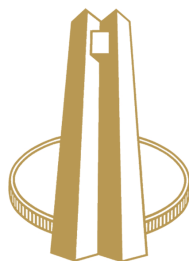


The core forecasting model of the South African Reserve Bank

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South African Reserve Bank

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Abstract

This paper describes the key stochastic equations in the core model of the South African Reserve Bank. During the development phase of the model, comments and suggestions from experts of other central banks, research institutions, and international and local academics were invited and where feasible, included. The core model is a medium-sized Type II hybrid model, since it incorporates a long-run equilibrium that is based on economic theory and historical relationships, as well as short-run dynamics that allow the economy to gravitate towards its long-run equilibrium.

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Non-technical summary

This paper describes the key stochastic equations in the core model of the South African Reserve Bank (the Bank). During the development phase of the model, comments and suggestions from experts of other central banks, research institutions, and international and local academics were invited and incorporated, where feasible.

As monetary policy influences the economy with time lags, it is important to have a view of future economic developments. Models are an indispensable tool in the monetary policy formulation process, providing a systematic framework for economic reasoning and helping to identify factors relevant in explaining mechanisms that could influence the economy in the future. A further benefit of models is that they allow the Bank to address uncertainty within a well-defined conceptual framework, and thereby examine the key risks associated with any forecast in a quantitative sense. The core model is used for forecasting purposes at Monetary Policy Committee (MPC) meetings and for simulation purposes, i.e. to quantify the impact of monetary policy decisions and possible shocks.

The core model is a medium-sized Type II hybrid model, since it incorporates a long-run equilibrium that is based on economic theory and historical relationships, as well as short-run dynamics that allow the economy to gravitate towards its long-run equilibrium. The model uses official, seasonally adjusted quarterly data. In evaluating the model, overall model properties and performance receive preference over the properties of individual stochastic equations.

An accuracy analysis of the Bank's inflation forecasts and the monthly *Reuters Survey*, both covering the period 2000 to 2005, shows that CPIX inflation forecasts were mostly upwardly biased. However, the forecast errors produced by the Bank's core model were consistently smaller and less biased than other institutions' forecasts. Based on various peer reviews, the model appears to be a reasonable representation of the South African economy and is in line with international best practice for estimated structural models.

1 General description of the model

1.1 History of the model and general description

The 1960s saw an explosion of attempts to combine two strands of modern economic analyses, i.e. mathematical model development and the quantitative measurement of macroeconomic aggregates. Against this backdrop a decision was taken by the Bank in 1974 that a quantitative macroeconomic model had to be developed for the South African economy. The structure of the initial model consisted of 23 stochastic equations, which eventually expanded to about 89 stochastic equations. With the adoption of inflation targeting, monetary policy initiatives in a number of central banks led to the introduction of suites of (smaller) models. The Bank decided, after the adoption of a similar framework for South Africa in February 2000, to adjust its modelling philosophy in accordance with this trend. The core model is one of the models that have been developed by the Bank since 1999 and is described in this paper. The core model is the key macroeconomic model of the Bank and the forecasts generated by this model are conditional on the current economic situation and the assumptions provided by the MPC. Apart from forecasting, the model is used for simulations to analyse the impact of monetary policy actions and exogenous shocks on variables.

During the early development phase of the model, the Bank used input from modelling experts of other central banks, in particular the Bank of England, the Sveriges Riksbank, the Bank of Canada and the Reserve Bank of Australia. A process of continual development and review (in an evolving cycle) was followed. The Bank initially developed the model, based on South African conditions and data, whereafter staff from the above-mentioned central banks visited the Bank to review the technicalities of the model and to make recommendations. The Bank then developed and refined the model further. This process was repeated a number of times.

Several experts conducted a peer review of the core model in 2005 and 2006. Modellers from the Centre for Central Bank Studies at the Bank of England, the National Institute of Economic Policy Research in London and a panel of South African academics from the Universities of Johannesburg, the Free State, Pretoria, North West, Stellenbosch and KwaZulu-Natal formed part of the review process. From this, it is evident that the core model has been undergoing a number of rigorous reviews since its development commenced. The recommendations and suggestions made by all the reviewers were constructive and assisted the Bank in improving the properties of the core model. However, some suggestions could not be incorporated in the model as certain statistical tests were not satisfied. The peer reviews also confirmed that the modelling standard at the Bank is in line with conventional international practice for estimated structural models.

In developing a model, a balance is needed between the desire to incorporate a large number of variables and equations in the model and to keep the overall structure relatively uncomplicated. The number of equations must be sufficient to generate forecasts of key economic variables and analyse economic developments, but at the same time the model needs to remain transparent and ensure simplicity of operation. The current features of the model are conditioned on the requirements of pursuing monetary policy under an inflation-targeting framework. Broadly speaking, the core model should provide a reasonable representation of the South African economy. Furthermore, the set of equations describing the economy should enable the preparation of internally consistent forecasts (i.e. true structural interdependencies) and externally consistent forecasts (i.e. reflecting the actual course of macro processes in the South African economy). In addition, the model's structure should also allow information from outside the model (i.e. expert judgement) to be incorporated.

The forecasting cycle for the MPC meeting begins approximately five to six weeks before the scheduled MPC meeting. Data are updated and the current state of the domestic and international economy is analysed and interpreted. In producing the forecast, the knowledge and experience of internal and external sources are used. Where there are external agencies with greater expertise than the Bank producing forecasts for some exogenous variables (such as world economic growth, global inflation, and government consumption expenditure) the Bank will, in most cases, incorporate the forecasts from these agencies.

The members of the MPC then finalise the assumptions and request alternative scenarios, if deemed necessary, at a special assumptions meeting. Once these assumptions are finalised, a forecast over an 8-to-12-quarter horizon (depending on the available number of quarters of actual data) is produced. Alternative simulations highlight the significance of the transmission channels and the impulse responses to shocks.

The current core model consists of 18 structural equations and a number of identities to complete the model. It uses highly aggregated data and broadly describes the economic processes in South Africa. The major building blocks of the model describe the price formation process (inflation) and exchange rate, gross domestic product (GDP) and its expenditure components, wages, employment, the external sector and interest rates. The repurchase rate is assumed exogenous in forecasting, but in alternative simulation exercises a Taylor-type rule is used, based on equal weights assigned to the output gap and deviation from the inflation target. Government policy is treated as exogenous for forecasting purposes and is obtained from the annual *Medium Term Budget Policy Statement* and the annual Budget Speech of the Minister of Finance.

The structure of the core model incorporates both a long-run equilibrium based on economic theory and historical relationships, and short-run dynamics that allow the economy to gravitate towards its long-run equilibrium. The core model thus falls in the category described by Pagan (2003) as a medium-sized Type II hybrid model, i.e. where the long-run equilibrium component is explicitly modelled.

Table 1 Summary of the model structure*

Model structure	Core model
Supply side.....	Small Cobb-Douglas production function model used to determine potential growth over the forecast horizon
Demand side	Modelled according to national accounts: Consumption, capital formation, imports and exports
Inflation.....	Model a number of price indices: CPIX, GDP deflator, PPI, inflation expectations, export and import deflators. Inflation is modelled based on cost-push theory
Monetary policy – transmission channels	
- Interest rate.....	Modelled to reflect cost of credit
- Exchange rate.....	NEER modelled consistent with the theory of PPP REER modelled consistent with UIP
- Asset.....	Currently broad money supply (M3) used as proxy (improvement pending)
Fiscal policy	Obtained from the annual Budget or MTBPS
Monetary policy rule.....	Specified exogenous in forecasting; Taylor-type rule used in alternative simulation analysis
* CPIX = consumer price index for metropolitan and other urban areas, excluding mortgage interest cost; PPI = production price index; GDP = gross domestic product; NEER = nominal effective exchange rate of the rand; REER = real effective exchange rate of the rand; PPP = purchasing power parity; UIP = uncovered interest parity; MTBPS = <i>Medium Term Budget Policy Statement</i>	

Changes are continuously observed in the economy and subsequently new theories, methods and modelling techniques are developed. Therefore, models are constantly updated and no model version should be considered as final. This paper describes the core model of the Bank as at December 2006. Section 1.2 describes the estimation techniques, forecasting and simulation methods used. The theoretical structure of the model is highlighted in Section 1.3. Section 2 presents a review of the model's key stochastic equations. The simulation analysis is dealt with in Section 3. Section 4 concludes the paper.

1.2 Estimation techniques, forecasting and simulation methods

The core model, based on official seasonally adjusted quarterly data, broadly covers the period from 1978 to 2005, depending on the estimation period for each structural equation. A co-integration estimation approach with a long-run equilibrium path and short-run dynamic path is distinguished. Each individual stochastic equation is estimated separately. Some coefficients are restricted according to economic priors, i.e. certain homogeneity constraints are set (Westaway, 1999). Constraints to coefficients were set only after the coefficients were estimated without any restriction before testing whether the deemed constraint was in accordance with the data. Homogeneity ensures neutrality in the model, i.e. price level neutrality (by imposing static homogeneity) ensures that the long-run growth path is independent of the price level, whereas inflation neutrality (by imposing dynamic homogeneity) ensures that the long-run level of output is independent of the inflation rate. It also ensures that inflation expectations are constrained to converge on actual inflation in the long run. The short-run dynamics are estimated to match average historical behaviour. Impulse responses are analysed for each explanatory variable of every equation to monitor the magnitude and pace at which the variables return to equilibrium.

A large battery of diagnostic tests is performed on each equation. These diagnostic tests include tests to evaluate the distribution of the residual, validate coefficient restrictions, assess parameter stability and to identify structural breaks. Stationarity and cointegration tests are also performed.

All individual equations are then combined in a model structure and jointly subjected to tests to validate the model's structure. Various shocks are imposed on the full model to analyse the dynamic impact. The overall model properties override individual equation properties and equations will subsequently be adjusted to improve the overall model performance. Once the model properties are validated, the model is implemented in the MPC forecasting processes.

Expert judgement is used during forecasting by modifying the add factors and incorporating available off-model information. The model accuracy, structure and use of off-model expert knowledge are checked regularly.

The model is also used for alternative scenarios, i.e. where the model is first simulated over the forecast horizon to produce a baseline forecast (considered as the most probable future outcome). Then an alternative path for one or more variables is set in accordance with requests from the MPC and a simulation conditional on these variables is run. No other changes to the model or expert judgements are made so that the outcome is a reflection of all the model multipliers.

1.3 Overall theoretical aspects of the model

In the short run, aggregate demand, i.e. final consumption expenditure by households, capital formation, government consumption expenditure, and imports and exports, determines the economic growth path. In the long run, supply-side factors determine the economic growth rate.

Households participate in the economic process by selling their labour and receiving income in the form of remuneration as well as interest and dividend payments and transfers from government. They pay taxes on their income received and use their disposable income to buy goods and services and to accumulate wealth.

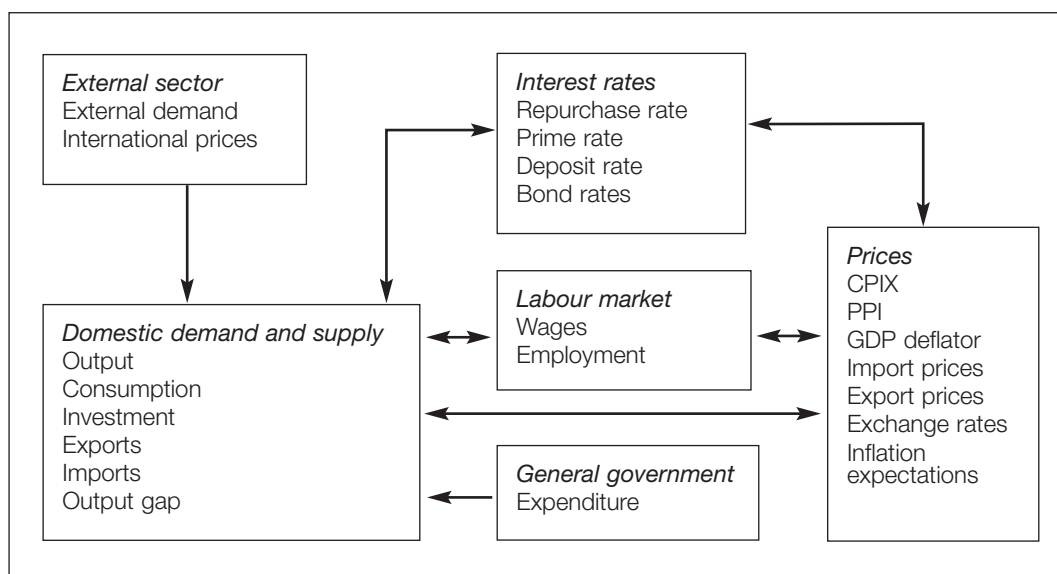
Business enterprises produce goods and services, which they sell in the domestic and global market. They use production factors, i.e. capital and labour, in the production process. They also pay taxes and make investment decisions.

Government spends revenue on consumer goods and services, and also undertakes investment. It receives taxes and makes transfer payments. Government income and expenditure as published in the annual Budget and *Medium Term Budget Policy Statement* are taken as given. The central bank controls the level of the official nominal short-term interest rate in order to meet the inflation target.

Financial intermediaries constitute an element of the transmission channel of monetary policy through their interest rates on loans and deposits.

The external sector contributes to the transmission mechanism through countries that provide goods and services to South Africa and are, in turn, buyers of manufactured goods, commodities and services produced domestically.

Figure 1 Simplified diagram of interdependencies between variables in the model



Impulse response: Change in EMPLO5

t	SALAV5 (+1%)	CPIXMD (+1%)	GDPMP6 (+1%)
1	-0.18549%	0.18584%	0.26566%
4	-0.43444%	0.43634%	0.49167%
8	-0.65072%	0.65498%	0.68888%
LR	-0.98971%	0.99960%	0.99964%

List of variables

CPIXMD	=	Consumer price index, excluding the interest cost on mortgage bonds (2000 = 1)
EMPLO5	=	Employment in the formal non-agricultural sector (number of people)
GDPMP6	=	Gross domestic product at constant 2000 market prices
SALAV5	=	Average remuneration per worker at current prices
DUM03Q1Q2	=	Dummy to account for outliers (2003Q1 = 1, 2003Q2 = 1)
DUM05Q1	=	Dummy to account for outliers (2005Q1 = 1)
DUMEM2	=	Dummy to account for outliers (1995Q2 = 1, 1995Q4 = -1)

2.1.2 Demand side

2.1.2.1 Consumption expenditure

Friedman's permanent income hypothesis, which postulates the proportionality between permanent consumption and permanent disposable income, is the foundation for the final consumption expenditure by households (Friedman, 1957). In the model, real personal disposable income is considered as the long-run determinant of final consumption expenditure and represents a combination of both permanent and transitory income, i.e. remuneration of employees is considered a more permanent type of income while the income from property of households reflects more the characteristics of temporary or transitory income. Transfer payments and receipts, adjusted for current taxes on income and wealth, are also included.

Another long-run determinant of real final consumption expenditure of households in the model is real net wealth. The difference between real household assets (fixed assets, financial assets, shares and interest in pension funds) and real household debt (total consumer credit and mortgage advances to households) is currently used as a proxy for real net wealth. Ideally, a more appropriate measure of financial and tangible wealth is desirable and further research on this measure is in progress.

A further long-run determinant of real consumption expenditure by households is the real interest rate, which portrays the trade-off between current and future consumption expenditure. Apart from the increased cost of consumption, the increase in the rate of return on accumulated savings also increases the opportunity costs associated with current consumption expenditure. The inverse relationship between the real interest rate and real private consumption expenditure of households suitably illustrates the so-called "substitution effect" between current and future consumption through the interest rate.

$$\begin{aligned} \Delta \ln \text{FCEHH6} = & [- 0.1097 (\ln \text{FCEHH6}_{-1} - 0.8 \ln \text{PDINC6}_{-1} - 0.2 \ln \text{WEALTH}_{-1}) \\ & (-3.62) \\ & - 0.0006 (\text{PRIMEI}_{-2} - \text{CPIXMR}_{-2}) + 0.1165 \\ & (-3.66) \qquad \qquad \qquad (3.92) \\ & + 0.0410 \Delta \ln \text{WEALTH} + 0.1143 \Delta \ln \text{PDINC6} \\ & (1.90) \qquad \qquad \qquad (3.86) \\ & - 0.0134 \text{DUM9192} - 0.0155 \text{DUM85Q2Q4} \\ & (-6.40) \qquad \qquad \qquad (-3.96) \end{aligned}$$

Adjusted R ²	=	0.50212
Equation standard error	=	0.00548
Sample size	=	83 (1985Q2 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.08159 (4)

Impulse response: Change in FCEHH6

t	PDINC6 (+1%)	WEALTH (+1%)	PRIMEI (+1)	CPIXMR (+1)
1	0.11378%	0.04078%	0.00000%	0.00000%
4	0.31494%	0.08736%	-0.10822%	0.10834%
8	0.49462%	0.12891%	-0.26182%	0.26251%
LR	0.79915%	0.19919%	-0.52099%	0.52372%

List of variables

CPIXMR	=	Consumer price inflation rate, excluding mortgage interest cost
FCEHH6	=	Final consumption expenditure by households at constant 2000 prices
PDINC6	=	Personal disposable income at constant 2000 prices
PRIMEI	=	Prime overdraft rate
WEALTH	=	Real net wealth
DUM85Q2Q4	=	Dummy to account for outliers (1985Q2 = 1, 1985Q4 = 1)
DUM9192	=	Dummy to account for outliers (1991Q1 to 1992Q4 = 1)

2.1.2.2 Investment

The long-run specification of private fixed capital formation essentially incorporates the neo-classical theory of investment (Jorgenson, 1963). For parsimony, the core model specification does not include all tax considerations and uncertainty.

Shapiro (1986) points out that the neoclassical theory of investment considers output as the consequence and not the cause of firms' choice of capital stock and other factors. Two possible reasons for the absence of capital stock in the long run of the investment equation are measurement difficulties and aggregation, i.e. where firm-level analyses do not necessarily hold when aggregated. Despite the availability of reliable data on capital stock, the test statistics failed the set minimum criteria for inclusion of capital stock in the long run of the equation.

The main determinants of private fixed capital formation in the model are the level of GDP, the user cost of capital³ and a proxy for financial-market developments. The inclusion of a proxy for financial-market developments captures the suggestion that improved access to financial markets contributes to growth through its effect on the level of investment. As no measure of financial-market development is readily available, a smoothed measure of trade openness, i.e. the ratio of real import and export volumes to real GDP, is used as a proxy for financial-market development and access to global financial markets.

$$\begin{aligned} \Delta \ln \text{GFCFP}_6 = & \left[-0.1551 (\ln \text{GFCFP}_{6,-1} - \ln \text{GDPMP}_{6,-1}) - 0.0026 (\text{UCC}_{6\text{RSC}}) \right. \\ & \quad (-6.29) \qquad \qquad \qquad (-2.75) \\ & \quad \left. + 0.2547 ((\text{OPENN}_{-1} + \text{OPENN}_{-2})/2) \right] - 0.4439 \\ & \quad (5.37) \qquad \qquad \qquad (-6.48) \\ & \quad + 1.6880 \Delta \ln \text{GDPMP}_{6,-1} + 0.6712 \Delta \ln \text{CAPSP}_6 + 0.0519 \Delta \ln \text{GFCFC}_{6,-1} \\ & \quad (5.99) \qquad \qquad (2.16) \qquad \qquad (2.12) \\ & \quad + 0.1170 \text{DUM}_{83\text{Q}1} + 0.0973 \text{DUM}_{83\text{Q}4} - 0.1255 \text{DUM}_{86\text{Q}1\text{Q}4} \\ & \quad (5.12) \qquad \qquad (4.43) \qquad \qquad (-8.03) \end{aligned}$$

Adjusted R ²	=	0.60859
Equation standard error	=	0.02093
Sample size	=	99 (1981Q2 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.02991 (4)

³ The user cost of capital summarises the impact of changes in the interest rate, the prices of capital goods and tax rates in a single variable.

Impulse response: Change in GFCFP6

t	GDPMP6 (+1%)	UCC6RSC (+1)	OPENN (+1%)	CAPSP6 (+1%)	GFCFC6 (+1%)
1	0.00000%	0.00000%	0.00000%	0.67015%	0.00000%
4	1.60663%	-0.66748%	0.23021%	0.40360%	0.03688%
8	1.30863%	-1.16198%	0.40689%	0.20543%	0.01879%
LR	1.00000%	-1.67303%	0.88855%	0.00000%	0.00000%

List of variables

CAPSP6	=	Fixed capital stock of private business enterprises at constant 2000 prices
GDPMP6	=	Gross domestic product at constant 2000 market prices
GFCFC6	=	Gross fixed capital formation by public corporations at constant 2000 prices
GFCFP6	=	Gross fixed capital formation by private business enterprises at constant 2000 prices
OPENN	=	Openness ((real imports + real exports)/real GDP)
UCC6RSC	=	Real user cost of capital
DUM83Q1	=	Dummy to account for outliers (1983Q1 = 1)
DUM83Q4	=	Dummy to account for outliers (1983Q4 = 1)
DUM86Q1Q4	=	Dummy to account for outliers (1986Q1 = 1, 1986Q4 = 1)

2.2 Prices and costs

2.2.1 Consumer prices

The consumer price index excluding the interest cost on mortgage bonds for metropolitan and other urban areas (hereafter referred to as CPIX), is the official measure of the inflation target set for monetary policy formulation purposes. CPIX is only officially available from January 1997 and is published on a monthly basis by Statistics South Africa. A proxy for CPIX prior to 1997 was calculated by extrapolating backwards, using the index for mortgage rates in the consumer price index, and then excluding this component from the total CPI.

A weighted combination of domestic output prices and import prices explains consumer prices, excluding mortgage interest cost and administered prices. The deflator for GDP is a proxy for domestic output prices and reflects a measure of prices in the goods and services sectors. The gap between actual domestic demand and potential domestic demand is an indicator of capacity constraints.

Despite the number of price-regulated products declining over time, the weight of administered prices in CPIX is still approximately 20 per cent. Prices of products regulated by special legislation, such as electricity, petrol and transport costs, have a significant effect on the prices of other products. The administered prices are set exogenously⁴ in the model and added to calculate CPIX.

⁴ The assumption regarding administered prices is obtained from a separate disaggregated inflation model, where the individual components of CPIX are modelled and forecasted. The prices of regulated products are then added with appropriate weights to calculate administered prices to be incorporated in the core model.

$$\begin{aligned}
 \Delta \ln \text{CPIXAMD} = & \left[\underset{(-2.14)}{-0.0317} (\ln \text{CPIXAMD}_{-1} - 0.1 \ln \text{IMPOTHD}_{-1} - 0.9 \ln \text{GDPMPD}_{-1}) \right] + \underset{(2.31)}{0.0027} \\
 & + \underset{(1.42)}{0.0004} \Delta \text{DDGAPR} + \underset{(12.92)}{0.6099} \Delta \ln \text{CPIXAMD}_{-1} + \underset{(7.46)}{0.3793} \Delta \ln \text{PPIIND} \\
 & + (1 - 0.3793 - 0.6099) \Delta \ln \text{IMPOTHD} + \underset{(3.63)}{0.0264} \text{DUM87Q4} - \underset{(-2.24)}{0.0159} \text{DUM04Q2} \\
 & - \underset{(-2.14)}{0.0153} \text{DUM05Q2} - \underset{(-2.29)}{0.0163} \text{DUM96Q2}
 \end{aligned}$$

Adjusted R ²	=	0.97559
Equation standard error	=	0.00701
Sample size	=	109 (1978Q4 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.24397 (4)

Impulse response: Change in CPIXAMD

t	IMPOTHD (+1%)	GDPMPD (+1%)	DDGAPR (+1)	PPIIND (+1%)
1	0.01079%	0.00000%	0.04110%	0.37813%
4	0.03571%	0.12663%	0.08245%	0.75984%
8	0.05770%	0.35000%	0.07184%	0.66173%
LR	0.09955%	0.89953%	0.00000%	0.00000%

List of variables

CPIXAMD	=	Consumer price index, excluding mortgage interest cost and administered prices (2000 = 1)
DDGAPR	=	Demand gap
GDPMPD	=	Deflator for gross domestic product
IMPOTHD	=	Deflator for non-oil imports
PPIIND	=	Production price index (2000 = 1)
DUM87Q4	=	Dummy to account for outliers (1987Q4 = 1)
DUM96Q2	=	Dummy to account for outliers (1996Q2 = 1)
DUM04Q2	=	Dummy to account for outliers (2004Q2 = 1)
DUM05Q2	=	Dummy to account for outliers (2005Q2 = 1)

2.2.2 Production price index

The price-formation process in the model postulates that output prices are in essence determined as a mark-up over costs, in which labour costs are an important cost factor. In the model, changes in wage rates incorporate changes in the average productivity of labour. In the short run, changes in wage rates are likely to dominate changes in productivity levels.

A weighted combination of unit labour cost and import prices explains movements in production prices. Unit labour cost is by definition the ratio of total compensation of employees to the real GDP at market prices.

The imported component of the overall production price index is currently about 27 per cent and thus exerts a significant impact on price pressures in the domestic economy. The high correlation between exchange rate fluctuations and the volatility in production prices confirms the susceptibility of domestic prices to exchange rate movements.

The degree of utilisation of available resources is an important concept in assessing economic activity. The gap between the actual GDP and the potential GDP (the output gap), is an indicator of the pressure on prices exerted by the surplus or shortfall of available resources in the production process.

$$\begin{aligned}
 \Delta \ln \text{PPIIND} = & \left[\underset{(-3.36)}{-0.0632} (\ln \text{PPIIND}_{-1} - 0.73 \ln \text{ULCSTD}_{-1} - 0.27 \ln \text{IMPTTD}_{-1}) \right] + \underset{(3.11)}{0.0347} \\
 & + \underset{(4.74)}{0.3162} \Delta \ln \text{ULCSTD} + (1 - 0.3162 - 0.3360 - 0.1454) \Delta \ln \text{ULCSTD}_{-1} \\
 & + \underset{(4.37)}{0.3360} \Delta \ln \text{PPIIND}_{-1} + \underset{(3.22)}{0.0059} \Delta \text{GDGAPR}_{-1} + \underset{(5.91)}{0.1454} \Delta \ln \text{IMPTTD} \\
 & + \underset{(5.27)}{0.0371} \text{DUM90Q4} + \underset{(3.58)}{0.0260} \text{DUM02Q1}
 \end{aligned}$$

Adjusted R ²	=	0.85135
Equation standard error	=	0.00678
Sample size	=	64 (1990Q1 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.11620 (4)

Impulse response: Change in PPIIND

t	ULCSTD (+1%)	IMPPTD (+1%)	GDGAPR (+1)
1	0.31516%	0.14479%	0.00000%
4	0.80471%	0.23524%	0.76336%
8	0.79699%	0.24972%	0.53578%
LR	0.72922%	0.26896%	0.00155%

List of variables

GDGAPR	=	Output gap
IMPPTD	=	Deflator for total imports
PPIIND	=	Production price index (2000 = 1)
ULCSTD	=	Unit labour cost (cost of labour per unit of production)
DUM90Q4	=	Dummy to account for outliers (1990Q4 = 1)
DUM02Q1	=	Dummy to account for outliers (2002Q1 = 1)

2.2.3 Gross domestic product deflator

Movements in the production price index are used to explain movements in the deflator for gross domestic product under the assumption of unit elasticity, i.e. a one-to-one link between changes in the GDP deflator and changes in production prices is assumed.

$$\Delta \ln \text{GDPMPD} = [-0.0335 (\ln \text{GDPMPD}_{-1} - \ln \text{PPIIND}_{-1})] + 0.0045 + 0.3287 \Delta \ln \text{PPIIND} \\ \quad \quad \quad (-2.16) \quad \quad \quad (2.75) \quad \quad (3.05) \\ + (1 - 0.3287) \Delta \ln \text{PPIIND}_{-1} - 0.0368 \text{DUM94Q3} - 0.0321 \text{DUM02Q2Q3} \\ \quad \quad \quad \quad \quad \quad (-3.59) \quad \quad \quad \quad \quad \quad (-4.25)$$

Adjusted R ²	=	0.42724
Equation standard error	=	0.01011
Sample size	=	64 (1990Q1 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.77427 (4)

Impulse response: Change in GDPMPD

t	PPIIND (+1%)
1	0.32757%
4	1.02113%
8	1.01843%
LR	1.00283%

List of variables

GDPMPD	=	Deflator for gross domestic product
PPIIND	=	Production price index (2000 = 1)
DUM94Q3	=	Dummy to account for outliers (1994Q3 = 1)
DUM02Q2Q3	=	Dummy to account for outliers (2002Q2 = 1, 2002Q3 = 1)

2.2.4 Wages

The wage equation incorporates the original ideas of Phillips (the natural rate of unemployment hypothesis of Phillips, 1958) and inflation expectations (according to the later insights of Friedman, 1968, and Phelps, 1968), i.e. the so-called expectations-augmented Phillips curve. This generally indicates that employees' remuneration reflects productivity improvements and inflation expectations.

$$\begin{aligned} \Delta \text{INFEXPR} = & [-0.1516 (\text{INFEXPR}_{-1} - 0.8 (\text{CPIXMR}_{-1} + \text{CPIXMR}_{-2})/2 - 0.2 \text{TARGINFR}_{-1})] \\ & (-4.35) \\ & - 0.2224 + 0.3043 \Delta \text{CPIXMR} + 0.6600 \Delta \text{INFEXPR}_{-1} \\ & (-1.86) \quad (9.35) \quad (19.67) \\ & + 0.0329 (\ln \frac{\text{M3MON5}_{-1}}{\text{GDPMP6}_{-1}} - \ln \frac{\text{M3MON5}_{-5}}{\text{GDPMP6}_{-5}}) \cdot 100 + (1 - 0.3043 - 0.6600 - 0.0329) \\ & (-3.09) \\ & \cdot (\ln (\text{OILPDD} \cdot \text{EXDOLLD}) - \ln (\text{OILPDD}_{-4} \cdot \text{EXDOLLD}_{-4})) \cdot 100 \end{aligned}$$

Adjusted R ²	=	0.99983
Equation standard error	=	0.35905
Sample size	=	77 (1986Q4 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.14468 (4)

Impulse response: Change in INFEXPR

t	CPIXMR (+1)	TARGINFR (+1)	M3MON5 (+1%)	GDPMP6 (+1%)	OILPDD (+1%)	EXDOLLD (+1%)
1	0.30428	0.00000	0.00000	0.00000	0.00286	0.00286
4	0.84064	0.12506	0.13480	-0.13480	0.01589	0.01589
8	0.93602	0.23487	0.11837	-0.11837	0.00640	0.00640
LR	0.80000	0.20000	0.00000	0.00000	0.00000	0.00000

List of variables

CPIXMR	=	Consumer price inflation rate, excluding mortgage interest cost
EXDOLLD	=	Rand/dollar exchange rate
GDPMP6	=	Gross domestic product at constant 2000 market prices
INFEXPR	=	Inflation expectations rate
M3MON5	=	Nominal M3 money supply
OILPDD	=	Oil price in dollars (2000 = 1)
TARGINFR	=	Target rate for CPIXMR (consumer price inflation, excluding mortgage interest cost)

2.3 Monetary policy transmission channels

2.3.1 Exchange rate

For forecasting purposes, the real effective exchange rate is set exogenously. However, when simulating alternative scenarios, it is set endogenously.

A number of theories endeavour to explain exchange rate movements. According to the theory of uncovered interest parity (UIP), the interest rate differential between trading countries is considered a useful predictor of changes in the exchange rate, that is if the conditions of rational expectations and risk neutrality are satisfied.

Movements in the real effective exchange rate equation are explained in the long run by UIP conditions, while the dynamic short-run adjustments are obtained through terms of trade conditions and a measure of market risk. UIP is defined as the differential between the real domestic prime interest rate and the real prime interest rate in the United States of America (as a proxy for world interest rates). The terms of trade is defined as the ratio of export prices to import prices. Changes in the reserve position are used as a proxy for market risk.

$$\begin{aligned} \Delta \ln \text{EXREALD} = & [-0.2043 \ln \text{EXREALD}_{-1} + 0.0010 ((\text{PRIMEI}_{-1} - \text{PPIINR}_{-1}) - (\text{USRPRMI}_{-1} - \text{FORINF}_{-1}))] \\ & (-3.99) \qquad (1.64) \\ & + 0.9691 + 0.0011 \Delta \text{TTRADE}_{-1} + 0.3080 \Delta \frac{\text{CHRES5}_{-1}}{\text{GDPMP5}_{-1}} \\ & (4.00) \qquad (1.44) \qquad (2.25) \\ & + 0.0063 (\Delta \text{PRIMEI} - \Delta \text{PPIINR} - \Delta \text{USPRMI} + \Delta \text{FORINF}) - 0.1745 \text{DUM98Q3} \\ & (2.75) \qquad (5.00) \\ & - 0.0327 \text{DUM99Q2} - 0.1398 \text{DUM01Q4} - 0.0829 \text{DUM02Q1} \\ & (-2.38) \qquad (-4.13) \qquad (-2.33) \end{aligned}$$

Adjusted R ²	=	0.52684
Equation standard error	=	0.03224
Sample size	=	79 (1986Q2 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.15676 (4)

Impulse response: Change in EXREALD

t	PRIMEI (+1)	PPIINR (+1)	USPRMI (+1)	FORINF (+1)	CHRES5 (+1000)	GDPMP5 (+1%)	TTRADE (+1%)
1	0.63650%	-0.63247%	-0.63247%	0.63650%	0.00000%	0.00000%	0.00000%
4	0.55868%	-0.55558%	-0.55558%	0.55868%	0.45485%	-0.01602%	0.08612%
8	0.51138%	-0.50878%	-0.50878%	0.51138%	0.09455%	0.00887%	0.02615%
LR	0.47975%	-0.47746%	-0.47746%	0.47975%	-0.01089%	0.00134%	0.00010%

List of variables

CHRES5	=	Change in foreign reserves
EXREALD	=	Real effective exchange rate of the rand
FORINF	=	Foreign inflation rate (percentage change in the weighted combined index of foreign wholesale prices)
PPIINR	=	Production price inflation rate
PRIMEI	=	Prime overdraft rate
TTRADE	=	Terms of trade
USPRMI	=	Prime overdraft rate in the USA
GDPMP5	=	Gross domestic product at current market prices
DUM98Q3	=	Dummy to account for outliers (1998Q3 = 1)
DUM99Q2	=	Dummy to account for outliers (1999Q1 to 2002Q4 = 1)
DUM01Q4	=	Dummy to account for outliers (2001Q4 = 1)
DUM02Q1	=	Dummy to account for outliers (2002Q1 = 1)

Both the effective and rand/dollar exchange rates are modelled to strengthen the analytical abilities of the model. The rand/dollar exchange rate relates to the nominal effective exchange rate to facilitate parsimonious and stable adjustment of the exchange rate channel in the model.

2.3.2 Interest rates

The prime overdraft rate is an important money-market interest rate and is a benchmark rate at which a bank will lend money to a fairly low-risk individual or business enterprise (i.e. in the form of an overdraft facility). Since February 1982, commercial banks have been allowed a greater degree of freedom in determining their overdraft rates independently of the official central bank rate, but these rates still broadly track the official rate. The differential between the official rate and the prime overdraft rate has remained fairly stable within a range of 3,0 to 3,5 percentage points. A long-run elasticity restriction of one with regard to the repurchase rate, where changes in the prime rate follow changes in the repurchase rate on a one-to-one basis, is confirmed by the data.

$$\begin{aligned} \Delta \text{PRIMEI} = & \left[-0.1786 (\text{PRIMEI}_{-1} - \text{REPORI}_{-1}) \right] + 0.5940 + 0.9364 \Delta \text{REPORI} \\ & \quad (-3.30) \quad \quad \quad (3.36) \quad \quad (56.36) \\ & + 0.0594 \Delta \text{REPORI}_{-1} - 0.5810 \text{DUM87Q1} + 0.4534 \text{DUM96Q2Q3} \\ & \quad (3.68) \quad \quad (-4.01) \quad \quad (4.42) \\ & - 1.0554 \text{DUM98Q2Q3} + 0.5778 \text{DUM01Q4} \\ & \quad (-9.77) \quad \quad (3.90) \end{aligned}$$

Adjusted R ²	=	0.98592
Equation standard error	=	0.14344
Sample size	=	87 (1984Q2 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.12137 (4)

Impulse response: Change in PRIMEI

t	REPORI (+1)
1	0.93636
4	1.00483
8	1.00220
LR	1.00000

List of variables

PRIMEI	=	Prime overdraft rate
REPORI	=	Repo rate from March 1998, previously the Bank rate
DUM87Q1	=	Dummy to account for outliers (1987Q1 = 1)
DUM96Q2Q3	=	Dummy to account for outliers (1996Q2 = 1, 1996Q3 = -1)
DUM98Q2Q3	=	Dummy to account for outliers (1998Q2 = 1, 1998Q3 = -1)
DUM01Q4	=	Dummy to account for outliers (2001Q4 = 1)

The deposit rate of clearing banks used in the model represents a weighted average of short-term, medium-term and long-term deposit rates. The longer the term of investment, the higher the risk associated with investing in such an instrument. The interest rate structure of deposits with different maturities reflects these differences in risk profiles. Deposit interest rates are modelled to respond to changes in the prime overdraft rate.

$$\begin{aligned} \Delta \text{DEPOSI} = & \left[-0.1857 \text{DEPOSI}_{-1} + 0.1409 \text{PRIMEI}_{-1} \right] - 0.2054 + 0.9240 \Delta \text{PRIMEI} \\ & \quad (-2.21) \quad \quad (1.72) \quad \quad (-0.49) \quad \quad (21.87) \end{aligned}$$

Adjusted R ²	=	0.92218
Equation standard error	=	0.30607
Sample size	=	56 (1992Q1 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.68863 (4)

Impulse response: Change in DEPOSI

t	PRIMEI (+1)
1	0.92399
4	0.84796
8	0.79795
LR	0.75871

List of variables

DEPOSI	=	Deposit rate (a weighted average of short-term, medium-term and long-term deposit rates)
PRIMEI	=	Prime overdraft rate

The capital market is the market for lending and borrowing long-term funds. The major issuers of securities in the capital market are the central government of South Africa, public corporations, public enterprises, local authorities and private companies. The main purchasers of these securities include the Public Investment Corporation, insurance companies, pension funds and non-residents. The yield on one category of fixed-interest securities, namely long-term government bonds, is used as a proxy for capital-market rates in the model. Inflation expectations and expectations of prospective changes in the monetary policy stance play a prominent role in the determination of capital-market yields.

$$\Delta\text{LBONDI} = \begin{matrix} [-0.0619 (\text{LBONDI}_{-1} - \text{REPORI}_{-2}) - 0.0283 + 0.3292 \Delta\text{REPORI} + 0.1158 \Delta\text{CPIXMR} \\ (-2.21) & & (-0.38) & (5.11) & (1.73) \\ - 1.5523 \text{DUM86Q3} + 1.7681 \text{DUM94Q2Q3} \\ (-2.13) & & (3.55) \end{matrix}$$

Adjusted R ²	=	0.33110
Equation standard error	=	0.69549
Sample size	=	93 (1982Q4 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.74836 (4)

Impulse response: Change in LBONDI

t	REPORI (+1)	CPIXMR (+1)
1	0.32924	0.11577
4	0.39174	0.09559
8	0.52885	0.07404
LR	0.99779	0.00035

List of variables

CPIXMR	=	Consumer price inflation rate, excluding mortgage interest cost
LBONDI	=	Yield on government stock with maturity exceeding 10 years
REPORI	=	Repo rate from March 1998, previously the Bank rate
DUM86Q3	=	Dummy to account for outliers (1986Q3 = 1)
DUM94Q2Q3	=	Dummy to account for outliers (1994Q2 = 1, 1994Q3 = 1)

2.3.3 Money supply

The literature on the demand for money indicates that in the long run, real money balances depend on a scale variable for transaction purposes, and on an interest rate representing the opportunity cost of holding money balances. The M3 money supply relative to the CPIX defines the real M3 money supply in the core model.

Real aggregate output (GDP) is a proxy for the transactions motive related to money demand and is constrained to unit elasticity. The yield on government bonds with maturities exceeding 10 years is used as an indicator of the yield on substitute assets and, to some extent, incorporates expectations about the opportunity cost of holding money balances, i.e. inflation expectations.

To capture the effect of disintermediation and reintermediation, the interest rate differential between the prime overdraft rate and the deposit rate (as an own interest rate) is used.

The wealth-eroding impact of inflation led to the inclusion of inflation to represent the opportunity cost of holding money. When inflation starts to rise, investors begin to hedge against inflation by considering alternative investments, i.e. by possibly transferring potentially low real-yielding deposit balances into some higher real-yielding class of asset such as shares or real estate.

$$\begin{aligned} \Delta \ln \frac{M3MON5}{CPIXMD} = & \left[-0.0549 \left(\ln \frac{M3MON5_{-1}}{CPIXMD_{-1}} - \ln GDPMP6_{-1} \right) - 0.0017 LBONDI_{-1} \right. \\ & \left. - 0.0037 (PRIMEI_{-1} - DEPOSI_{-1}) \right] + 0.1138 - 1.1363 \Delta \ln CPIXMD \\ & + 0.2275 \Delta \ln \frac{M3MON5_{-1}}{CPIXMD_{-1}} - 0.0245 DUM9313 + 0.0476 DUM2002Q1 \end{aligned}$$

(-3.07)
(-2.09)
(5.28)
(-7.04)
(2.83)
(-3.13)
(3.70)

Adjusted R ²	=	0.60833
Equation standard error	=	0.01249
Sample size	=	94 (1982Q3 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.22231 (4)

Impulse response: Change in M3MON5

t	CPIXMD (+1%)	GDPMP6 (+1%)	LBONDI (+1)	PRIMEI (+1)	DEPOSI (+1)
1	-0.13552%	0.00000%	0.00000%	0.00000%	0.00000%
4	-0.22454%	0.18145%	-0.56270%	-1.20858%	1.22337%
8	0.08876%	0.39387%	-1.21615%	-2.60218%	2.67170%
LR	0.99850%	0.99901%	-3.04680%	-6.44997%	6.89468%

List of variables

CPIXMD	=	Consumer price index, excluding mortgage interest cost (2000 = 1)
DEPOSI	=	Deposit rate (a weighted average of short-term, medium-term and long-term rates)
GDPMP6	=	Gross domestic product at constant 2000 market prices
LBONDI	=	Yield on government stock with maturity exceeding 10 years
M3MON5	=	Nominal M3 money supply
PRIMEI	=	Prime overdraft rate
DUM9313	=	Dummy to account for outliers (1993Q1 to 1993Q3 = 1)
DUM2002Q1	=	Dummy to account for outliers (2002Q1 = 1)

2.4 External sector

2.4.1 Exports

A combined index of real world GDP, as calculated by the Organisation for Economic Co-operation and Development (OECD), represents international economic developments and is used as a proxy for the international demand for South African goods and services. The country weights used in the index mirror the South African export distribution to these countries.

The real effective exchange rate of the rand (REER) is used as a proxy for relative prices. When the real effective exchange rate of the rand depreciates, it will tend to increase the export of manufactured goods, commodities, and minerals because of the increased price competitiveness of South African products.

The volume of exports of goods and services are estimated by two equations, namely one for manufactured goods and one for commodities, minerals and services to capture the different income and price elasticities.

2.4.1.1 Volume of exports of manufactured goods

The long-run price elasticity of the export demand for manufactured goods is estimated to be 0,41. The long-run elasticity of the income variable, i.e. foreign demand, is

constrained to one. This constraint is necessary to ensure long-run stability in the model (Westaway, 1999).

$$\Delta \ln \text{EXPMF6} = [-0.4500 (\ln \text{EXPMF6}_{-1} - \ln \text{WGDP}_{-1}) - 0.1836 \ln \text{EXREALD}_{-1}] + 1.2499$$

(-4.40) (2.62)

$$+ 3.9970 \Delta \ln \text{GDPMP6}_{-1} - 0.2784 \Delta \ln \text{EXREALD}$$

(2.30) (-1.83)

Adjusted R ²	=	0.37070
Equation standard error	=	0.04771
Sample size	=	38 (1996Q3 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.05091 (4)

Impulse response: Change in EXPMF6

t	WGDP (+1%)	EXREALD (+1%)	GDPMP6 (+1%)
1	0.00000%	-0.27661%	0.00000%
4	0.83292%	-0.38376%	1.21042%
8	0.98470%	-0.40318%	0.11017%
LR	1.00000%	-0.40513%	0.00000%

List of variables

EXPMF6	=	Volume of manufacturing exports
EXREALD	=	Real effective exchange rate of the rand
GDPMP6	=	Gross domestic product at constant 2000 market prices
WGDP	=	Real world GDP

2.4.1.2 Volume of commodities, minerals and services exports

The long-run price elasticity of the demand for South African commodities, minerals and services is estimated to be 0,1, indicating that the exports of commodities, minerals and services are fairly price inelastic. The long-run income elasticity is also constrained to one to ensure long-run stability in the model.

$$\Delta \ln \text{EXPCS6} = [-0.6380 (\ln \text{EXPCS6}_{-1} - \ln \text{WGDP}_{-1} + 0.1 \ln \text{EXREALD}_{-1})] + 1.4603$$

(-6.79) (6.75)

$$+ 3.7311 \Delta \ln \text{WGDP}_{-1} + 0.2132 \Delta \ln \text{FORCMD} - 0.1493 \text{DUM86Q1}$$

(2.38) (1.48) (-2.53)

$$- 0.1322 \text{DUM95Q2Q3} - 0.1314 \text{DUM93Q4} - 0.1437 \text{DUM86Q4}$$

(-3.16) (-2.24) (-2.46)

Adjusted R ²	=	0.48352
Equation standard error	=	0.05787
Sample size	=	94 (1982Q3 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.06073 (4)

Impulse response: Change in EXPCS6

t	WGDP (+1%)	EXREALD (+1%)	FORCMD (+1%)
1	0.00000%	0.00000%	0.21240%
4	1.44471%	-0.09474%	0.01007%
8	1.00762%	-0.09937%	0.00017%
LR	1.00000%	-0.09945%	0.00000%

List of variables

EXPCS6	=	Volume of commodity and services exports
EXREALD	=	Real effective exchange rate of the rand
FORCMD	=	Commodity price index (2000 = 100)
WGDP	=	Real world GDP
DUM86Q1	=	Dummy to account for outliers (1986Q1 = 1)
DUM86Q4	=	Dummy to account for outliers (1986Q4 = 1)
DUM93Q4	=	Dummy to account for outliers (1993Q4 = -1)
DUM95Q2Q3	=	Dummy to account for outliers (1995Q2 = 1, 1995Q3 = -1)

2.4.2 Imports

The import of crude oil is treated as exogenous in the model. Changes in the import of non-oil goods and services are closely related to changes in domestic demand. Proxies for income (economic activity) and relative prices are the main explanatory variables in the equation for non-oil imports.

Aggregate domestic demand, excluding the residual item in the national accounts, is used as the income variable. The ratio of the prices of imported goods and services relative to the prices of locally produced goods and services defines the relative price variable. The derived deflator for non-oil imports is an indicator of imported prices, while the derived deflator for the gross value added is a measure of domestic prices. The exchange rate does not enter the equation explicitly, but exerts its influence through the effect of exchange rate changes on the prices of imported goods.

Export volumes are included as an explanatory variable to account for programmes where goods are imported, assembled, and then exported again, such as vehicles in the Motor Industry Development Programme (MIDP). The long-run price elasticity of the demand for non-oil imports is calculated as 0,80. The income elasticity of the demand for non-oil imports is constrained to one.

$$\begin{aligned} \Delta \ln \text{IMPOTH6} = & \left[-0.1014 (\ln \text{IMPOTH6}_{-1} - \ln (\text{DODEM6}_{-1} - \text{RESIT6}_{-1})) - 0.0808 \ln \frac{\text{IMPOTHD}_{-1}}{\text{GDPMPD}_{-1}} \right] \\ & (-3.07) \qquad \qquad \qquad (-2.17) \\ & - 0.1566 + 0.9658 \Delta \ln (\text{DODEM6} - \text{RESIT6}) \\ & (-3.05) \qquad (4.28) \\ & + 0.8771 \Delta \ln (\text{DODEM6}_{-1} - \text{RESIT6}_{-1}) + 0.1510 \Delta \ln \text{EXPTT6} \\ & (4.22) \qquad \qquad \qquad (2.31) \\ & - 0.1661 \text{DUM83Q1} - 0.1361 \text{DUM86Q4} \\ & (-3.64) \qquad \qquad \qquad (-3.00) \end{aligned}$$

Adjusted R ²	=	0.41270
Equation standard error	=	0.04287
Sample size	=	104 (1980Q1 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.11951 (4)

Impulse response: Change in IMPOTH6

t	DODEM6 (+1%)	RESIT6 (+100%)	IMPOTHD (+1%)	GDPMPD(+1%)	EXPTT6 (+1%)
1	1.07406%	-0.62599%	0.00000%	0.00000%	0.15032%
4	1.97540%	-1.07525%	-0.21740%	0.21787%	0.10905%
8	1.66170%	-0.87348%	-0.41703%	0.41877%	0.07109%
LR	1.00107%	-0.29796%	-0.78999%	0.79628%	0.00000%

The dollar price of oil is exogenous in the model. The deflator for non-oil imports of goods and services is an indicator of import prices. A combined index of foreign wholesale prices, based on trade in manufactured goods between South Africa and its 13 most important trading partners, is used to proxy foreign inflation.

$$\begin{aligned} \Delta \ln \text{IMPOTHD} = & \left[-0.1422 (\ln \text{IMPOTHD}_{-1} - \ln \frac{\text{FORPRD}_{-1}}{\text{EXNOMD}_{-1}}) \right] + 0.0165 \\ & \quad (-2.21) \qquad \qquad \qquad (3.57) \\ & + 0.3738 \Delta \ln \frac{\text{FORPRD}}{\text{EXNOMD}} + 0.1248 \Delta \ln \frac{\text{FORPRD}_{-1}}{\text{EXNOMD}_{-1}} - 0.1216 \text{DUM90Q4} \\ & \quad (5.54) \qquad \qquad (1.96) \qquad \qquad \qquad (-3.71) \\ & + 0.0821 \text{DUM98Q3Q4} \\ & \quad (3.35) \end{aligned}$$

Adjusted R ²	=	0.49931
Equation standard error	=	0.03201
Sample size	=	81 (1985Q4 – 2005Q4)
Breusch-Godfrey serial correlation test	=	0.04300 (4)

Impulse response: Change in IMPOTHD

t	FORPRD (+1%)	EXNOMD (+1%)
1	0.37259%	-0.37121%
4	0.69550%	-0.69069%
8	0.83503%	-0.82811%
LR	1.00000%	-0.99010%

List of variables

EXNOMD	=	Nominal effective exchange rate of the rand
FORPRD	=	Foreign wholesale price index – i.e. a combined index based on trade in and consumption of manufactured goods between South Africa and its 13 most important trading partners (2000 = 100)
IMPOTHD	=	Deflator for non-oil imports
DUM90Q4	=	Dummy to account for outliers (1990Q4 = 1)
DUM98Q3Q4	=	Dummy to account for outliers (1998Q3 = 1, 1998Q4 = -1)

3 Simulation analysis

The system dynamics and long-run stability properties of the model are tested through simulation exercises. It is essential to determine how the model reacts to exogenous shocks and whether it returns to equilibrium values. It is also useful to determine whether the model provides a plausible outcome in terms of the transmission mechanism of monetary policy. For a more detailed explanation of the South African monetary policy transmission mechanism, see Smal and De Jager (2005).

3.1 Interest rate shock

The interest rate channel of monetary policy is verified by imposing a 100-basis-point change in the repurchase rate over four quarters and then allowing it to return to its original level. A policy model needs to reflect the monetary policy transmission mechanism. Therefore, the changes in the repurchase rate should influence the interest rates on financial products at the retail level. Soon after the Bank changes the official interest rate, domestic banks normally adjust their lending rates. Firms and individuals in general respond to the change in interest rates by altering their investment and spending patterns. As a result, consumer spending (C), fixed capital formation (I) and real output (y) start to respond. It is precisely through this channel that demand pressures feed through to changes in the output gap and then to inflation (Π). Following the simple, yet adequate, framework of Mishkin (1995), the interest rate channel is as follows:

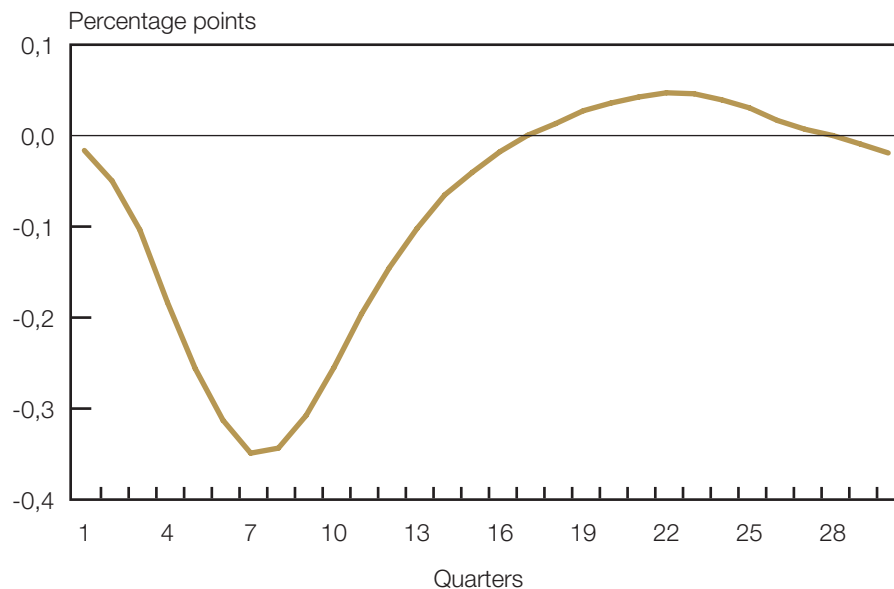
$$\uparrow \text{repo} \rightarrow \uparrow \text{interest rates} \rightarrow (\downarrow I, \downarrow C) \rightarrow \downarrow y \rightarrow \downarrow \Pi$$

Another channel through which interest rates influence the economy relates to asymmetric information in financial markets. It works, firstly, through effects on bank lending and, secondly, through effects on the balance sheets of firms and households. Certain borrowers will not have access to credit markets unless they borrow from banks. Tighter monetary policy decreases bank reserves and bank deposits, thereby decreasing the amount of loans available. This decrease in loans will cause investment and consumer spending to drop, reduce demand pressures and feed through the output gap to inflation. Schematically, this monetary policy effect is:

$$\uparrow \text{repo} \rightarrow \downarrow \text{bank deposits} \rightarrow \downarrow \text{bank loans} \rightarrow (\downarrow I, \downarrow C) \rightarrow \downarrow y \rightarrow \downarrow \Pi$$

Figure 2 illustrates the response of inflation to a 100-basis-point change in the repurchase rate, i.e. the repurchase rate is raised by 100 basis points for four quarters and then returns to its original level for the remainder of the simulation period. Inflation reacts steadily to the change in the repurchase rate and the maximum impact of about 0,35 percentage points is seen after seven quarters. Thereafter inflation gradually returns to its equilibrium level.

Figure 2 Response of inflation to a four-quarter repurchase rate increase



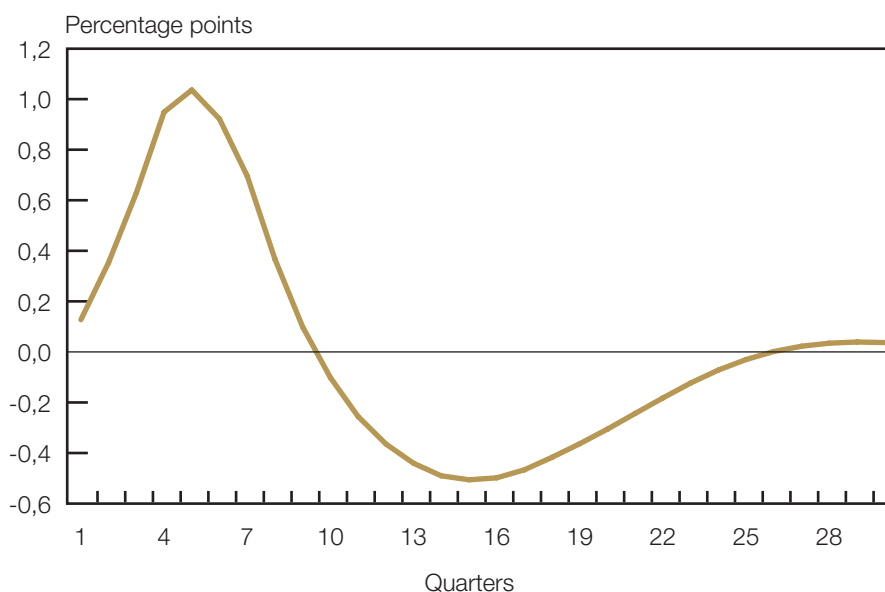
3.2 Exchange rate shock

Other relative asset prices and real wealth are also channels for transmitting monetary policy effects through the economy. Two other asset prices (foreign exchange and equities), in addition to bond prices, act as channels for the transmission of monetary effects. When South African real interest rates fall, deposits denominated in rand become less attractive than deposits denominated in foreign currencies and the rand depreciates. The lower value of the rand (ER) makes foreign goods more expensive than domestic goods, causing a rise in net exports (NX) and, consequently, in aggregate output. A further important consequence of the depreciation of the rand is that it directly increases the cost of imported goods and therefore has a negative effect on the domestic price level and hence on inflation. The schematic illustration of the exchange rate channel is:

$$\downarrow \text{repo} \rightarrow \downarrow \text{interest rates} \rightarrow \downarrow \text{ER} \rightarrow \uparrow \text{NX} \rightarrow \uparrow y \rightarrow \uparrow \Pi$$

Figure 3 shows the response of inflation to a 5-per-cent depreciation in the real effective exchange rate of the rand for four quarters and how it is then followed by a return to its baseline level. Inflation reacts quickly and the maximum impact of just over 1 percentage point on inflation is recorded after five quarters. Thereafter inflation declines to levels below those that prevailed before the change and then approaches its long-run equilibrium value.

Figure 3 Response of inflation to a four-quarter exchange rate depreciation



3.3 Accuracy analysis

Ehlers and Smal (2006) compared the accuracy and efficiency of forecasts prepared by the Bank's core model (quarterly data), ARIMA model (monthly data), disaggregated inflation model (monthly data) and the monthly *Reuters Survey*.⁵ Their analysis, covering the period 2000 to 2005, shows that CPIX inflation forecasts, including those of the Bank, were mostly upwardly biased. However, the set of errors produced by the Bank's core model was consistently smaller and less biased than that of the other forecasts. Considering the large degree of volatility in CPIX inflation as well as the other input variables in the model (i.e. the assumptions) relative to those experienced by other countries, the Bank's forecast accuracy compares favourably to those of other international forecasting agencies.

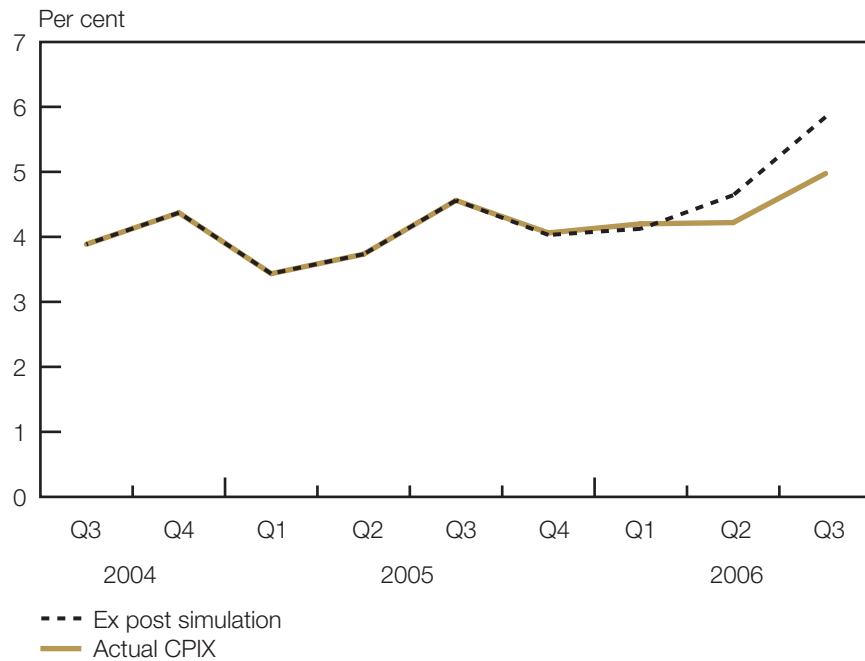
⁵ The main findings of the study were reported in Box 3 in the *Monetary Policy Review* published in November 2006.

Table 2 Comparison of the four-quarter-ahead CPIX inflation forecasts

	Core model	Reuters	ARIMA	Disaggregated
Sample size	14	22	23	23
Average forecasting error (AFE)	0,75	0,92	1,09	0,78
Mean absolute error (MAE).....	0,81	0,94	1,09	1,00
Mean square error (MSE)	1,02	1,33	1,59	1,38
Root mean square error (RMSE) ..	1,01	1,15	1,26	1,17
Theil's U-statistic	0,36	0,63	0,61	0,40

An ex post simulation was conducted where the model was simulated using the actual outcome of the exogenous assumptions and the result for CPIX was then compared with the actual CPIX outcome. As can be seen from Figure 4, the simulated outcome of CPIX tracks the actual outcome reasonably well. Ehlers and Smal (2006) indicated in their paper that the assumption on the oil price and REER of the rand has a prominent impact on the accuracy of the model forecasts.

Figure 4 Ex post simulation comparison with actual CPIX outcome



4 Conclusion

This paper describes the key stochastic equations in the current core model, based on quarterly data of the Bank. The MPC uses the model for forecasts and alternative simulations. The model performed relatively well when judged by the accuracy analysis performed early in 2006. Moreover, based on peer reviews, the model appears to be a reasonable representation of the South African economy and is broadly aligned with international best practice for estimated structural models.

The structure and theoretical foundation of the core model certainly do not guarantee successful monetary policy implementation, but its importance in illustrating the interlinkages between the key sectors and key variables in the inflationary process cannot be denied. This makes the model a useful tool in the arsenal of analytical tools at the Bank's (MPC) disposal and the process induces a more transparent environment. However, ultimately, the credibility of the monetary authority defines the effectiveness of monetary policy.

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Appendix A

Variable	Description
ADMIND	Administered prices index (2000 = 1)
CHRES5	Change in foreign reserves
CPIXAMD	Consumer price index (for metropolitan and other urban areas) excluding the interest cost on mortgage bonds and administered prices
CPIXAMR	Consumer price inflation rate (for metropolitan and other urban areas) excluding the interest cost on mortgage bonds and administered prices
CPIXMD	Consumer price index (for metropolitan and other urban areas) excluding the interest cost on mortgage bonds
CPIXMR	Consumer price inflation rate (for metropolitan and other urban areas) excluding the interest cost on mortgage bonds
DDGAPR	Domestic demand gap
DEPOSI	Deposit rate (a weighted average of short-term, medium-term and long-term deposit rates)
DODEM6	Domestic demand at constant 2000 prices
EMPLO5	Employment in the formal non-agricultural sectors
EXDOLL	Rand/dollar exchange rate
EXNOMD	Nominal effective exchange rate of the rand
EXPCS6	Volume of exports of commodities, minerals and services
EXPMF6	Volume of exports of manufactured products
EXPTT6	Volume of total exports
EXPTTD	Deflator for total exports
EXREALD	Real effective exchange rate of the rand
FCEHH6	Final consumption expenditure by households at constant 2000 prices
FORCMD	Commodity price index (2000 = 1)
FORINF	Foreign inflation rate (percentage change in the weighted combined index of foreign wholesale prices)
FORPRD	Foreign wholesale price index — combined index based on trade in manufactured goods between South Africa and its 13 most important trading partners (2000 = 100)
GDGAPR	Output gap
GDPMP6	Gross domestic product at constant 2000 market prices
GDPMPD	Deflator for gross domestic product

GFCFC6	Gross fixed capital formation by public corporations at constant 2000 prices
GFCFP6	Gross fixed capital formation by private business enterprises at constant 2000 prices
IMPOTH6	Volume of non-oil imports
IMPOTHD	Deflator for non-oil imports
IMPTTD	Deflator for total imports
INFEXPD	Inflation expectations index (2000 = 1)
INFEXPR	Inflation expectations rate
LBONDI	Yield on government bonds with maturity exceeding 10 years
M3MON5	M3 money supply
OILPDD	Oil price in dollars
OPENN	Proxy for the openness of the economy
PDINC6	Personal disposable income at constant 2000 prices
PPIIND	Production price index (2000 = 1)
PRIMEI	Prime overdraft rate
REPORI	Repurchase rate from March 1998, previously the Bank rate
RESIT6	Residual item as calculated in the national accounts
SALAV5	Average remuneration per worker
TARGINFR	Target rate for consumer price inflation, excluding mortgage interest cost
TTRADE	Terms of trade
UCC6RSC	Real user cost of capital
ULCSTD	Unit labour cost
UNEMPR	Unemployment rate
USPRMI	Prime overdraft rate in the USA
WEALTH	Real net wealth
WGDP	World GDP