\beta_0 \approx \gamma\alpha$, we can replace $\gamma\alpha X_{t-1} + \beta_0 \Delta X_t$ by $\gamma\alpha X_t$. If $\beta_0 \approx 0.5\gamma\alpha$, we can replace $\gamma\alpha X_{t-1} + \beta_0 \Delta X_t$ by

4 The investigator using a sequential model selection process, without properly controlling for the overall size of the tests, runs the risk of choosing to include variables which are not in the data generation process, but which happen to have a sample correlation with the dependent variable.

$\gamma\alpha X(ma2)_t$. Such moving averages can be sensible when the X variable is quite volatile, or where aggregation over different sectors of the economy results in an averaging of effects over time. However, if $\beta_0 = 0$ and $\beta_1 \approx -0.5\gamma\alpha$, the moving average is at t-1 instead of t. This is a good example of why the prior restriction of non-negative short effects of X on Y does not necessarily mean that β_1, or β_2, need be non-negative. For example,

$$0.1X_{t-1} - 0.075\Delta X_{t-1} - 0.05\Delta X_{t-2} - 0.025\Delta X_{t-3}$$

simplifies to $0.1X(ma4)_{t-1}$. However, if $\gamma\alpha$ were zero, the prior restriction of short-term non-negative effects would imply non-negative values of the β_j, and we impose such restrictions, for example in the form $\sum_{j=o}^{k} \beta_j \geq 0$.

Another possibility is $\beta_1 = \beta_2 = \beta_3 = \beta_4$, which would imply $\beta_1 \Delta_4 X_{t-1}$. Annual changes of this form are often plausible because agents tend to think of inflation in annual terms, and contracts are often annual.

In most VARs, lag lengths are restricted to one or two quarters and rarely beyond four. The longer the lag, the less likely is it that the precise timing can be estimated, since one expects such effects to die away as the lag length increases e.g., distinguishing between effects at t-5, t-6 and t-7. This supports the case for allowing the possibility of longer lags, but restricting the effects to $\Delta_4 X_{t-4}$ and $\Delta_4 X_{t-8}$. For a variable such as the current account to GDP ratio, or the terms of trade, both subject to erratic movements, annual or biannual changes tend to smooth out erratic jumps in the data.

Asymmetric effects can be tested for as follows. Suppose the short-run inflationary effect of a 10 percent rise in the oil price is more than the disinflationary effect of a 10 percent price fall. If ΔX is the change in the log oil price, we can test for this through including the terms: $\beta_1 \Delta X + \beta_2 |\Delta X|$. If $\beta_2 = \beta_1$, the effect of a fall in the oil price is zero, while the effect of a rise is $2\beta_1$. If $\beta_2 = 0$, there is no asymmetry. If $0 < \beta_2 < \beta_1$, we have an intermediary case, in which the effect of an oil price fall is less than that of an increase.

3. South African Policy Regime Changes

During the 1980s, there were significant regime changes with the move to new operating procedures for monetary policy and domestic financial liberalization. Macroeconomic management was complicated by large changes in capital flows following major shocks in the form of significant gold price fluctuations and political events. A series of political crises for the "Apartheid" government from 1976 entailed the increasing international isolation of South Africa, reflected in diminished trade and finance. In particular, from late 1985 until the democratic elections of 1994, South Africa had little access to international capital (apart from trade finance). These constraints, together with South Africa's mineral dependency in exports, are expected to give an important role to terms-of-trade shocks and the current account balance in determining prices.

3.1 Monetary Policy Regimes and Financial Liberalisation

Broadly speaking, there have been three monetary policy regimes since the 1960s. The first regime was based on liquid asset ratios with quantitative controls on interest rates and credit, and limited importance was attached to the interest rate as a corrective tool. Considerable disintermediation occurred in the late 1970s, and increasing dissatisfaction with the system led to a range of reforms from the early 1980s (see Aron and Muellbauer, 2002b).

A cash reserves-based system was introduced following the recommendations of the De Kock Commission (De Kock, 1978, 1985), and direct controls were gradually removed. There were technical changes to asset requirements over a few years, and the role of the central bank's discount rate was redefined. The regime was in full operation by mid-1985, with pre-announced, flexible monetary targets used from 1986. The discount rate was used to influence the cost of overnight collateralised lending and hence market interest rates.

Financial liberalisation began in the early 1980s, rapidly expanding credit growth (for a measure of financial liberalisation, see Aron and Muellbauer, 2000). With a more open capital account in the 1990s, any usefulness of monetary targets was diminished. In later years the targets were supplemented by a broader set of indicators (see SARB *Quarterly Bulletin,* October 1997), though it is likely that such indicators played a role in previous years too.[5]

Under a third system of monetary accommodation introduced in 1998, the repurchase interest rate is determined at auction. The SARB signals its policy intentions on short-term interest rates to the market through the amount offered at the daily tender for repurchase transactions (see *SARB Quarterly Bulletin*, June 1999). In practice there has been little difference in interest rate behavior between the current and previous regime, and the commercial banks collectively have remained heavily influenced by SARB-directed preferences for the level of the interest rate. From early 2000, an inflation targeting regime was instituted.

[5] Extended Taylor rules have been used to examine empirically which factors influenced monetary

3.2 Exchange Rate Policy Regimes[6]

Until 1979 the Rand was pegged to either the U.S. dollar or the pound sterling. Exchange controls restricted residents' capital flows, and proceeds from the sale of assets by nonresidents were placed in blocked Rand accounts, which made the repatriation of capital difficult.

Greater flexibility was introduced in 1979 with a dual-currency exchange rate system, following the recommendations of the interim De Kock Commission (De Kock, 1978). A "commercial" exchange rate was announced on a daily basis in line with market forces. A "financial" exchange rate applied to most non-resident transactions, with all other transactions channeled through the commercial Rand market. The intended impact of the dual system was to break the direct link between domestic and foreign interest rates, as well as to insulate the capital account from certain categories of capital flows.

In 1983 the commercial rate was set free to be determined in the market, subject to direct intervention by the SARB, and the dual rates were unified as recommended by the De Kock Commission (De Kock, 1978, 1985). Controls on non-resident capital movements were removed, and while those on residents remained they were treated more leniently.

The unified currency remained stable for a few months, but following the gold price decline in 1983, it began a sharp descent. In 1985, following a prolonged period of political upheaval, U.S. banks recalled their loans, precipitating a debt crisis, followed by a debt standstill, and subsequently a series of debt rescheduling agreements. The unified Rand fell even further, and eventually the financial Rand was reintroduced and capital controls on residents were tightened. The dual-currency system remained in existence until its unification a decade later, in March 1995, under a managed float. Under inflation targeting, however, the exchange rate is officially fully floating.

3.3 Trade Policy Regimes

From the mid-1980s, protracted capital outflows due to foreign disinvestment and sanctions required an adjustment in the economy to maintain current account surpluses in excess of required foreign debt repayments. This was partly achieved through large increases in tariffs and introducing import surcharges. Trade barriers began to be dismantled in 1990, and especially after 1994, which put downward pressure on inflation.

One might expect the degree of openness to affect the influence of the real exchange rate on growth, via the impact on the demand for exports and leakage of demand into imports.

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policy in the second monetary policy regime (Aron and Muellbauer, 2002b).

Unfortunately, we do not have an index of effective protection combining the effects of surcharges, tariffs, and quotas (these last are dominant in South African trade policy until the early-1980s); nor can we directly capture the effects of trade sanctions. Instead we use a proxy for openness, which is derived from a model for the share of manufactured imports in home demand for manufactured goods, where the latter is defined as domestic production plus imports, less exports, for which we have annual data.

We do not employ the import share itself to measure openness, because it depends on other factors, such as fluctuations in domestic demand and relative prices of imports or the exchange rate. However, our model for the log of the import share controls for these influences. The model includes a measure of import tariffs and surcharges, which is one (negative) component of openness. The unmeasured component of quotas and the effect of sanctions are captured in our model by a smooth non-linear stochastic trend, estimated in *STAMP* (Koopman, and others, 2000).

To capture demand side influences (other than home demand for manufactured goods as defined above), the model includes the growth rate of real GDP, the log of the real exchange rate, and a lag in the log of the terms-of-trade, heavily influenced by the price of gold. The latter might reflect sectoral differences in GDP growth, relevant for imports, as well as the relaxation of balance of payments constraints when gold prices are high. Variables are defined in Table 1, where some statistics are presented.

The results, estimated on annual data, are shown in Table 3, column 1 (estimated over shorter samples demonstrates robustness of the parameters, see columns 2 and 3), Aron and Muellbauer (2002a). The tariff measure, the real exchange rate, and the import share are all $I(1)$ variables and are expected to be cointegrated, while the log terms-of-trade and GDP growth are $I(0)$. The hypothesis could be accepted that the coefficient on the lagged (log) level of the import share was zero.

The influences of openness operate both through the measured effects of import tariffs and surcharges (*RTARIF*), and through the unobservable effects captured in the stochastic trend. We therefore define our openness indicator as the fitted stochastic trend plus the fitted effect of *RTARIF* (-4.30 x *RTARIF* (-1)).[7] The openness indicator is shown in Figure 2, where a rise indicates trade liberalisation.

[6] See Aron, Elbadawi, and Kahn (2000).

[7] We convert to a quarterly measure by taking the moving average of the step function implied by the annual data and make a plausible guess as to the trend before 1970 and after 1998, with a slower pace of tariff reductions.

4. Modeling framework and price equations [8]

In this section we present single equation equilibrium correction model estimates for four price variables: consumer prices excluding mortgage interest cost (or *CPIX*), domestic producer prices, the nominal effective exchange rate and import prices. We discuss both OLS and Instrumental Variable (IV) estimates; and FIML estimates from a simultaneous estimation of all four equations.

4.1 Model specification

For each of the price variables, we use a single equation equilibrium correction model of the following general form:

$$\begin{aligned}\Delta \log P_{j,t} &= \gamma(\alpha_0 + \mu + \sum_{i=1}^{n} \alpha_i X_i - \log P_j)_{t-1} \\ &+ \sum_{i=1}^{n}\sum_{s=0}^{k} \beta_{i,s} \Delta X_{i,t-s} + \sum_{i=1}^{n}\sum_{s=0}^{k} \theta_{i,s} \left|\Delta X_{i,t-s}\right| \\ &+ \sum_{s=1}^{l} \lambda_{j,s} \Delta \log P_{j,t-s} + \varepsilon_{j,t}\end{aligned} \tag{4.1}$$

where the X_i variables are determinants for P_j , the relevant price, and ε_t is white noise. The terms in absolute values test for possible asymmetries in price responses.

We tested all OLS price equations to ensure that there is no smooth stochastic trend, μ, present (or else the error term ε_t may also include a moving average error component). The stochastic trend μ_t is defined as follows (Harvey, 1993; Harvey and Jaeger, 1993):

$$\begin{aligned}\mu_t &= \mu_{t-1} + \gamma_t + \eta_{1t} \\ \gamma_t &= \gamma_{t-1} + \eta_{2t}\end{aligned} \tag{4.2}$$

where η_{it} are white noise errors. When the variance, var η_{2t} , is zero, μ_t is an $I(1)$ trend with drift. When the variance, var η_{1t} , is zero, μ_t is a smooth $I(2)$ trend. These non-linear trends are estimated using the Kalman filter in the *STAMP* package (Koopman and others, 2000).

In the OLS estimations, a general-to-specific testing procedure on quarterly data for 1979Q–2000Q1 was applied to equation (4.1) with the relevant set of X variables for each

[8] Estimations were carried out using TSP 4.5, PcGets (D F Hendry and H-M Krolzig, 1998-2001, package version 1.02), and PcGive 10 Professional (Hendry and Doornik, 2001).

price, and other stationary variables. We retain data for 2000Q2 to 2002Q3 as a check on possible shifts in the system following the introduction of inflation targeting in 2000Q1.

The *X* variables employed in each price equation are discussed under separate headings below. All the variables are defined in Table 1, together with statistics and stationarity characteristics for the data.

4.2 Consumer prices equation

The SARB publishes four main consumer price series [9]: *CPI* ("metropolitan areas"); the equivalent excluding interest rates on mortgage bonds, or *CPIX* ("metropolitan"), published back only to 1994; *CPI* ("metropolitan and other urban areas"), published back to 1997; and the equivalent excluding interest rates on mortgage bonds, or *CPIX* ("metropolitan and other urban areas"), published back to 1997 - and targeted since 2000q1. We have constructed a *CPIX* ("metropolitan") series back to 1970 from *CPI* ("metropolitan") data, see Aron and Muellbauer (2004a). The series is shown in Figure 1 as an annual rate of change. The figure shows a major fall in inflation in the 1990s. The divergence between the two indices arises from mortgage costs incorporated in *CPI* ("metropolitan").

Equations were run for log (*CPIX)*, using the equilibrium correction form (4.1), and the following potential determinants were investigated:

$$\begin{aligned} X_i = \{&\log(RWPI48X); \log(RULCMX); \log(RHPRICEX); \\ &\log(RIMPPX); \log(RPOILX); \log(REERN); \log(TOTIG); \\ &OUTGAP; RCASUR; VAT; RPRIME; DUMOPEN\} \end{aligned} \tag{4.3}$$

With the sign priors given in parentheses, the first five are equilibrium error terms relative to *CPIX*, preserving long-run price homogeneity: the log ratio of domestic producer prices[10] to *CPIX* (+), which will capture feed-through of producer price pressure; the log ratio of (normalised) manufacturing unit labour costs[11] to *CPIX* (+), reflecting wages costs (net of

[9] Administered prices, defined as the prices of goods and services that are directly determined by government departments or public sector agencies, play an important role in consumer inflation. These prices are relatively inflexible and less sensitive to monetary policy actions. The SARB calculated an administered price index (Monetary Policy Review, March 2001, p18 and April 2002, p3), with a weight in the CPIX currently of about 25 percent. The key components (with the respective weights in the CPIX) are Education (3.77), Communication (3.19), Medical health services (3.23), Electricity (3.55) and Petrol (5.08).

[10] Domestic producer prices exclude the import price component of total producer prices.

[11] The "normalized" unit labour cost measures were calculated by subtracting a measured (stochastic) trend in log productivity from the log wage in the manufacturing sector. The stochastic productivity trends were estimated using the STAMP (Koopman et al, 2000). The change in the log of productivity was regressed on the level and change in the log of capacity utilization (to capture cyclical effects), and the lagged level and lagged change in log productivity, plus a smooth I(2) stochastic trend. The

productivity); the log of real house prices (+), which may capture housing costs not fully reflected in the *CPIX* measure; and log ratios to *CPIX* of import prices[12] (+) and world oil prices in Rands (+), to capture imported price inflation. Another price term is the log of our constructed[13] real exchange rate index (-), where more expensive imports through real exchange rate depreciation feeds into living costs (pass-through).

The remaining terms are: the log of the terms of trade index (+), as a trade boom drives up non-traded prices, and also manufactured prices, depending on the extent to which they are shielded from world prices[14]; the output gap (+), since with higher excess demand, consumer prices may increase relative to wage costs and wholesale prices[15]; the ratio of the current account surplus to GDP (-), partly as an excess demand indicator, and partly as a predictor of exchange rate movements; indirect tax rates (+) are expected to increase consumer prices[16].

The real prime interest rate (see Figure 3) is included to capture the effect of business costs increasing when interest rates rise, or the disinflationary effect via lower demand pressure, exchange rate appreciation, or inflation expectations. We also permit the lagged rate of change of *CPI* ("metropolitan") to enter the equation, on the following rationale: it is unlikely that wage costs in manufacturing completely capture all labour costs, for example in the service sector. But our model for wages suggests a strong *CPI* ("metropolitan") effect at a lag of 2 quarters. We therefore permit changes in the log of *CPI* ("metropolitan") at lags of 2 or longer to appear, thus capturing the mortgage cost channel. Rates of change of all nominal variables appearing in ratio form in equation (4.3) also appear in the general model.

The 'cost channel' of monetary policy via the real prime rate is likely to be controversial for central bankers and has been the subject of a significant literature, see Barth and Ramey (2001). A related mechanism by which higher interest rates may raise subsequent inflation is via the effect of high interest rates on investment and bankruptcies. These reduce capacity and so may increase inflation in subsequent upturns. In principle, an output gap measure incorporating the well-measured capital stock should capture this effect. However, official capital stock estimates are typically based on fixed service life assumptions for

differenced "normalized" unit labour cost measure thus captures changes in the wage level that are not attributable to productivity improvements.

[12] As an alternative measure of import prices we tried an index of world commodity prices in rands (International Monetary Fund).

[13] Details of the construction of the real exchange rate index are in section 4.4, below.

[14] However, our prior on this sign is weak since higher terms of trade now tend to appreciate the exchange rate, with a disinflationary effect on expectations.

[15] The output gap measure is derived by regressing log (GDP) on a stochastic trend, lagged log (GDP), and distributed lags in capacity utilisation and changes in the log terms of trade, to proxy cyclical effects. The output gap is then defined as the deviation of log output from the stochastic trend, scaled appropriately.

[16] We tried two alternative measures of indirect taxes: the second measure takes the ratio to household expenditure of various categories of taxes on goods.

equipment, and will not fully reflect scrapping of capital arising through business closure. A third related mechanism by which higher interest rates could raise subsequent inflation can arise when businesses rebuild profit margins or balance sheets after suffering losses or reduced profits during a period of high interest rates. Chevalier and Scharfstein (1996) have provided evidence for counter-cyclical mark-ups for U.S. supermarkets. It seems plausible that some service sector companies, such as insurance companies, are also subject to such behaviour.

An important institutional variable included in the long-run equilibrium term is changing openness to international trade: higher foreign trade taxes are consistent with raised producer prices from more expensive imported inputs, which may feed into consumer prices. Our openness measure, *DUMOPEN*, discussed above, includes both reported tariffs and import surcharges, and captures unmeasured quotas and the effect of international trade sanctions on South Africa – the latter two especially important in the 1970s and 1980s. We expect a negative sign for *DUMOPEN*, which increases with increasing liberalisation. We also test for an interaction effect between *DUMOPEN* and the real exchange rate, to see whether the latter effect is more powerful in a more liberalised economy. Potentially, interaction effects could also be important for other variables. For example, if the cost channel discussed above works through the capital stock, the effect may have been overshadowed in more recent years by the opening of the economy to international trade and capital flows. It is also plausible that the terms of trade channel has altered with greater openness.

The introduction discussed the principal components technique for testing the model against other alternatives. We derived six principal components from an auxiliary data set including levels and differences of real share prices, real domestic credit, foreign activity measures, and volatility indicators of the inflation rate and of exchange rate changes. One of these proved significant in the consumer and import price equations. Checking the factor loadings, suggested exchange rate volatility as the key ingredient. Since this is likely to have become more important with the opening of the economy, the effect is interacted with our openness indicator.

The parsimonious equations following a general-to-specific methodology are shown in Table 2. In the equations reported, all long-run explanatory variables in equation (4.3) are $I(1)$. In column 1, an OLS equation is estimated from the second quarter of 1979, when the exchange rate began to float in one form or another – see section 3 - to 2000Q1. In column 2, a shorter sample is presented for the same equation to demonstrate robustness of the estimates. This sample ends just before the 1994 elections, which brought the democratically elected ANC government to power. Column 3 shows full sample estimates to 2002Q3. In column 4, an IV estimation instruments the current change in the log wholesale price index[17].

The stability and other diagnostics are satisfactory. The speed of adjustment is around 20 percent per quarter. All sign priors are supported by the data. The key effects in the long-run are from (adjusted) manufacturing unit labour costs, from the domestic wholesale price index (Figure 4), a linear trend, and the real interest rate, entering negatively with a one quarter lag, and positively as a two-year moving average lagged one year. However, as foreshadowed above, the latter interest rate effect decays with increased openness. Because of the importance for policy of the cost channel, we carefully investigated alternative models with and without level effects, and with and without interaction effects for the real interest rate. The negative effect at a lag of one quarter is always quite robust, so the critical issue concerns the stability and interpretation of the positive effect of the long lag in the real rate. It is clear that this effect is not merely a proxy for the debt crisis and associated shocks: the estimates are little changed by omitting the period 1984Q1 to 1987Q1 from the sample. However, that the effect declines in the 1990s is also very clear. We handle this through the openness interaction effect, though capital account liberalisation, beginning after the freeing of Nelson Mandela in 1990, and accelerating after democratic elections in 1994, is likely to have been at least as important.

The positive trend effect can be interpreted in terms of the Balassa-Samuelson effect (sometimes also termed the 'Scandinavian model of inflation'). The ratio to *CPIX* of both unit labour costs in manufacturing and the wholesale price index trend down from around 1990 as productivity growth improved. It is likely that productivity growth in the tradeable sectors is rarely matched by growth in the non-tradeable sectors. However, wages there need to keep pace with wages in the tradeable sectors and this generates inflation. The trend can be regarded as a proxy for the slower productivity growth in the non-tradeable sectors.

The long-run solution[18] is

$$\begin{aligned} \log(CPIX) &= c + 0.0025T + 0.53\log(NULCM) \\ &+ 0.47\log(WPI) - 0.46RPRIME \\ &- 1.3(DUMOPEN + 0.25) * (RPRIME - 0.05) \end{aligned} \tag{4.4}$$

[17] We use a very efficient instrument: the fitted value from an equation for the change in the log wholesale price index, where, in turn, all endogenous variables have been purged and replaced by instruments.

[18] Note that when interacted with RPRIME, DUMOPEN is set to zero at its *maximum* by adding 0.25 while RPRIMEma8 is mean-adjusted by subtracting 0.05 (see Table 2). This normalises the impact of RPRIMEma8 to be zero in 2002, which is the year when economy is most open according to our DUMOPEN measure. The cost channel effect is expected to reduce as the economy opens.

Turning to the dynamics of the equations, current domestic wholesale price inflation matters (instrumented in the IV estimation, resulting in a slightly lower coefficient, confirmed by the FIML estimates, which suggest a small endogeneity bias in columns 1-3), and the Rand oil price changes enter with a lag. More persistent effects are found through the current account surplus to GDP ratio, which enters as a two-year change, lagged one quarter, reflecting a mix of excess demand and exchange rate expectations (Figure 5). We find a significant positive indirect tax rate effect, and some evidence that improvements in the terms of trade over the previous year cause consumer prices to rise. The effect of recent exchange rate volatility on consumer price inflation is considerable.[19]

The lagged dependent variable enters as the three-quarter rate of change with a negative coefficient. This may reflect some kind of negative feedback, possibly from policy. Lagged changes in the log of *CPI* ("metropolitan"), as anticipated above, enter as an annual change lagged by three quarters. We know from the renumeration equation (below) that cost of living effects enter this equation with a two-quarter lag. In the current *CPIX* equation, unit labour costs enter with a one-quarter lag. Thus, the three-quarter lag of annual *CPI* ("metropolitan") inflation is consistent with its proxying changes in labour costs outside the manufacturing sector, where these changes are driven by changes in *CPI* ("metropolitan"). The equation also includes a dummy for 1991Q4-1992Q1, representing temporary inflation effects from the drought of that period.

The effects of expectations of inflation, growth and the percentage change in the exchange rate over the full sample, drawn from our forecasting equations (Appendix) were all insignificant. We also tested for inflationary expectations as measured by the short-term government bond yield (King, 1994), again without significant findings.

Finally, results from the simultaneous estimation are presented in column 5. Running the OLS equations in STAMP established that there is indeed no stochastic trend.

4.3 Producer prices equation

The producer price equations were run using the domestic price component of the producer price index – which excludes import prices. It is shown as an annual rate of change together with total producer prices in Figure 6. The rate of inflation has trended down since 1986, but has risen strongly in the wake of the exchange rate depreciations of recent years.

In the version of the error correction equation (4.1), we investigate the variables:

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[19] Note that when interacted with the volatility term, DUMOPEN is set to zero at its *minimum* by adding 0.88 (see Table 2). This normalises the impact of VOLEX to be zero in 1980, which is the year when the economy is most closed according to our DUMOPEN measure. Exchange rate volatility is expected to matter much more in an open than a closed economy.

$$X_i = \{\log(RIMPP48); \log(RULCM48); \log(RPOIL48); \log(RPFOOD48); \log(REERN); \log(TOTIG); OUTGAP; DUMOPEN\} \qquad (4.5)$$

With the sign priors given in parentheses, the first five are equilibrium error terms relative to domestic producer prices, preserving long-run price homogeneity: the log ratio of import prices to producer prices (+), which will capture feed-through of imported goods prices to the extent that they are inputs into domestic production; the log ratio of (normalised) manufacturing unit labour costs to producer prices (+), reflecting wages costs (net of productivity) to producers; the log ratio of the rand price of oil to producer prices (+), where we are testing for an additional effect of oil prices apart from their effect measured within import prices; the log ratio of raw food prices to producer prices (+); and the log of our constructed real exchange rate index (-). Note that this measures the ratio of domestic wholesale prices to foreign wholesale prices in Rands and is therefore an equilibrium correction term.[20] Also in the long-run solution is the log of the terms of trade index (+), as a trade boom drives up manufactured prices when they are shielded from world prices – but see footnote 14; and the output gap (+), since as excess demand increases, producers have more scope to raise prices.

An important institutional variable included in the long-run equilibrium term is changing openness to international trade: higher foreign trade taxes are consistent with higher producer prices via more expensive imported inputs – see discussion in section 4. We expect a negative sign for *DUMOPEN*, which increases with increasing liberalisation. We also test for an interaction effect between *DUMOPEN* and the real exchange rate.

This set of variables was examined initially. However, in estimating the system by FIML, a comparison with the unrestricted reduced form suggested an effect from the spread, USSPREADS, between the short-term interest rate in South Africa and that in the U.S. (this variable also proves important in the exchange rate equation). It seems likely that the effect on wholesale prices embodies an expected inflation effect from tighter monetary policy, acting via the exchange rate channel.

The parsimonious equations following a general-to-specific methodology are shown in Table 3. In the equations reported, all long-run explanatory variables are $I(1)$. In column 1, an OLS equation is estimated from the second quarter of 1979 to 2000Q1, while in column 2, the sample is 1979Q2 to 1994Q1 to demonstrate robustness of the estimates (as above). Full sample estimates are shown in column 3. In column 4, an IV estimation instruments the

[20] To be precise, in the Reserve Bank's index, the wholesale price measure includes import prices, which have a weight, in recent years, of around 27 percent.

current change in the log import price index[21], the Rand oil price (in logs), entering in asymmetric form. Since the change in raw food prices is weakly exogenous in the model, we do not instrument it. The IV estimate of the import price effect - confirmed by the FIML estimate in column 5 - is three-quarters of the OLS estimate, suggesting a mild endogeneity bias in the OLS estimate. The FIML estimates replace the non-linear Rand oil price effect by its US equivalent, since PCGIVE does not permit non-linearities in endogenous variables.

The stability and other diagnostics are satisfactory. No sign priors are rejected by the data. The long-run solution is:

$$\begin{aligned}\log(WPI48) = c &+ 0.42\log(NULCM) + 0.24\log(PFOOD) \\ &+ 0.34\log(forprice) + 0.12\log(forprice/impprice) \\ &- 0.21DUMOPEN - 0.37USSPREAD + 0.96OUTGAP\end{aligned} \tag{4.6}$$

The long-run effects are significant for the real exchange rate, representing the impact of foreign prices[22], unit labour costs, raw food prices, the interest rate differential, openness and the output gap. Figures 7 and 8 show the interest rate spread and the log real exchange rate index, and the log-ratio to wholesale prices of (normalised) unit labour costs and raw food prices. The trade liberalisation measure, *DUMOPEN*, is highly significant, suggesting increased openness as a major reason for the decline in inflation in the 1990s. The speed of adjustment is around 12.5 percent per quarter.[23]

Turning to the dynamics of the equations, while variables in the long-run are expressed as ratios or real variables, the delta variables are all nominal. Current changes in log import prices, in raw food prices and the U.S. Brent oil price (in rands) appear. The evidence for short-term asymmetry in adjustment to food and oil prices is interesting: it appears that a contemporaneous rise in raw food prices and in crude oil prices is passed on in higher producer prices, while a corresponding decrease is not, though eventually food price reductions have their effect through the equilibrium correction term.

The effects of expectations of inflation, growth and the percentage change in the exchange rate over the full sample, drawn from our four-quarter ahead forecasting equations (Appendix), are not significant. Even expected domestic producer price inflation has a t-ratio under 1. Running the OLS equations in STAMP established that there is no stochastic trend.

4.4 Nominal exchange rate equations

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[21] We use the fitted value from an equation for the change in the log import price index, where, in turn, all endogenous variables have been purged and replaced by lagged instruments.

[22] The middle two terms in equation (4.6) come from untangling the domestic producer price index from the expression for the real exchange rate.

Equations were run for a constructed nominal effective exchange index (*NEERN*), with the aim of giving a larger weighting to the US dollar than in the Reserve Bank's recent measure of the index. Since 1995, the weights used in construction of the index have been altered three times[24]. In the most recent change in September, 1999, weights have been newly-based on manufactured exports, and the importance of the dollar has fallen sharply, from around 50 percent in early 1999, to only 15 percent. The drastic decline reflects the new emphasis on manufactured goods weighting, neglecting the heavy weight of dollars in mining exports, which comprise the bulk of South Africa's exports.

To construct an index with a greater weight on the US dollar, we ran an ECM-style regression of the old nominal effective exchange rate (January, 1999) on the bilateral Rand/dollar rate and the SARB's new nominal effective exchange rate measure (September, 1999), for the period 1979Q3-1999Q1. From this regression we obtain the *additional* weight on the bilateral rate (1-w1), given the weights already accounted for in nominal effective exchange rate index[25]. Our constructed nominal effective exchange rate index, *NEERN*, is then defined as a weighted average, where w1=0.62:

$$\log(NEERN) = w1\log(NEER) + (1 - w1)\log bilateral \qquad (4.7)$$

The two effective exchange rate measures are shown in Figure 9. It is clear that they move closely together, though there is some trend divergence, due to changes in the U.S dollar exchange rate with respect to other currencies.

We use the new *NEERN* measure in equation (4.1) to give an equilibrium correction model, where the long-run solution is a relationship between the *real* effective exchange rate and other (real) variables, and where the rate of change of prices (foreign and domestic prices as included in the real exchange rate measure) are included on the right hand side. The *X* variables investigated in the long-run solution include:

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[23] This is computed as the sum of the coefficients on lagged log WPI48, which appears in the log relative unit labour cost and food price terms, and with a weight of 73 percent (the weight of domestic wholesale prices in the overall wholesale prices index) in the negative log real exchange rate term.

[24] The SARB publishes nominal and real effective exchange rate indices from 1970. Prior to 1995 the weights used were not published. As from 1 April, 1995, the weights (based on total trade in goods and services) were published as: U.S. dollar (51.7); British pound (20.2); Deutsche mark (17.2); and Japanese yen (10.9). From 1 January, 1999, the weights became: U.S. dollar (42.8); Euro (31.6); British pound (16.7); and Japanese yen (8.9). As from September, 1999, new weights were published based on the trade in and consumption of manufactured goods between S.A. and 14 major trading partners (see article in Sep. 99, QB, SARB). The weights of the four major currencies amongst these are given as: U.S. dollar (15.15); Euro (35.70); British pound (14.91); and Japanese yen (10.26).

[25] The result would have been more extreme, in terms of giving even more weight to the bilateral rate, had we used the April 1995-weighted nominal effective exchange rate in the regression.

$$X_i = \{\log(TOTIG); RLTFLOW; RGSUR; USSPREAD; \\ RCASUR; \log(RPCREDIT); \log(TECHPROR); DUMOPEN) \tag{4.8}$$

With the sign priors given in parentheses, these are the log terms of trade (+), as trade booms probably[26] appreciate the real exchange rate; the ratio of long-term[27] flows to GDP (+), where a higher equilibrium level of inflows requires a more appreciated real exchange rate; the government surplus to GDP ratio (+/-), to capture fiscal effects[28]; the current account surplus to GDP ratio (+), since surpluses, *ceteris paribus*, can indicate an undervalued exchange rate; the log of real private sector credit extension (+); the foreign interest spread (+), proxied by the difference between domestic and U.S. interest rates[29]; and finally, the log of technical productivity (+), measured as the difference between the log of South African real GDP and log of the industrial production index for industrial countries (Figure 10).

Population data in South Africa bears little relation to the formal labour force relevant for productivity measures, and thus we do not use per capita measures. Instead the included trend should capture the evolving labour force differential between South Africa and industrial countries. This proxy is expected to capture the Balassa-Samuelson effect[30], where higher productivity operates through shifting the relative schedules of traded and non-traded

[26] The effects of the terms of trade (i.e. price of exports over price of imports) cannot be signed *a priori*. However, empirical evidence indicates improved terms of trade in resource-rich economies tend to lead to real exchange rate appreciation, with the income effect of terms-of-trade improvement dominating its substitution effect (e.g. Edwards, 1989).

[27] The SARB used to publish the categories short-term and long-term capital flows, replacing these in June, 1999 by the IMF classification into portfolio, direct and other flows, back only to 1985 (quarterly data). We extended the long-term flow measure by regressing this variable on the portfolio components between 1985 and 1998, and then forecasting the long-term flows to the end of 2001. Caveats on the use of the long-term/short-term division are presented in Aron, Elbadawi and Kahn (2000).

[28] The preferred fiscal variable in real exchange rate models is government expenditure. Higher and "sustainable" levels of public expenditure on non-tradables is consistent with equilibrium real exchange rate appreciation; but effects due to total government expenditure ratio cannot be signed *a priori*, though may be expected to be positive as government tends to have a higher propensity to spend on non-traded goods than does the private sector (e.g. Edwards, 1989).

[29] A widening spread suggests imminent depreciation (through the intertemporal efficiency hypothesis). Our equation is best regarded as one for the solved exchange rate, obtained by solving a sequence of such efficiency conditions. In such a solved-out model, the spread should have a positive effect.

[30] For this proxy to capture the Balassa-Samuelson effect, where productivity in non-traded versus traded goods is the critical comparison, we make two assumptions: firstly, that in this capital-intensive mineral exporting economy, growth in productivity in the traded sector far dominates that in the non-traded sector; and secondly, that trends in relative productivity in non-traded goods do not differ significantly between South Africa and her trading partners. Nevertheless, we were not confident that this measure would capture differential productivity trends cleanly, given the importance of commodity shocks in this economy, and also pronounced political shocks via financial and other sanctions and foreign disinvestment. Thus there are likely to be systematic breaks in the relationship between our measure of relative productivity levels and the appropriate theoretical concept. First-differencing will typically turn structural breaks such as important political shifts into short-term noise, so that the differenced productivity measure could turn out to be significant while the level is not - see Clements and Hendry (1995) on the effects of differencing on structural breaks. This is indeed what we find.

goods, allowing a more appreciated level of the real exchange rate to be consistent with equilibrium - holding other variables fixed (Balassa, 1964; Samuelson, 1964).

An important institutional variable included in the long-run equilibrium term is changing openness to international trade, *DUMOPEN*, and we expect a negative sign for *DUMOPEN*, which increases with increasing liberalisation. We also test for an interaction effect between *DUMOPEN* and the real exchange rate.

Further, three impact dummies are included to address exogenous shocks to the exchange rate. The first is a dummy to capture the dramatic debt crisis in 1995Q3 and 1996Q1; the second dummy captures global emerging market foreign exchange contagion in 1998Q3, when the exchange rate fell sharply; while the third dummy addresses an episode in 2001Q4 and the following quarter, when exchange control regulations were suddenly stringently monitored, with some publicity given to possible violations, and in the ensuing uncertainty, liquidity in the market diminished with concomitant currency depreciation. Note that when a measure of global "risk appetite" (from Credit Suisse First Boston) is included in the equation, the second of these dummies is much reduced in significance.

The difference in the rates of change of domestic wholesale prices and foreign prices were included on the right hand side of the equilibrium correction model to capture the negative consequences of higher relative domestic inflation. Foreign prices were measured by the US producer price index,[31] the rate of change entering as a two-quarter moving average.

The parsimonious equations following a general-to-specific methodology are shown in Table 4. In the equations reported, all explanatory variables are *I*(1). In column 1, an OLS equation is estimated from the second quarter of 1979 to the beginning of inflation targeting in 2000Q1, while in columns 2 and 3, a shorter sample and full sample estimates are presented for the same equation to demonstrate robustness of the estimates. In column 4, an IV estimation instruments the current rate of change of the domestic wholesale price index. Both this estimation and the FIML estimation results suggest little endogeneity bias.

All sign priors are supported by the data. The terms of trade appreciates the nominal exchange rate, entering at a two-quarter lag, suggesting its effect is relatively persistent. The impact dummies are all significant, while *DUMOPEN*, the measure of trade liberalisation, suggests that higher trade taxes and trade quotas increase the exchange rate.

[31] We also tested the U.S. wholesale price index relative to the measure of foreign prices embodied in the Reserve Bank's multilateral real exchange rate calculation. The log index of foreign prices was derived from subtracting the South African Reserve Bank's log real effective exchange rate index from the log nominal effective exchange rate index, and adding the log of wholesale prices in South Africa. This (effective) foreign price index then captures the prices of 14 trading partners, using the South African Reserve Bank's weights of September, 1999. A re-weighted log foreign price index - giving greater weight to the U.S. dollar - was calculated as the weighted sum of the logs of the foreign price index and of U.S. wholesale prices, using the same weights as in the *NEERN* construction (described above).

Neither the current account surplus nor the government surplus is relevant in the long-run solution. Both appear as two-year changes in the dynamics, though in the final parsimonious equation, the change in the government surplus was eliminated. The positive effect from a two-year change in the ratio of the current account surplus to GDP, provides information on the output gap and on the direction of change of net foreign assets, and hence the confidence of investors. If the current account is improving systematically, it suggests the currency may be undervalued.

The interest rate spread between the South African and U.S. T bill rates (Figure 7) has a strong positive effect, with a coefficient of around 0.4. Since the coefficient on the difference between quarterly domestic and foreign inflation rates, *DIFFWPUS*, is around -1.6 (the equivalent of –0.4 at annual rates), the combination of the two differentials may be interpreted as the real interest parity differential (see MacDonald and Ricci, 2002, for a similar result). The variable is non-stationary (I(1)), forming a cointegrating vector with the real exchange rate and the terms of trade.

Neither the level nor rate of growth of private sector credit appears in these equations. While a levels effects for technical productivity differentials is absent, as expected, possibly because of important political regime changes, the three year growth differential proxying comparative productivity growth, *D12TECHPROR*, has a significant and positive effect (Figure 10). This is consistent with the theoretical predictions of models that assume differentiated productivities between the tradable and non-tradables sectors, with productivity growth being higher in the former. The variable is defined as the average annual rate of change over three years. The variable may also be reflecting the greater profit opportunities and so capital inflows, in a relatively strongly growing economy, tending to appreciate its currency. The dynamics also includes the lagged rate of change of the nominal exchange rate in the previous two quarters, suggesting a tendency towards the partial correction of previous overshooting of the rate.

A crucial parameter, estimated at 0.18, is that associated with the equilibrium-correction term, measuring the degree of adjustment of the actual real exchange rate with regard to its equilibrium level. The correction term enters as a two-quarter moving average of the log real exchange rate, lagged one quarter. Given that all variables (except the dummies) are lagged - or where endogenous, can be replaced by their predicted values with little loss of fit - the equation contradicts the efficiency hypothesis, under which the exchange rate is a random walk plus an interest differential term, see Aron and Ayogu (1997).

The long-run solution is given by

$$\log(REERN) = c + 1.5\log(TOT) + 2.1(prime(SA) - Tbill(US)) + 7.4\Delta_{12}TECHPROR \quad (4.9)$$

We have included the three year change in TECHPROR in the long-run solution because it is quite persistent, though not strictly $I(1)$. The implication of equation (4.9) is that if the annualised growth rate of SA minus industrialised countries in the last three years improves by 1%, then the REERN rises by 7.4%. Note that the interest rate would have to rise by 3.5 percentage points to achieve the same effect on the REERN

The effects of expectations of inflation, growth and the percentage change in the exchange rate over the full sample, drawn from our four-quarter ahead forecasting equations (Appendix), are explored in column 5. All variables operate in the anticipated direction. Higher expected growth in South Africa tends to appreciate the exchange rate, but the effect was not significant. However, higher expected domestic inflation and expected exchange rate depreciation (based on information dated t-1), both significantly depreciate the Rand.

Finally, results from the simultaneous estimation are presented in column 6. On the basis of the specification that excludes expected inflation and expected depreciation, the equation standard error for the structural equation exceeds the standard error of the unrestricted reduced form. For the four-equation system as a whole, this is sufficient for failure of the test of the overidentifying restrictions, though the FIML versions of the remaining three equations all fit notably better than the unrestricted reduced forms. However, adding the generated value of the four-quarter ahead forecasts of domestic (*WPI*) inflation and currency depreciation, to the FIML system leads to acceptance of the over-identifying restrictions, at the 2.5 percent probability level.[32] One might still have expected failure of the test, given that the exchange rate is subject to large shocks, which could easily have a small-sample correlation with part of the large set of variables in the unrestricted reduced form. Examination of those variables close to being significant in the reduced form equation, did not suggest any other omitted effect in our parsimonious equation, consistent with sign priors from economic theory.

Running the OLS equations in STAMP established that there is a stochastic trend. While all the other coefficients remain much the same (that of $\Delta_{12}TECHPROR$ declines slightly), *DUMOPEN* becomes insignificant. Unsurprisingly, the stochastic trend, which has roughly the shape to *DUMOPEN* is superior to *DUMOPEN*, probably also capturing some other effects, such as political uncertainty and emigration.

[32] We do not report these results since those for the exchange rate are close to the IV results in column 5 of Table 4, while the FIML estimates for the other equations hardly alter.

4.5 Import price equations

The import price equations use the import price component of the producer price index, shown as an annual rate of change in Figure 11. The main driving factors behind import prices are likely to be the oil price, foreign prices, the volatile exchange rate, pricing to market reflected in an influence from domestic prices, and South Africa’s trade policy, as reflected in our openness indicator. The effects of the oil price shocks of 1979 and 1991 are apparent in the figure. In Figure 12, the log ratio of foreign producer prices (in Rands) to import prices is shown. The rise over the 1990s reflects trade liberalisation, but also the fact that importers’ margins have been squeezed, suggesting that import prices may have to rise to correct this to some degree.

The equation for the rate of change of import prices has an error correction form, and variables investigated for the long-run solution thus include:

$$X_i = \{\log(RPOILIM); \log(RPFORIM); \log(RWPI48IM); \log(REERN); DUMOPEN\} \quad (4.10)$$

The sign priors are given in parentheses. The first three terms are equilibrium error terms relative to import prices, imposing long-run homogeneity of prices: the log ratio of the U.S. Brent price of oil (expressed in rands) to import prices (+); the log ratio of our effective measure of foreign prices (expressed in rands) to import prices (+); and the log ratio of domestic wholesale prices to import prices (+), to capture price discrimination through pricing to market. The final price term is the log of our constructed real exchange rate index (-), where an appreciating real exchange rate cheapens imports. The real exchange rate, strongly negatively correlated with the ratio of foreign to import prices both in rands (compare Figures 7 and 12), also measures foreign prices relative to domestic prices (domestic wholesale prices have a weight of 73 percent and import prices 27 percent in total wholesale prices).

The stance of trade policy, which has undergone significant changes, seems likely to influence import pricing. Changing openness to international trade, is captured in the equilibrium term by *DUMOPEN*, described above. *DUMOPEN* is expected to have a negative sign: it increases with trade liberalization, and lower trade taxes imply lower after-tax import prices. We also test for an interaction effect between *DUMOPEN* and the real exchange rate.

Further, three impact dummies are included to address exogenous shocks to the exchange rate. The first is a dummy to capture the publication of the Government's Growth, Employment and Redistribution strategy (GEAR), announced in mid-June 1996, which helped restore investor confidence in the falling currency; the second dummy captures global emerging market foreign exchange contagion in 1998Q3, when the exchange rate fell sharply; the third, (*DLIQCR*) is the dummy for the 2001Q4-2002Q1 foreign exchange liquidity crisis.

The general form of the dynamic specification of the equation includes nominal rates of change of domestic wholesale prices, oil prices, the exchange rate, our foreign price measure, as well as the US producer price index as an alternative measure of foreign inflation. We allow for possible asymmetries in nominal prices showing significant falls at some point in the sample – oil prices and the exchange rate. We also include the measure of exchange rate volatility brought to light by testing, as discussed earlier, for the effects of principal components of an auxiliary data set.

The parsimonious equation for the period 1979Q2-2000Q1 is shown in the first column of Table 5. Different samples in the following two columns demonstrate robustness of the OLS estimates. In column 4, an IV estimation instruments the current change in the nominal exchange rate, and in wholesale prices (using the fitted values from parsimonious instrumenting equations as before). These results, and the FIML estimates in column 5, give point estimates for the effect of domestic wholesale price inflation of only about 55 percent of the OLS estimates, consistent with a more moderate degree of "pricing to market" in the short-run than would have been suggested by the OLS results.

Theoretical priors are confirmed in the signs. Tightening trade policy through the *DUMOPEN* variable has the expected sign as do both the impact dummies. The speed of adjustment is of the order of 18 percent per quarter. A cointegrating vector is formed between oil prices, the real exchange rate, wholesale prices and import prices. Figure 13 shows log ratios to import prices of domestic producer prices and Rand oil prices (Brent).

The long-run solution[33] can be written as follows.

$$\begin{aligned} \log(IMPP) = c + 0.11\log(POIL) + 0.48\log(forprices) \\ + 0.41\log(WPI48) - 0.58DUMOPEN \end{aligned} \tag{4.11}$$

This is clear evidence of pricing to market, see Krugman (1987): when the exchange rate changes, the impact on import prices is less than one for one. This is likely to alter the mark-up on costs for foreign firms exporting to South Africa.

While variables in the long-run are expressed as ratios or real variables, the delta variables are all nominal. Changes in the previous quarter's oil price have a positive, but asymmetric impact: a 20 percent rise in oil prices feeds into a 0.9 percent rise in import prices one quarter later, in addition to whatever effect comes via the U.S. wholesale price index;

[33] The computation of the long-run solution and the speed of adjustment uses the result that log(REERN) ~0.73log(foreign prices/WPI48)+0.27 log(foreign prices/IMPP)

while a 20 percent fall in prices has no short-run effect. In the long-run, the effect would be 2.3 percent in each direction.

A major influence is the rate of change in foreign prices. We found that the U.S. wholesale price (in US dollars) out-performed a trade-weighted wholesale price index of 14 trading partners. An increase of 1 percent in US wholesale prices translates into a 0.5 percent increase in import prices in the same quarter. Current depreciation over the year in the nominal exchange rate raises the price of imports, but the coefficient is well below that of the rate of change of the U.S. producer price index. This may be because, with a volatile exchange rate, importers take some time to pass on exchange rate changes, while they regard changes in foreign wholesale prices as more permanent.

We tested for asymmetries in the change in the log of the nominal exchange rate, allowing a different coefficient for depreciation and appreciation, but the effect was not significant, though hinting at a slight short-run asymmetry. The equation is reasonable stable over different samples, as shown in the table. The effects of expectations of inflation, growth and the percentage change in the exchange rate over the full sample, drawn from our four-quarter ahead forecasting equations (Appendix), were all insignificant.

Running the OLS equations in STAMP established that there is no stochastic trend.

4.6. The systems approach, expectations effects and the Sims critique

The systems approach of modelling the simultaneous part of the system using maximum likelihood methods proved beneficial in several respects. First, it offered a convincing check for endogeneity bias in the OLS estimates, empirically relevant in some equations. Secondly, it proved a valuable specification check from the test for over-identifying restrictions, and brought to light, as discussed above, one or two effects not anticipated in our single equation modelling. This is an important part of the case made in this paper - that it is feasible to design macro-econometric models, not subject to the charge of Sims (1980), that such models embody 'incredible restrictions'.

The second part of our case was specifically to check for expectations effects (which gave rise to the Sims critique), generated from parsimonious four-quarter ahead forecasting models for output, the exchange rate and WPI inflation. Interestingly enough, these proved relevant in the asset-price equation for the exchange rate. In a separate paper we also found evidence for expectations effects in the asset-price equation for house prices (Aron and Muellbauer, 2004b). Running specification tests using principal components of data from a larger range of variables relevant for the South African macro-economy was a further check against this criticism, and revealed some relevant exchange rate volatility effects.

5. Policy Implications and Discussion

5.1. Monetary transmission

Our paper gives many indications of the complexity of monetary transmission into inflation in South Africa. The exchange rate clearly plays a key role in the South African inflation process and enters directly into the import price equation, the producer price equation and the *CPIX* equation. Our exchange rate equation itself suggests four main routes for the interest rate effect. The first is the direct effect via the interest rate differential between South Africa and the U.S.: a rise in domestic interest rates helps appreciate the currency via this channel. The second effect, in the same direction, operates via the current account surplus: a rise in domestic interest rates, by curbing demand, will increase the surplus and so appreciate the currency. In a third route, if expected producer price inflation is reduced by a rise in interest rates, the currency will appreciate. Indeed, our equation for domestic wholesale price inflation indicates a negative interest rate effect. However, there is a potentially important offsetting factor. The rate of growth in South Africa relative to industrial countries has an important appreciating influence on the exchange rate. We have evidence from Aron and Muellbauer (2002a) for strong negative effects on growth from higher interest rates. It seems likely that the appreciating influence would win in the short run. However, without simulating a larger econometric model, with endogenised output gap and current account surplus, the time path of the net effect of higher domestic interest rates cannot be traced.

The output-gap appears to matters only in the producer price equation. Since producer prices feed into consumer prices, this effect implies the conventional monetary transmission channel. However, the ratio of the current account surplus to GDP is a related indicator of demand pressure, and it has important effects in the exchange rate and *CPIX* equations. As noted above, this is likely to be an important part of monetary transmission.

The *CPIX* equation itself offers important evidence on monetary transmission. Given the literature on the 'cost channel' of monetary transmission, Barth and Ramey (2001), we investigated the direct role of interest rates on *CPIX* with great care. We find a robust negative real prime rate effect at a lag of one quarter. However, our findings also suggest that high real interest rates from between two and three years ago used to feed into higher *CPIX* inflation. Such an effect could be interpreted in terms of costs of capital, lost capacity, and the need to rebuild margins or balance sheets, all implying upward pressure on prices. However, since the early 1990s, this effect has faded. When we interact it with our openness dummy, we find the effect has vanished by 2002, a result any central bank would surely far prefer. Back of the envelope calculations suggest that higher interest rates do bear down on inflation in South Africa, despite the offsets via the mortgage channel onto wages and the currency depreciating effects of lower growth. However, a formal analysis awaits the completion of the full model, endogenising the other domestic variables in the system. We suspect that this will suggest that the output costs of disinflation via higher interest rates are large. The implication is that improved competition policy, wage restraint, further opening of the economy to international competition, and avoiding unnecessary negative exchange rate shocks, could all contribute to bring down inflation in South Africa.

5.2. Sources of inflation in S.A.

Our models suggest that the key reasons why inflation fell from the early 1990s until recently were increased openness to international competition and lower world inflation, as well as higher real interest rates. More generally, our results give scope for exchange rate shocks, wage shocks, oil price shocks and terms of trade shocks – though disinflationary effects of the last of these via the exchange rate are partly offset by inflationary effects via the consumer price index. Excess demand is reflected in the trade deficit or surplus; domestic asset price shocks, especially in housing; credit growth, again via house prices; and fiscal policy also play a role. Indirect tax rates appear in the *CPIX* equation. The wage equation we discuss in Aron and Muellbauer (2004c) suggests that workers are able to obtain partial compensation for higher income tax rates through higher wages, giving a small role to a fiscal variable.

5.3. Exchange rate pass-through

Fascinating insights into the dynamics of the exchange rate pass-through are provided by our research. The feed-through via import prices is, of course, the most rapid; followed by producer prices, and the *CPIX*. Our separate research on wages suggests that they respond to information, including price information, of two or more quarters ago, so the feed-through of an exchange rate shock via this channel is substantially delayed. However, even into import prices, the short-run effect and even the long-run effect is far from one-for-one. We have strong evidence for pricing to market, which slows transmission from exchange rate shocks. The domestic wholesale price index responds to exchange rate shocks much more slowly than import prices. However, as argued in the Monetary Policy Review (SARB, March, 2002), it seems likely that excess demand for maize in sub-Sarahan Africa may have temporarily increased the sensitivity of maize prices, and so the producer price index, to the exchange rate. Given that the exchange rate has a small direct effect in the *CPIX* equation, and that producer prices feed into *CPIX* far less than one-for-one, the *CPIX* rises less and with a longer lag to an exchange rate shock, than does the producer price index. This implication of the model is certainly borne out by recent experience, after the depreciation at the end of 2001.

5.4. Persistence of inflation

Apart from the fact that some of the underlying forces driving consumer prices in South Africa are very persistent, namely greater openness and world disinflation, the wage equation is the key to inflation persistence in South Africa. The evidence from Aron and Muellbauer (2004c) is that wage inflation in South Africa is driven largely by the concerns of workers, rather than of firms, though greater openness to international competition has helped to bring down the rate of wage rises. Wages appear to be set in overlapping contracts, with backward looking cost of living increases feeding through into wages. Short-term asymmetries in the response of import prices to oil prices, and of producer prices to raw food prices and to oil prices, suggest another reason for short-term persistence of inflationary shocks.

5.5. Modelling strategy

Our modelling strategy has aimed to learn as much as possible from the data, but subject to the important disciplines of being consistent with economic reasoning and coherent long-run solutions for each equation, as well as passing standard specification tests. Sign priors played a key role in reducing very general specifications to parsimonious ones. Another important prior was to impose long-run homogeneity on all equations, but not short-run homogeneity. One example of the latter, is that we permit the short-term effect of an exchange rate change to be different from that of a change in foreign prices.

The key structural change incorporated into our models is international openness, which we proxy with a carefully constructed measure, derived from data on trade in manufactures. We also checked for expectations effects, to avoid the charge of Sims (1980) that macro-econometric policy models of this type lack such effects, and are therefore prone to the Lucas critique - as well as imposing 'incredible restrictions'. Apart from the exchange rate equation, the one-year ahead expectations of output growth, producer price inflation and exchange rate depreciation, are insignificant in every equation. This does not necessarily mean that price determination is free from expectations effects, merely that our equations already largely incorporate the information relevant for the formation of these expectations.

Finally, in future work, this set of equations will be incorporated in a larger system, which will endogenise wages, food prices, house prices, interest rates, output and the trade balance to GDP ratio. In such a system, it will then be possible to simulate the impulse response functions of various shocks, and ask questions about the design of monetary policy rules in South Africa. Our evidence is for significant structural breaks, non-linearities and volatility effects, implying that the impulse response functions will not be time invariant. We also find evidence for some effects at longer lags than those considered in standard VARs. Standard VAR methods are thus bound to give misleading results, for example, for exchange rate pass-through, for economies such as that of South Africa.

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APPENDIX: Forecasting Equations for Output, Exchange Rate and Growth.

The following three forecasting equations were estimated, using STAMP and a stochastic I(2) trend for the output forecast (see Aron and Muellbauer (2002a); and by OLS for the forecasts of inflation and for the rate of change of the exchange rate.

Variable	*Definition of Variable*	*Estimation*
	Output Forecasting Equation	1967:4-2001:3
Δ_4 log (Y)	Annualised real GDP growth rate (seas. adj.)	[See reference]
log (Y)	Log of real GDP (seas. adj.)	
RPRIMA	Real prime interest rate/100 (four-quarter MA)	
Δ_4 PRIME	Annual change of prime interest rate/100	
RCASURMA	Ratio to current GDP of the seas. adjusted current account surplus (four-quarter MA)	
RGSURMA	Gov. surplus to GDP ratio (three-year MA)	
FLIB	Financial liberalisation measure – see text	
DFLIB	First difference in FLIB	
Monetary regime shift dummy	Dummy progressing from 0 to 1 in 1983:2-1985:4 , derived from short term liquid asset requirements	
ND4PRIME	Shift dummy x Δ_4 PRIME	
NRPRIMA	Shift dummy x RPRIMA	
Δ_{12} log (TOTIG)	Three-year change in the log terms-of-trade	
DUM92	Drought dummy=1 for 1991:3-92:2, or =0	
	Inflation Forecasting Equation	1979:2-2001:2
Δ_4 log (WPI48) (+4)	Four-quarter-ahead annual rate of change of domestic producer prices	
C		-0.26 [0.95]
log (RULCM48)	Log ratio of NULCM – normalised unit labour costs (manufacturing) - to WPI48	0.10 [2.51]
log (TOTIG)(ma4)	Log terms-of-trade (including gold)	0.083 [2.2]
log (REERN)(ma3)	Weighted average of the log of the SARB's real effective exchange rate & bilateral US$/R rate – see text.	-0.25 [10.1]
DUMOPEN*REER(ma3)	Normalised interaction between DUMOPEN and log (REERN)(ma3)	-0.28 [3.18]
DUMOPEN	The saved stochastic trend from the share of import demand equation in Table 3, column 1, minus (4.30 x RTARIF(-1)), Aron and Muellbauer (2002a)	-0.23 [12.5]
D884	Step dummy which is 1 before 1988:3, and zero otherwise (captures change in WPI weights)	-0.0096 [-1.0]
D884*Δ_4 log (IMPP)	Interaction effect of D884 with D4LIMPP	0.18 [3.5]
Δ_4 log (USWP)	Annual rate of change of US producer prices ($)	0.14 [2.1]
Δ_8 RCASUR	Two-year change in current a/c to GDP ratio	0.12 [4.0]
Δ_4 OUTGAP	Annual change in the output gap	0.31 [3.8]
NEERFIT2(-1)	Exchange rate forecast	-0.064 [3.5]
Δ log (WPI48)(-1)	Quarterly rate of change of domestic producer prices	-0.90 [4.2]
Δ_4 log (WPI48)(-1)	Annual rate of change of domestic producer prices	-0.69 [3.5]
Std. error		0.01146
CHOW test (mid)		p=0.126

Variable	*Definition of Variable*	*Estimation*
Adj. R square		0.90
	Exchange Rate Forecasting Equation	1979:1-2001:2
Δ_4 log (NEERN) (+4)	Four-quarter-ahead annual rate of change of the adjusted nominal exchange rate	
C		0.79 [2.0]
DUMOPEN	The saved stochastic trend from the share of import demand equation in Table 3, column 1, minus (4.30 x RTARIF(-1)), Aron and Muellbauer (2002a)	-0.43 [-2.1]
DDEBT	Dummy=1 in 1985:3, and 0 otherwise	-0.20 [-2.0]
LREERN	Log of the (adjusted) real effective exchange rate	-0.62 [-3.3]
TREND		0.003 [2.4]
D12TECHPROR	Difference between the log of South African real GDP and log of the industrial production index for industrial countries, plus a trend to account for differential labour force growth	2.57 [2.4]
D4LWPI48(-4)	Annual domestic wholesale price inflation	-1.08 [-1.9]
D4LRPSCR(-4)	Annual rate of growth of real private sector credit extension	1.07 [5.0]
D4LUSWP(-4)	Annual U.S. producer price inflation	0.57 [1.5]
D4LREERN	Annual change in log real effective exchange rate	0.37 [2.1]
RGSURMA4	Ratio to current GDP of the government surplus (4 quarter moving av.)	-2.30 [-2.7]
RCASURMA2	Ratio to current GDP of the seas. adjusted current account surplus (2 quarter moving av.)	1.99 [3.6]
Std. error		0.09247
Adj. R square		0.405

Table 1: Statistics and Variable Definitions: 1979:2-2002:2

Variable	*Definition of Variable*	*Mean*	*Standard Deviation*	*I(1)*[a,b]	*I(2)*[a,b]
	1. Consumer Price Equation				
log(CPIX)	Log of CPIX, the consumer price index excluding mortgage interest costs – constructed before 1997 (see text), after which it is published	3.57	0.817	-2.41	-3.47*
Log(RWPI48X)	Log ratio of domestic wholesale prices to CPIX	0.181	0.118	-2.68	-6.23**
Log(RNULCMX)	Log ratio of NULCM – normalised unit labour costs (manufacturing) - to CPIX	3.95	0.115	-1.30	-9.82**
Log(RHPRICE)	Log of price of medium-sized houses (ABSA) deflated by CPIX	8.04	0.248	-3.05	-3.20*
Log(RIMPPX)	Log ratio of import price component of the producer price index to CPIX	0.236	0.191	-2.40	-3.51**
Log(RPOILX)	Log ratio of the Rand price of Brent oil, to CPIX	2.26	0.471	-1.96	-4.86**
Log(REERN)	Weighted average of the log of the SARB's real effective exchange rate & bilateral US$/R rate – see text.	2.18	0.166	-2.04	-4.55*
Log(TOTIG)	Log terms-of-trade (including gold)	4.62	0.066	-3.20*	-12.6**
OUTGAP	Measure of the output gap derived as explained in section 4.2.	-0.009	0.024	-2.89	-5.71**
RCASUR	Ratio to current GDP of current account surplus	0.004	0.033	-3.46*	-4.66**
RPRIME	Prime rate/100 less the annual change in the log of CPIX	0.055	0.056	-4.02*	-4.82**
VAT	Rate of general sales tax	11.1	3.62	-1.82	-9.03**
DUMOPEN	The saved stochastic trend from the share of import demand equation in Table 3, column 1, minus (4.30 x RTARIF(-1)), Aron and Muellbauer (2002a)	-	-	-	-
Log (WPI48)	Log of domestic wholesale prices	3.75	0.704	-2.67	-4.20**
log (POIL)	Log of (Rand) Brent oil price	5.83	0.584	-2.97	-5.00**
VOLEX	Volatility measure, the absolute value of the 4-quarter change in log(NEERN) inflation minus last year's change. VOLEXma4 is the 4-quarter moving average.	0.121	0.106	-5.55**	-8.78**
ND	ND is a monetary policy regime dummy, based on prescribed liquidity ratios, rising from 0 up to 1983Q2, to 1 from 1985Q4, see Aron and Muellbauer (2002b).	-	-	-	-
D91:4, 92:1	Drought dummy set equal to 1 in 1991:4 and 1992:1	-	-	-	-
GST	General Sales Tax	-	-	-	-
	2. Producer Price Equation				
Log (WPI48)	Log of domestic wholesale prices	3.75	0.704	-2.67	-4.20**
log(RULCM48)	Log ratio of NULCM – normalised unit labour costs (manufacturing) – to domestic wholesale prices	3.77	0.061	-0.165	-9.15**
log(RIMPP48)	Log ratio of import price component of the producer price index to domestic wholesale prices	0.055	0.084	-2.54	-4.22**
log(RPOIL48)	Log ratio of the Rand price of Brent oil, to domestic wholesale prices	2.07	0.403	-2.17	-4.90**

Variable	*Definition of Variable*	*Mean*	*Standard Deviation*	*I(1)*[a,b]	*I(2)*[a,b]
log(RPFOOD48)	Log ratio of the price of raw food to the domestic wholesale price index	0.170	0.117	-3.07	7.05**
log(REERN)	Weighted average of the log of the SARB's real effective exchange rate & bilateral US$/R rate – see text.	2.18	0.166	-2.04	-4.55*
log(TOTIG)	Log terms-of-trade (including gold)	4.62	0.066	-3.20*	-12.6**
OUTGAP	Measure of the output gap derived as explained in section 4.2.	-0.009	0.024	-2.89	-5.71**
DUMOPEN	As above	-	-	-	-
log (POIL)	Log of (Rand) Brent oil price	5.83	0.584	-2.97	-5.00**
log (PFOOD)	Log of the raw price of food, from the agricultural food component of the CPIX index	3.921	0.602	-1.55	6.87**
log (IMPP)	Log of the import price index	3.81	0.648	-2.48	-3.49*
	3. Import Price Equation				
log(IMPP)	Log of the import price index	3.81	0.648	-2.48	-3.49*
log(RPOILIM)	Log ratio of the Rand price of Brent oil, to imports	2.02	0.373	-2.18	-8.19**
log(RWPI48IM)	Log ratio of domestic wholesale prices to import prices	-0.055	0.084	-2.54	-4.22**
log(RPFORIM)	Log ratio of a foreign price index of weighted wholesale prices to S.A. import prices – see text	-2.23	0.189	-2.70	-4.77**
log(REERN)	Weighted average of the log of the SARB's real effective exchange rate & bilateral US$/R rate – see text.	2.18	0.166	-2.04	-4.55*
DUMOPEN	As above	-	-	-	-
DCONT98	Dummy=1 in 1998:3, and 0 otherwise	-	-	-	-
DGEAR	Dummy=1 in 1996:3; and 0 otherwise	-	-	-	-
log(NEERN)	Log of the constructed nominal effective exchange rate (see text)	2.75	0.679	-2.66	-4.35**
log(USWP)	Log of US wholesale prices ($): note is only used as a differenced term	4.50	0.127	-4.48**	-3.22*
log(POIL)	log of (Rand) Brent oil price	5.83	0.584		
log(WPI48)	log of domestic wholesale prices	3.75	0.704	-2.67	-4.20**
	4. Nominal Exchange Rate				
log(NEERN)	Log of the constructed nominal effective exchange rate (see text)	2.75	0.679	-2.66	-4.35**
log(REERN)	Weighted average of the log of the SARB's real effective exchange rate & bilateral US$/R rate – see text.	2.18	0.166	-2.04	-4.55*
log(TOTIG)	Log terms-of-trade (including gold)	4.62	0.066	-3.20*	-12.6**
RLTFLOW	Ratio of net long-term capital inflows (old definition) to current GDP. Extended after 1998 using a regression (see text).	0.001	0.008	-5.87**	-7.08**
RGSUR	Gov. surplus to GDP ratio	-0.038	0.037	-1.79	-16.9**
USSPREADS	Spread between SA prime rate and US government Treasury Bill rate	0.104	0.052	-2.49	-6.60**
RCASUR	Ratio to current GDP of current account surplus	0.004	0.033	-3.46*	-4.66**
log(RPCREDIT)	The log ratio of private sector credit extension to the GDP deflator	13.8	0.165	-4.47*	-3.60*
TECHPROR	Difference between the log of South African real GDP and log of the industrial production index for industrial countries	8.66	0.054	-1.86	-6.35**
DUMOPEN	As above	-	-	-	-

Variable	*Definition of Variable*	*Mean*	*Standard Deviation*	*I(1)*[a,b]	*I(2)*[a,b]
RISKAPP	CSFB global risk appetite measure	1.31	2.55	-5.52**	-10.6**
DDEBT	Dummy=1 in 1985:3, and 0 otherwise	-	-	-	-
DCONT98	Dummy=1 in 1998:3, and 0 otherwise	-	-	-	-
DLIQCR	Dummy=1 in 2001:4, and 0 otherwise	-	-	-	-
log(WPI48)	Log of domestic wholesale prices	3.75	0.704	-2.67	-4.20**
log(USWP)	Log of US wholesale prices ($)	4.50	0.127	-4.48**	-3.22*

a. The variables are those included in equations (4.1)-(4.8). Tables 2-7 present parsimonious equations where some variables are transformed into moving averages and delta terms, during general to specific reduction.

b. For a variable X, the augmented Dickey-Fuller (1981) statistic is the t ratio on π from the regression: $\Delta X_t = \pi X_{t-1} + \Sigma_{i=1,k}\, \theta_i\, \Delta X_{t-i} + \psi_0 + \psi_1\, t + \varepsilon_t$, where k is the number of lags on the dependent variable, ψ_0 is a constant term, and t is a trend. The kth-order augmented Dickey-Fuller statistic is reported, where k is the last significant lag of the 3 lags employed. The trend is included only if significant. For null order I(2), ΔX replaces X in the equation above. Critical values are obtained from MacKinnon (1991). Asterisks * and ** denote rejection at 5% and 1% critical values. Stationarity tests are performed for the variables in levels before time-transformation i.e. before taking moving averages and changes.

c. Expectations effects are tested in all seven equations using fitted values from four-quarter ahead forecasting equations – see Appendix.

d. Variables from SARB except house prices (ABSA), government deficit (IMF), prime rate (IMF), US wholesale prices (IMF), world commodity prices (IMF) and Brent oil prices (IMF).

Table 2. Consumer price equations

Dependent variable: Δlog (CPIXC2)	1 *OLS* 1979 (2) – 2000 (1)	2 *OLS* 1979 (2) – 1994 (1)	3 *OLS* 1979 (2) – 2002 (3)	4 *IV* 1979 (2) – 2002 (3)	5 *FIML* 1979 (2) – 2002 (3)
Regressors					
Constant	-0.50 [7.2]	-0.62 [3.4]	-0.47 [7.4]	-0.48 [7.9]	-0.44 [8.2]
Trend/100	0.042 [3.9]	0.043 [3.5]	0.045 [4.7]	0.051 [5.3]	0.050 [5.7]
log(RNULCMX)(-1)	0.121 [6.9]	0.151 [3.2]	0.112 [7.4]	0.110 [7.7]	0.108 [8.0]
log(RWPI48X)(-1)	0.065 [2.6]	0.056 [1.5]	0.078 [3.7]	0.098 [4.4]	0.097 [4.8]
RPRIME(-1)	-0.13 [4.5]	-0.13 [3.5]	-0.13 [4.4]	-0.098 [3.3]	-0.096 [3.3]
(DUMOPEN +0.25)* (RPRIMEma8(-4)-0.05)	-0.35 [6.6]	-0.30 [4.7]	-0.34 [6.7]	-0.28 [5.2]	-0.27 [5.4]
ND*(PRIME(-1)- PRIMEma4(-4))	-0.14 [4.0]	-0.18 [3.6]	-0.13 [3.5]	-0.13 [3.5]	-0.12 [3.6]
(DUMOPEN+0.88)* VOLEXma4(-1)	0.24 [5.4]	0.13 [1.0]	0.22 [5.5]	0.19 [4.8]	0.18 [4.9]
ΔGST	0.0034 [3.8]	0.0033 [3.7]	0.0035 [4.1]	0.0035 [4.3]	0.0038 [4.8]
D91:4,92:1	0.020 [5.0]	0.020 [4.8]	0.020 [4.9]	0.021 [5.3]	0.021 [5.7]
$\Delta_3$log (OIL) (-1)	0.0098 [4.3]	0.117 [3.8]	0.089 [4.1]	0.0092 [4.7]	0.0090 [4.9]
Δlog (WPI48)	0.30 [3.2]	0.37 [3.1]	0.32 [3.6]	0.28 [2.4]	0.29 [2.6]
Δ_8RCASUR(-1)	-0.093 [5.5]	-0.092 [5.1]	-0.093 [5.5]	-0.098 [6.0]	-0.098 [6.5]
$\Delta_4$log(TOTIG)(-1)	0.024 [1.7]	0.030 [2.2]	0.021 [1.8]	0.038 [3.0]	0.038 [3.3]
Δ LAGFOOD	0.07 [2.7]	0.05 [1.6]	0.06 [2.9]	0.06 [2.7]	0.06 [2.7]
Δ_2 log(NEERN)(-1)	-0.020 [2.3]	-0.027 [2.6]	-0.019 [2.4]	-0.021 [2.4]	-0.020 [2.5]
$\Delta_3$log(CPIX)(-1)	-0.29 [5.7]	-0.25 [4.0]	-0.25 [5.1]	-0.25 [5.3]	-0.25 [5.5]
Δlog(CPIMET)(-3)	0.30 [3.9]	0.24 [2.3]	0.25 [3.5]	0.26 [3.8]	0.25 [3.8]
Diagnostics					
Equation Std error	0.00438	0.00438	0.00451	0.00450	0.00437
Normality	P=0.847	P=0.707	P=0.586		
CHOW(mid-sample)	p=0.566	p=0.213	p=0.415		
AR 1-4 test	P=0.084	P=0.163	P=0.245		
Breusch-Pagan het test	p=0.907	p=0.462	p=0.939		
DurbinWatson	2.15	2.70	2.23	2.24	
Adjusted R^2	0.850	0.799	0.844	0.843	

(Absolute values of asymptotic *t*-ratios in parentheses)

1. See Table 1 for definitions of the variables (before transformation).

2. The sample in column 2 ends when the inflation targeting regime begins; and in column 3, ends when the ANC government was elected. All samples begin in 1979:2 (floating exchange rate regime).
3. Instruments are the fitted value from an instrumenting equation for DLWPI48.
4. The forecasts proxying expectations are the fitted values from the four-quarter-ahead annual rate of change forecasting equations – see Appendix.
5. Note that when interacted with the volatility term, DUMOPEN is set to zero at its *minimum* by adding 0.88. This normalises the impact of VOLEX to be zero in 1980, which is the year when the economy is most closed according to our DUMOPEN measure. When interacted with RPRIME, DUMOPEN is set to zero at its *maximum* by adding 0.25 while RPRIMEma8 is mean-adjusted by subtracting 0.05. This normalises the impact of RPRIMEma8 to be zero in 2002, which is the year when economy is most open according to our DUMOPEN measure.

Table 3. Producer price equations

Dependent variable: Δlog (WPI48)	1 OLS 1979 (2) – 2000 (1)	2 OLS 1979 (2) – 1994 (1)	3 OLS 1979 (2) – 2002 (3)	4 *IV* 1979 (2) – 2002 (3)	5 *FIML* 1979 (2) – 2002 (3)
Regressors					
constant	-0.05 [1.2]	-0.05 [0.4]	-0.07 [1.6]	-0.08 [1.8]	-0.07 [1.5]
log(RULCM48) (–1)	0.047 [3.5]	0.025 [0.9]	0.052 [3.7]	0.055 [4.2]	0.053 [3.7]
log(REERNma2)(-1)	-0.057 [10.7]	-0.044 [6.5]	-0.056 [10.9]	-0.058 [11.8]	-0.058 [10.7]
USSPREADS(-1)	-0.047 [3.2]	-0.039 [1.9]	-0.050 [3.5]	-0.053 [4.8]	-0.046 [3.1]
log(RPFOOD48)(-1)	0.024 [3.6]	0.023 [2.8]	0.026 [3.8]	0.028 [4.0]	0.031 [4.1]
OUTGAP(-1)	0.119 [5.9]	0.118 [5.2]	0.118 [5.2]	0.116 [5.0]	0.120 [5.4]
DUMOPEN	-0.026 [7.1]	0.001 [0.1]	-0.027 [7.4]	-0.027 [7.9]	-0.026 [6.7]
Δlog (POIL) + ABS(Δlog (POIL))	0.004 [1.5]	0.006 [2.1]	0.005 [2.1]	0.005 [2.1]	0.005 [1.7]
Δlog (IMPP)	0.075 [3.8]	0.081 [3.5]	0.090 [4.4]	0.068 [3.1]	0.066 [2.7]
DLAGFOOD + ABS(DLAGFOOD)	0.084 [10.2]	0.082 [8.8]	0.071 [9.1]	0.073 [9.1]	0.074 [8.9]
Diagnostics					
Equation Std error	0.00366	0.00380	0.00393	0.00397	0.00416
Normality	p=0.183	p=0.505	p=0.923	-	
CHOW(mid-sample)	p=0.218	p=0.057	p=0.041	-	
AR 1-4 test	p=0.977	p=0.522	p=0.724	-	
het. test	p=0.377	p=0.419	p=0.679	-	
Durbin-Watson	1.91	2.07	2.01	2.01	
Adjusted R^2	0.886	0.844	0.865	0.862	

(Absolute values of asymptotic *t*-ratios in parentheses)

1. See Table 1 for definitions of the variables (before transformation).
2. The sample in column 2 ends when the inflation targeting regime begins; and in column 3, ends when the ANC government was elected. All samples begin in 1979:2 (floating exchange rate regime).
3. The instruments are derived from instrumenting equations for DLIMPP based on the Table 5 specification, proxying endogenous variables with appropriate lags; for DLNEER using the Table 4 specification, adjusted similarly; and for Δlog(POIL) using DLPOILUS, the US price of oil and the fitted value of DLNEER. Absolute values of fitted values are used where relevant to instrument the asymmetric effects. The FIML estimates substitute US Dollar oil prices for Rand oil prices.
4. The forecasts proxying expectations are the fitted values from the four-quarter-ahead annual rate of change forecasting equations – see Appendix.

Table 4. Nominal exchange rate equations

Dependent variable: Δlog (NEERN)	1 OLS 1979 (2) – 2000 (1)	2 OLS 1979 (2) – 1994 (1)	3 OLS 1979 (2) – 2002 (1)	4 IV 1979 (1) – 2002 (3)	5 *Expectations* IV 1979 (2) – 2002 (3)	6 *FIML* 1979 (2) – 2002 (3)
Regressors						
constant	-0.47 [0.9]	-0.64 [1.0]	-1.0 [2.1]	-1.0 [2.3]	-0.8 [2.3	-1.0 [2.3]
log(REERNma2) (–1)	-0.31 [4.6]	-0.31 [4.7]	-0.17 [3.2]	-0.19 [3.6]	-0.15 [1.6]	-0.18 [3.1]
log(TOTIG)(-2)	0.22 [2.2]	0.25 [2.0]	0.28 [3.1]	0.28 [3.1]	0.24 [3.1]	0.28 [3.1]
DUMOPEN	-0.15 [3.1]	-0.19 [1.0]	-0.13 [2.9]	-0.14 [2.8]	-0.15 [1.9]	-0.14 [2.9]
USSPREADS (–1)	0.36 [2.1]	0.42 [1.9]	0.37 [2.6]	0.38 [2.6]	-	0.39 [3.1]
Δ_8RCASUR(-1)	0.44 [4.0]	0.44 [3.6]	0.41 [3.7]	0.41 [3.6]	0.29 [3.0	0.42 [3.7]
DIFFWPUS	-2.0 [4.0]	-2.1 [3.0]	-1.6 [3.3]	-1.6 [3.1]	-0.8 [1.7	-1.7 [3.1]
Δ_{12}TECHPROR	1.9 [4.5]	2.0 [4.1]	1.3 [3.7]	1.3 [3.7]	0.5 [1.4]	1.4 [3.6]
DDEBT	-0.1 [5.6]	-0.16 [5.2]	-0.17 [5.5]	-0.17 [5.4]	-0.16 [5.7]	-0.17 [5.4]
DCONT98	-0.16 [3.9]	-	-0.15 [3.6]	-0.15 [3.6]	-0.17 [4.5]	-0.15 [3.5]
DLIQCR	-	-	-0.12 [3.5]	-0.12 [3.4]	-0.14 [4.2]	-0.12 [3.3]
$\Delta_2$log (NEERN)(-1)	-0.25 [4.1]	-0.27 [3.6]	-0.22 [3.9]	-0.14 [2.3]	-0.23 [4.2]	-0.14 [2.3]
Forecast at t-1 of $\Delta_4$log(WPI48)(+4)	-	-	-	-	-0.80 [2.9]	-
Forecast at t-1 of $\Delta_4$log(NEERN)(+4)	-	-	-	-	0.16 [2.4]	
Diagnostics						
Equation Std error	0.0383	0.0405	0.0397	0.0400	0.0354	0.0401
Normality	0.003	0.098	0.000			
CHOW(mid-sample)	p=0.487	p=0.000	p=0.116			
AR 1-4 test	p=0.415	p=0.548	p=0.336			
Breusch-Pagan het test	0.399	0.639	0.453			
Durbin-Watson	1.84	1.82	1.64	1.62	1.78	
Adjusted R^2	0.539	0.525	0.536	0.529	0.631	

(Absolute values of asymptotic *t*-ratios in parentheses)

1. See Table 1 for definitions of the variables (before transformation).
2. The sample in column 2 ends when the inflation targeting regime begins; and in column 3, ends when the ANC government was elected. All samples begin in 1979:2 (floating exchange rate regime).
4. The forecasts proxying expectations are the fitted values from the four-quarter-ahead annual rate of change forecasting equations – see Appendix.
5. DIFFWPUS is defined as the rate of change of domestic WPI48 prices, less the rate of change of US WPI (in $), averaged over two quarters. The fitted value for the former variable is used as an instrument in IV.

Table 5. Import price equations

Dependent variable: Δlog (IMPP)	1 *OLS* 1979 (2) – 2000 (1)	2 *OLS* 1979 (2) – 1994 (1)	3 *OLS* 1979 (2) – 2002 (3)	4 *IV* 1979 (2) – 2002 (3)	5 *Simultaneous estimation* 1979 (2) – 2002 (3)
Regressors					
Constant	0.10 [2.7]	0.12 [1.5]	0.06 [1.7]	0.08 [2.2]	0.09 [2.2]
log(RPOILIM) (–1)	0.022 [4.7]	0.026 [3.9]	0.019 [4.7]	0.020 [4.8]	0.021 [4.9]
log(REERN)(-1)	-0.088 [4.2]	-0.077 [3.0]	-0.073 [3.4]	-0.086 [3.7]	-0.090 [3.6]
log(RWPI48IM)(-1)	0.123 [2.5]	0.091 [1.4]	0.150 [3.5]	0.140 [2.4]	0.140 [3.0]
DUMOPEN	-0.08 [3.1]	-0.01 [0.2]	-0.09 [4.1]	-0.10 [4.2]	-0.11 [4.1]
DGEAR	-0.035 [3.3]	-	-0.033 [3.0]	-0.030 [2.7]	-0.033 [3.1]
DCONT98	0.043 [4.0]	-	0.043 [3.8]	0.044 [3.8]	0.043 [3.8]
DLIQCR	-	-	0.022 [2.4]	0.26 [2.7]	0.025 [2.7]
Δlog(POIL)(-1) + ABS(Δlog (POIL) (–1))	0.042 [5.7]	0.052 [5.6]	0.044 [5.7]	0.044 [5.6]	0.044 [5.6]
Δlog (USWP)	0.56 [4.5]	0.54 [3.4]	0.48 [4.2]	0.55 [4.4]	0.54 [4.3]
Δlog (WPI48)	0.80 [4.5]	0.73 [3.4]	0.85 [4.6]	0.54 [2.2]	0.47 [1.9]
$\Delta_4$log (NEERN)	-0.049 [3.6]	-0.040 [2.4]	-0.042 [3.0]	-0.045 [2.8]	-0.044 [2.4]
VOLEXma4(-1)	0.023 [1.1]	0.030 [1.2]	0.048 [2.6]	0.047 [2.5]	0.044 [2.3]
$\Delta_2$log (IMPP)(-1)	-0.17 [3.9]	-0.18 [3.4]	-0.18 [4.3]	-0.19 [4.4]	-0.19 [4.5]
Diagnostics					
Equation Std error	0.00995	0.01060	0.01064	0.0107	0.01087
Normality	p=0.365	p=0.262	p=0.679	0.0108	
CHOW(mid-sample)	p=0.081	p=0.108	p=0.057	-	
AR 1-4 test	p=0.510	p=0.955	p=0.662		
Breusch-Pagan het test	p=0.320	p=0.327	p=0.578	-	
Durbin-Watson	2.02	2.04	1.87	1.88	
Adjusted R^2	0.844	0.840	0.814	0.807	

(Absolute values of asymptotic *t*-ratios in parentheses)

1. See Table 1 for definitions of the variables (before transformation).
2. The sample in column 2 ends when the inflation targeting regime begins; and in column 3, ends when the ANC government was elected. All samples begin in 1979:2 (floating exchange rate regime).
3. The instruments are fitted values from instrumenting equations for DLNEER and DLWPI48.

Figure 1. Annual Consumer Price Inflation Measures

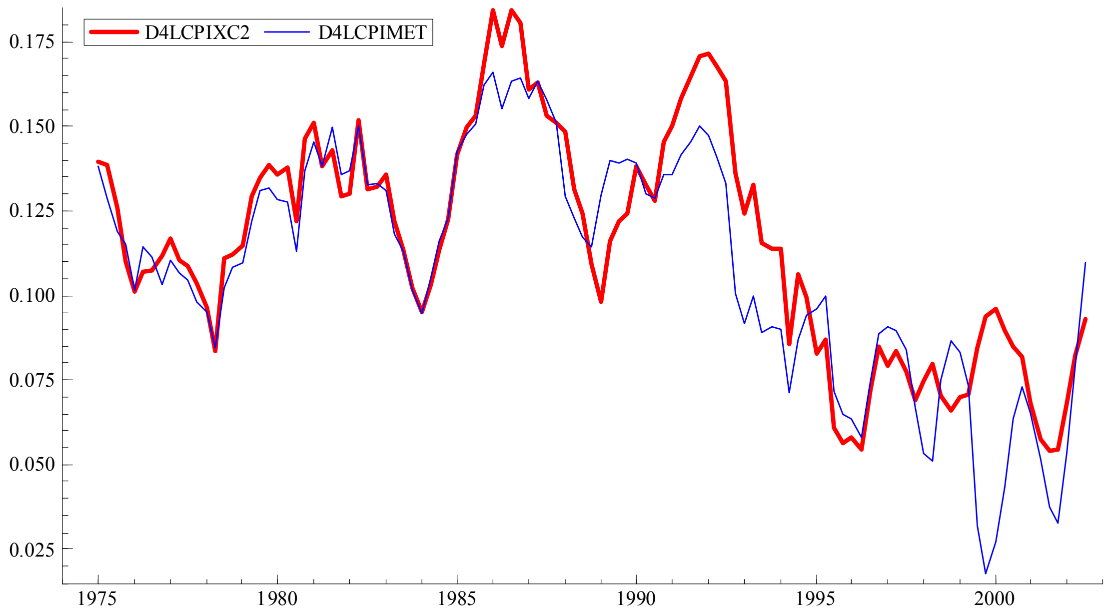

Figure 2. The Openness Indicator for South Africa.

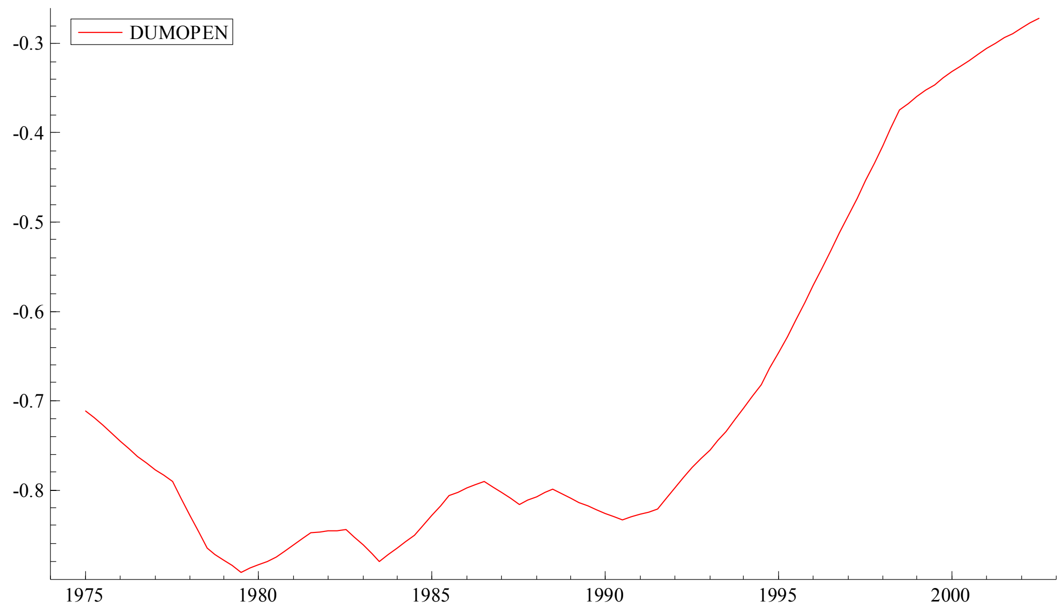

Figure 3. Real Prime Interest Rate

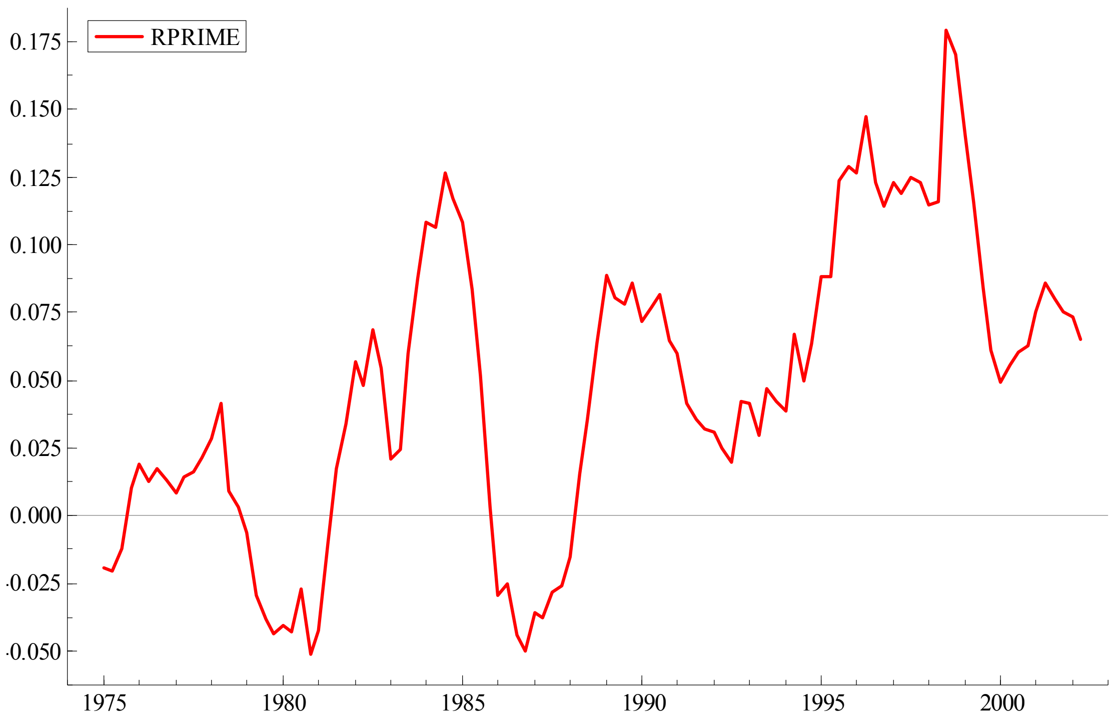

Figure 4. The log ratios to CPIX of domestic producer price index and normalised unit labour costs (RH scale)

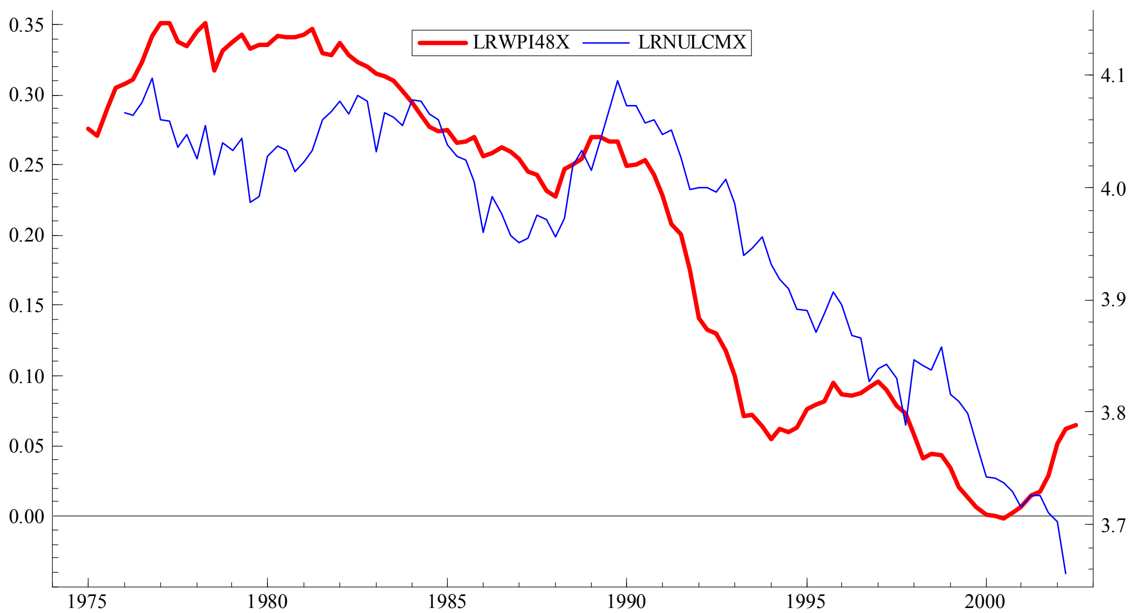

Figure 5. The two year change in the current account surplus to GDP ratio and the output gap

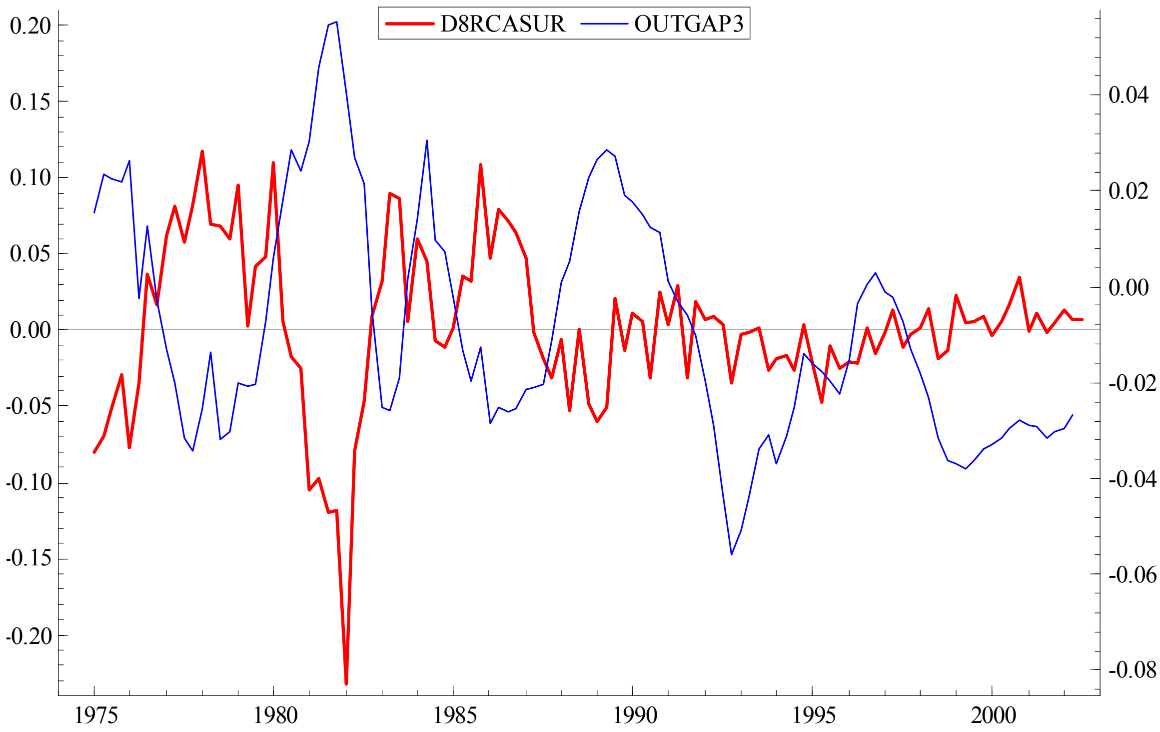

Figure 6. Annual Producer Price Inflation Measures

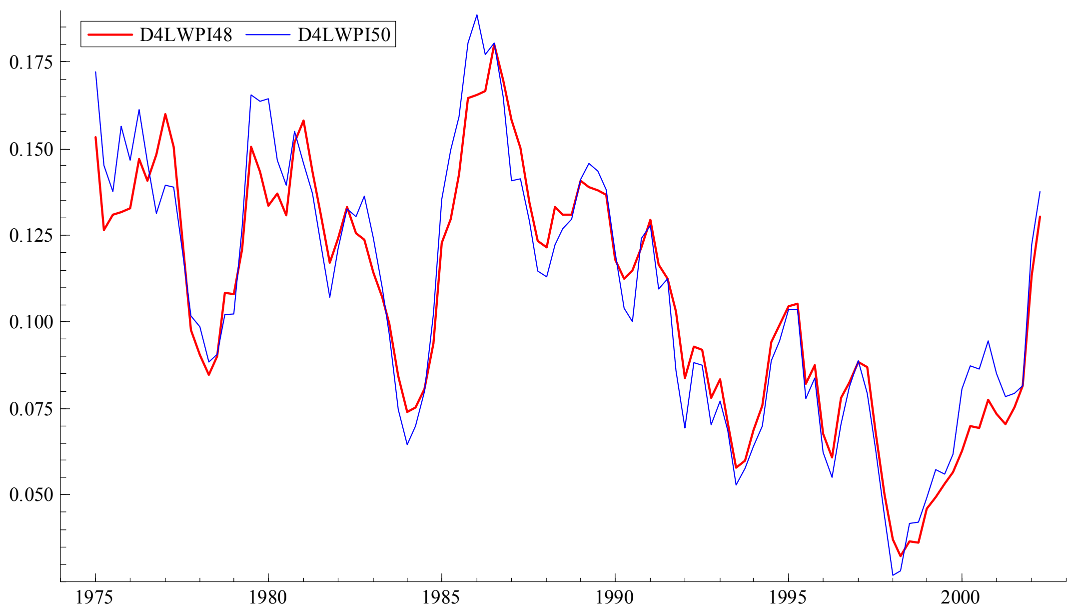

Figure 7. The log of the real exchange rate index (constructed), and the spread between the domestic prime rate and U.S. treasury bills (RH scale)

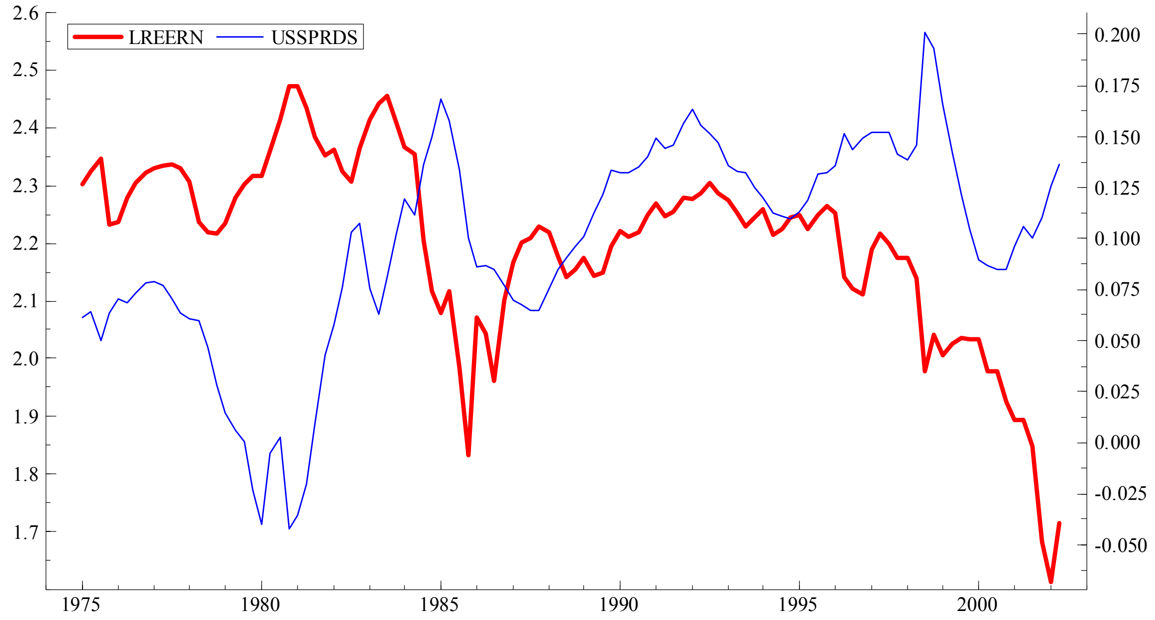

Figure 8. Log ratios to domestic producer prices of normalised unit labour costs and the price of raw food (RH scale)

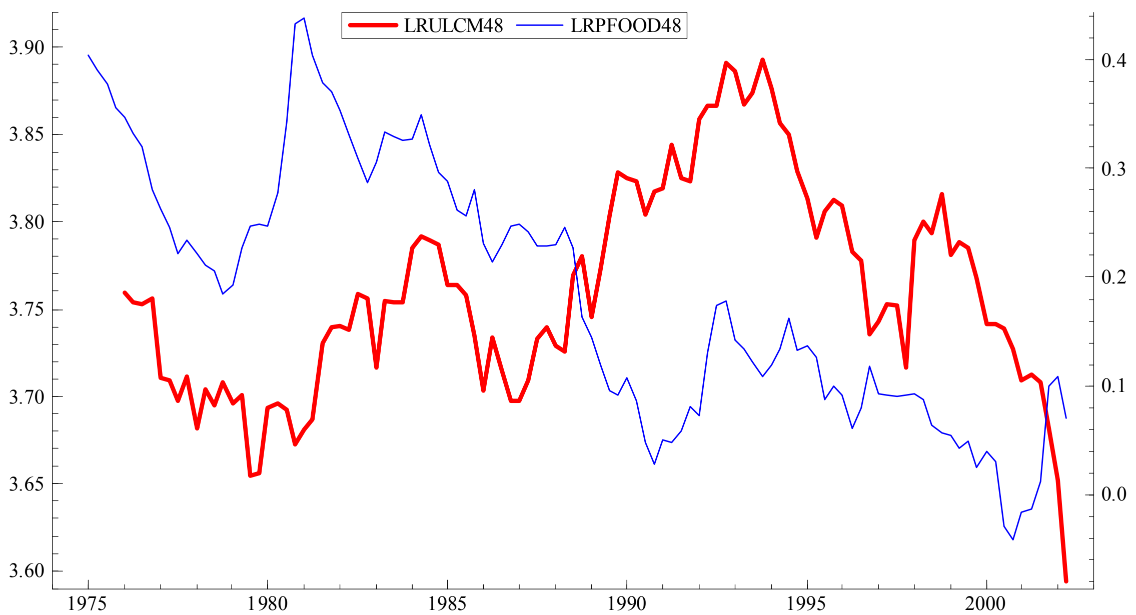

Figure 9. Nominal Effective Exchange Rate Measures

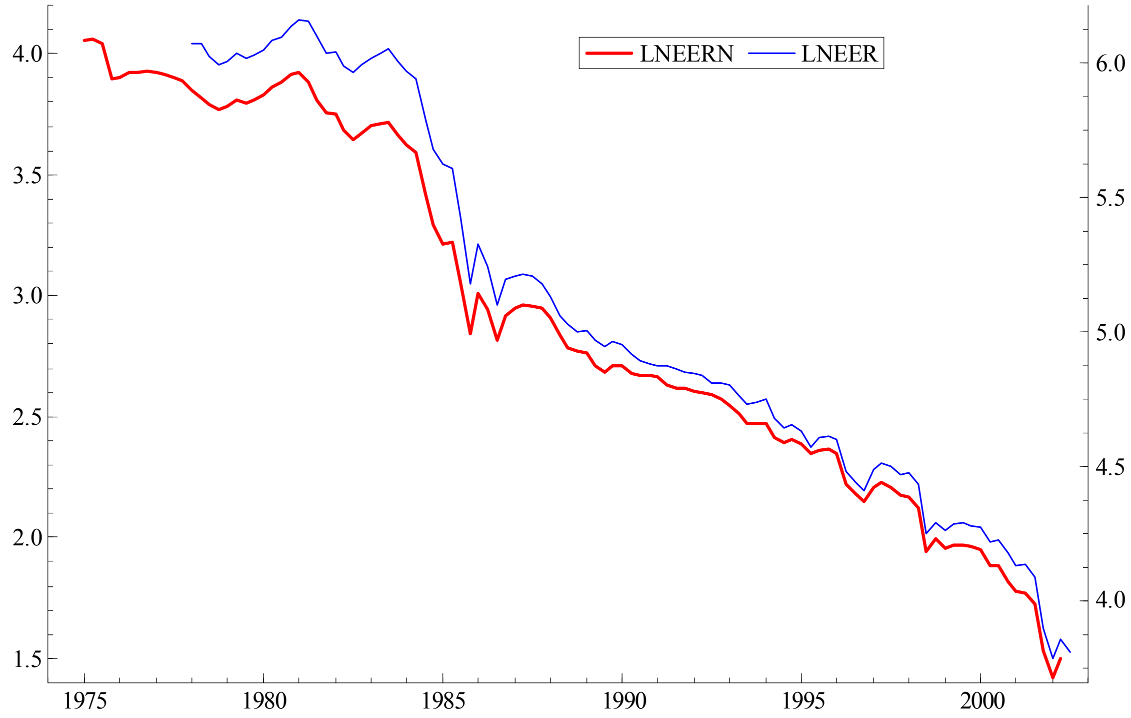

Figure 10. The three year growth differential (proxying comparative productivity growth) between South Africa and industrial countries, and the overall terms of trade (RH scale)

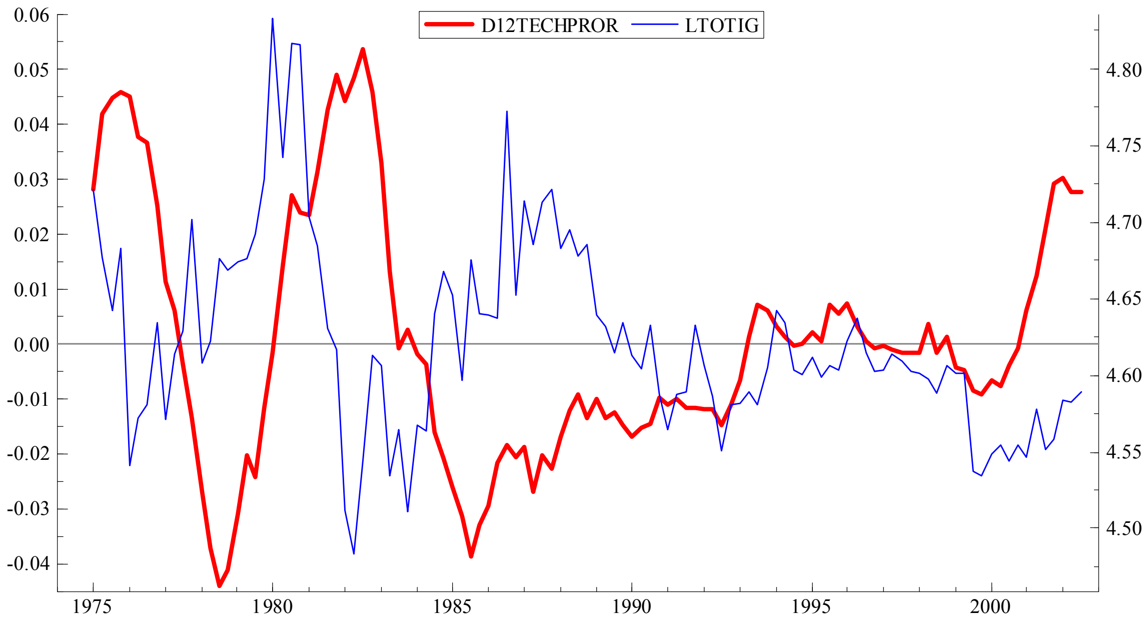

Figure 11. Annual Import Price Inflation

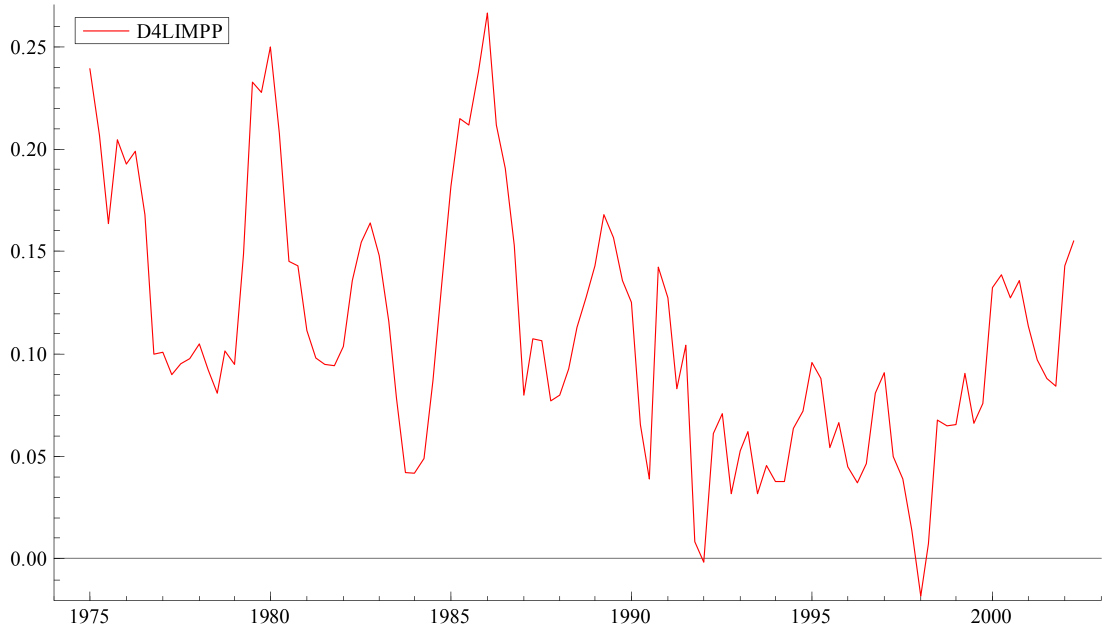

Figure 12. Ratio of foreign producer prices to import prices

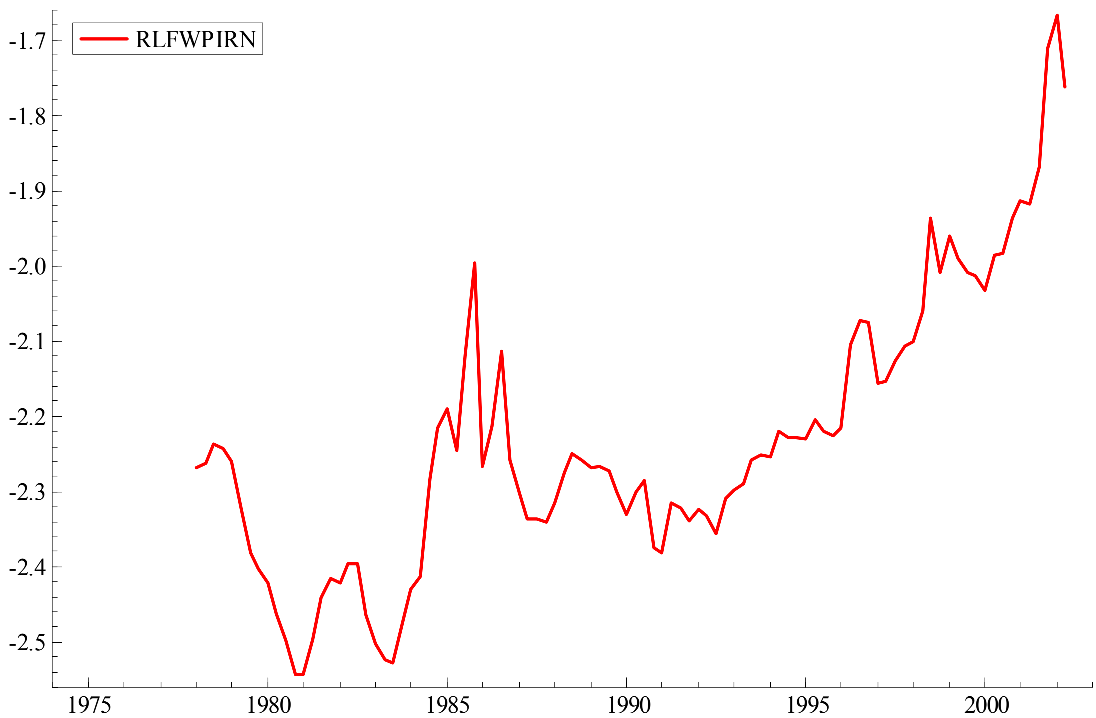

Figure 13. Log ratios to import prices of domestic producer prices and the Rand oil price (Brent) (RH scale).