Theoretical foundation for the macroeconomic model

United Nations
Economic Commission for Africa

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Instructions

This model is built using the EViews platform. To run it, an EViews program must be installed on the operator's computer. After the software has been successfully installed, the model files can be saved and opened at any time.

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I. Introduction

The Economic Commission for Africa (ECA) model has been developed to assist countries in implementing a sustainable development plan. It is characterized by a long run neoclassical supply side and a short-run Keynesian demand side.

In this model, behavioural equations are specified in a cointegration and error correction framework This is because there will be a model in a theoretically consistent manner while the short run can be modelled to fit the data, with the error correction mechanism ensuring that the system moves towards the long run in the absence of shocks. This approach will allow both policy analysis and forecasting to be encompassed in the same framework. In addition, policy variables are modelled with flexible options for discretionary policy actions, if necessary. The model has approximately 50 equations with demand- and supply-side variables. The demand side of the model is made up of the sum of the expenditure components with exports providing the global linkage. The supply side is underpinned by a general underlying production function that maps the factor inputs to final output, thereby representing the productive capacity of the economy.

II. Theoretical underpinning of the model selection

Most central banks use different models (large-scale macroeconomic model and vector autogressive (VAR) models) to achieve their objectives. The large-scale macroeconomic models possess the advantage of performing scenario analysis while VAR models offer the advantage of performing short-term forecasting. To be effective, a macroeconomic model must be efficient in producing short-term forecasting with VAR models with the long-term relationships supported by cointegration in the VAR model.

In order to ensure that countries conduct forecasting for rigorous policy analysis and formulation, an error correction model has been adopted. This model is a type of multiple time series model that estimates the speed at which a dependent variable returns to its equilibrium profile after a shock to one or more independent variables. This type of model is useful, as it estimates both the short- and long-run effects of variables on the variable in question. The model exhibits "Keynesian" features in the short run – that is, the demand side. Consequently, the factor prices are sticky and output is determined by aggregate demand, making it possible for government policy in the form of lower tax rates or higher spending to lift aggregate demand temporarily. In summary, the demand-side agents are households (consumers, savers of money and suppliers of labour and capital services to the firms); firms (producers of output and employers); Government (deviser of fiscal policy) and a central bank (implementer of monetary policy, using short-term interest-rate or exchange-rate policy).

In the long run (supply side), the model's properties are neoclassical, such that prices adjust fully, the equilibrium is determined by supply factors – productivity, labour and capital – and attempts to raise growth by boosting demand only leads to higher prices.

In summary, the model has been built to give a solid description of the historic relationship between economic variables and to capture the key linkages between those variables. Although a lot of weight is given to the fit of the model, this is not at the expense of economic theory and intuitive properties under a wide range of scenarios. The logic underpinning the model is that Governments can temporarily shift the level of aggregate demand using fiscal policy, but the longer-term properties ensure that if output is driven up beyond the economy's potential, then inflation will rise, which is not sustainable. Eventually, interest rates will rise and the economy will return to a state of equilibrium that is defined by the working age population and the amount of capital they have to work with.

III. Structure of the model

The model is specified to cover four sectors of the economy – the household sector, firms, Government and the foreign sector – to generate the demand and supply sides of the economy. In general, this model followed the specification in the work of the World

Economic Forecasting Model and Oxford Economics. The model is a combination of economic theories and econometric techniques with a cointegration and error correction framework. Behavioural relationships and accounting identities are used to link the various sectors of the economy to ensure the consistency of the system. Core behavioural linkages are specified as an error correction process and each equation is estimated separately, as the error correction mechanism ensures that the system moves towards the long run in the absence of innovation. This process allows for the inclusion of policy analysis and forecasting in the same model. In addition, the long-run relationship is also specified in line with the standard macroeconomic theory, imposing cross-equation restrictions when required. The cointegration relationships are estimated with a two-step process by applying the dynamic ordinary least squares process, while dynamic and static homogeneity properties are imposed in the price system as appropriate.

For the model to being used to obtain acceptable properties, in some cases, restrictions and coefficient values are imposed rather than exclusively using data estimates. Finally, with regard to expectation and policy variables, expectation is modelled as an adaptive process while policy variables are integrated through a rule-basis approach.

IV. Model assumptions

In developing the model, some key assumptions were made to capture the characteristics of the model. The assumptions, which explain how the model will react to an economic innovation, are as follows:

- It is assumed that a long-run growth rate is determined by the supply-side factors – productivity, labour and capital – and that attempts to bolster growth by boosting demand only leads to higher prices. The economy is similar to the classic one-sector models used in Cobb-Douglas technology, in which the level of potential output at any point in time is defined by the capital stock, labour supply adjusted for human capital, and total factor productivity. In addition, it is assumed changes in wages are fully passed through to prices and real wage determined by productivity growth.
- The model exhibits Keynesian characteristics in the short run and neoclassical characteristics in the long run. In the short run, factor prices are assumed to be sticky and output is determined by aggregate demand.
- As an error correction model, it gives estimates of the speed at which the dependent variables return to equilibrium after a shock to one or more explanatory variables.
- Aggregate demand is modelled as a function of the household (consumers and savers of money); the firm (producers of output and employers); the Government (devisers of fiscal policy) and a central bank (implementers of monetary policy, using short-term interest-rate or exchange-rate policy). Investment equations are underpinned by the Tobin's Q Ratio, in that the investment rate is determined by the return relative to the opportunity cost, adjusted for taxes and allowances. Consumer spending is assumed to be consistent with life-cycle and permanent-income theories, in which spending patterns change over the course of an individual's lifetime.
- In the long run, inflation is seen as a monetary phenomenon, vertical Phillips curve is assumed and implemented. This implies that expansionary demand policies place upward pressure on inflation, meaning that policymakers cannot stimulate the economy without the consequence of higher inflation. Owing to the negative consequences of inflation, the monetary policy variable is modelled as endogenous. Monetary policy is underpinned by Taylor's rule, a tool used to set inflation targets on the basis of the assumption that interest rates are assumed to rise when inflation is above the target rate, and/or output is above its potential.
- Exports of countries are assumed to be small (in the global market) and determined by aggregate demand, making it impossible for countries to determine their own terms of trade. Trade volumes are combined with price indices to partially determine the current account balance.

- Expectations are modelled as an adaptive process. On that basis, the model is subject to the Lucas critique, which argues that it is naive to try to predict the effects of a change in economic policy entirely on the basis of relationships observed in historical data. In order to address this issue, exogenous variables are assumed to be known as a prior variable.

V. Key equations

The ECA model is specified to have four major components – households, firms, the Government and the foreign sector – which together constitute the aggregate demand and supply of the whole economy. In order to ensure that the system is consistent, the various sectors are linked with behavioural relationships and accounting identities. The equations that comprise model can be viewed directly in the model interface and typically fall into two groups. The schematic of the model is explained in annex I.

The variables in the model are categories in the demand and supply variables, core and non-core. Core variables cover the basic variables, while non-core variables are determined by data availability and country objectives. The core demand variables include all the aggregate expenditure components, at constant and current prices, monetary policy variables and financial variables. The demand non-core section includes disaggregated consumption and investment, and important indicator variables, such as retail sales and car sales.

With respect to the core supply, the variables are the natural levels of output, unemployment and real wages. Prices are also disaggregated in the core supply block. Employment and nominal earnings are disaggregated in the non-core supply.

A. Aggregate demand side

In the short run, output is determined by demand, which can deviate from the potential level of supply. The deviations are measured by the output gap, which is defined as the ratio of actual to potential output. The aggregate demand is modelled as an identity relationship, summing the components of expenditure (private consumption, investment, government consumption, stock-building exports minus imports.

1. Household consumption expenditure

In this model the consumption expenditure equation is based on econometric treatment.

$$dlog(dji\_c) = 0.00211578952550249 + - 0.159848781633009 * (log(c(-1)) - log(pedy(-1))) + 0.899999999981582 * dlog(pedy) + (1 - 0.899999999981582) * dlog(pop) + - 0.309745790280765 * (dlog(infl) - log(infltarg / 100 + 1))$$

where household consumption expenditure depends on personal disposable income, the total population, the consumer price index and the inflation target. This specification is consistent with the life-cycle approach, in which an individual will consume all their earnings over a lifetime, spreading that spending out over time, according to their relative position in their life. It has also been specified to generate sensible scenario properties, which makes it possible to replicate the profile for consumption during previous business cycles.

2. Government consumption

Government consumption in this model is determined by capacity/potential output and gross domestic income.

$$dlog(gc) = \beta * dlog(yhat) + (1 - \beta) * dlog(gdi(-1))$$

3. Real inventory change

The inventory change in this model is a function of the population and the gross domestic product. An example of the inventory equation is specific as:

$$scr = scr(-1) - \beta * (scr(-1) - (log(pop / pop(-1)) + \alpha) * gdp(-1))$$

B. Gross fixed-capital formation

This equation is based on the so-called q-theories of investment. In these theories, capital is time-consuming to install and these adjustment costs drive a wedge between the post-tax marginal product of capital and its marginal cost. Profit-maximizing firms invest when the marginal return is greater than the replacement cost (q>1), and reduce investment, or even scrap an investment when the reverse takes place.

$$dlog(if) = - \alpha + - \beta * (log(if(-1) / (gdi(-1)))) + 0.1 * dlog(dji\_c + gc + x1 / pgdp) + \delta * dlog(if(-1))$$

Gross capital formation (investment) depends on gross domestic income, household consumption expenditure, government consumption, exports of goods and services given the deflator.

C. International trade

The trade aspect is made up of imports and exports. This component of the model provides the global linkage to the model. The import and the export equation are specified as follows.

Export

- $dlog(x) = dlog(wdr) + (1 - oxs) * (-\delta * dlog(pxgncom / wt) + - \beta * dlog(pxgncom(-1) / wt(-1)) + - \alpha * dlog(pxgncom(-2) / wt(-2))) + log(x\_adj)$

Export depends on country specific global demands, oil share of exports, non-oil import price deflator and global non-oil export price.

Import

- $dlog(m) = - \alpha + - \beta * (log(m(-1)) - (\delta * log(tfe(-1)) + - \theta * (log(pgdpncom(-1) / pgdp(-1))))) + \eta * dlog(x) + \xi * dlog(dji\_c) + \xi * dlog(if) + \acute{\omega} * dlog(gc)$

This equation reflects total final expenditure in the domestic economy, household consumption expenditure, gross fixed-capital formation and consumption, government.

In this model, the supply side determines the long-run growth path of the economy, including the evolution of potential output. The relationship between aggregate demand and potential output determines the state of the cycle, while the turning points are identified as changes in direction of the gap between the two. Information on the state and direction of the economy provide crucial reference points for policymakers to determine the direction and stance of macroeconomic policies. The supply side is underpinned by a general underlying production function that maps the factor inputs to final output, thereby representing the productive capacity of an economy. By starting with a general underlying production function, it is possible to avoid imposing a common production technology, such as the Cobb-Douglas or Constant Elasticity of Substitution production functions, across all countries. With two factors of production, the generalized form can be expressed as:

$$yhat = f (Kt , Lt ,Tt)$$

where YHAT is potential output, K is the desired capital stock, L is potential labour input and T indicates the state of technology, or total factor productivity (TFP).

By differentiating this equation with respect to time, and assuming perfect competition in factor markets and a homothetic production function, the growth rate of potential output can be expressed as the sum of the growth rates of each input, weighted by their relative factor share, plus the growth in TFP. Under the assumption of constant returns to scale, θLt = (1-θKt), from which the well-known growth accounting decomposition can be derived, the productivity trend is specified as:

$$\Delta\log(prod) = \Delta\log(L_t) + \Delta\log(K_t) + \Delta\log(trend_t)$$

$$= \Delta\log(L_t) + 0_{kt}\, \Delta\log(K_t) + \Delta\, (A_t)$$

where *trend* is trend productivity growth and k is capital per unit of labour input (K/L). This equation decomposes potential output growth into the contribution from potential labour input and trend labour productivity and, therefore, forms the basis of the supply-side trajectory for each for the model.

For the purpose of constructing a forecast baseline, potential labour input (L) evolves with labour force projections, while trend labour productivity growth is modelled as a simple error correction from recent productivity trends towards an exogenous trend rate of growth.

In scenario studies, the trend rate of labour productivity can be endogenized, and linked to factors that determine capital deepening, such as investment propensity, and/or TFP growth.
To consider potential market imperfections that may impede the feedbacks between external demand and domestic supply, especially in developing countries and in countries with fixed exchange rate regimes, an explicit link between export growth and potential output is incorporated into the model equation for potential output:

$$\Delta \log(yhat) = \alpha[\Delta \log(Ls_t) + \Delta \log(prod] + (1-\alpha)\Delta logX$$

where X is the volume of exports of goods and services and the weight, α, and tends to be 0.9 or higher.

Example:

*dlog(yhat) = α * (dlog(ls) + dlog(prod)) + (1 - α) * dlog(x)*

Labour force projections are modelled as a function of projections for the population aged 15+ from the United Nations Population Division and labour force participation. The model equation for labour force participation projections incorporates an automatic stabilizing relationship, in order to ensure that trend labour productivity growth does not drift too far from actual average labour productivity growth.

$$Ls_t = Ls_t + 0.2\begin{bmatrix}\Delta \log(labour\ productivity)_{3yr_{av},t-1} \\ -\Delta log(prod)_{t-1}\end{bmatrix}$$

A similar adjustment mechanism is incorporated into the trend productivity equation:

$$\Delta log\ (prod)_t = 0.8\Delta log\ (prod)_{t-1} + 0.2[\Delta log\ (labour\ producitivity)_{3y_{av},t-1} - log\ (prod)_{t-1}$$

where PROD is an exogenous setting for the long-run trend rate of productivity growth. As a starting assumption, 3 per cent per annum has been set for the country.

D. Prices and financial variables

In this section, some of the various price indexes and financial variables used in the model are highlighted.

1. Consumer price index

The consumer price index is a function of exchange rate, world crude prices, money supply, budget deficit and lending rate.

Example:

infl = constant + beta (rxd) + beta1 (Crude Oil price/barrel) + beta2 (m2) + beta3 (BD/gdp) + beta4 (rlend)

gross domestic product (GDP) deflator [2012=100]

2. Gross domestic product deflator

The GDP deflator is a function of the real GDP and the nominal GDP.

*pgdp = 100 * ((gdp1) / (gdp))*

3. Non-oil import price deflator

The non-oil import price deflator depends on the exchange rate and non-oil import price.

dlog (pgdpncom) = dlog(cmud) + dlog(rxd)

4. Import deflator

The import deflator in this model depends on exchange rate, non-oil import price and oil share of imports.

*pmg = dji_rxd / @elem(rxd , 2012) * ((1 - oms) * cmud + oms * wld_poilu / @elem(wld_poilu , 2012)) * @ elem(pmg , 2012)*

5. Non-oil export price deflator

The non-oil export price deflator is determined by exchange rate, GDP deflator and global non-oil export price.

*dlog(pxgncom) = - dlog(rxd) + α + - ώ * (log(pxgncom(-1) * rxd(-1)) - (ξ* log(pgdp(-1)) + (1. - η) * log(wt(-1) * rxd(-1)))) + 0.5 * dlog(pgdp) + (1.0 - 0.5) * dlog(wt * rxd)*

6. Central bank policy rate

The central bank monetary policy rate follows the Taylor rule. The instrument is a function of inflation, inflation target and output gap:

rcb = rcb(-1) + infl + 0.5 * (infltarg) + 0.5 * (cumod)

VI. Solving and testing over the past

Once the full model is defined, an attempt can be made to solve it, using a type of deterministic simulation. In this case, the set of equations is solved separately on the sample period. If the estimation residuals have been introduced as additional elements, the historical values in all cases should be given. In other words, the full model is simulated on the same period, in which the residuals are temporarily set to zero. This shows if considering current and lagged interactions does not amplify the estimation errors too much. However, it is not necessary to spend too much time on this, as simulations over the future will provide a much better context.

VII. Solving and testing over the future

As the model has passed all the tests (deterministic simulation) and on the reliability of baseline results, stochastic simulations should be used for forecasting into the future. As the stochastic simulation is passed, the model is considered to be suitable for forecasts and economic policy analysis.

VIII. Estimating the model equations

As already mentioned, the error correction framework had been adopted. Accordingly, there is need to address specific issues associated with the use of this framework. For example, the issue of establishing a long-term link between the variables becomes very critical and a prerequisite for the application of this framework. Despite this, the issue of stationarity must first be addressed.

IX. Stationarity and the Dickey-Fuller test

The stationary time series is one whose statistical properties such as mean, variance, autocorrelation, are all constant over time. This is useful, as descriptors of future behaviour variables are robust only if the series is stationary. To test the stationarity of the variables in the model, the Dickey-Fuller test was adopted. Details of the application of Dickey-Fuller techniques can be obtained from any basic econometric book.1

X. Forecasting and policy simulation

Before the model can be described as robust and used for forecasting and policy simulation, the residual of the model should satisfy the following characteristics:

- *No serial correlation or autocorrelation:* Serial correlation is the relationship between a given variable and a lagged version of itself over various time intervals. In other word, when error terms from different time periods are correlated.
- *No heteroscedasticity or have homoscedasticity (same variance);* Heteroscedasticity refers to the circumstance in which the variability of a variable is unequal across the range of values of a second variable that predicts it. That is, heteroscedasticity is said to be present when the size of the error term differs across values of an independent variable.
- *Must be normally distributed.* Normal distribution is an arrangement of a data set in which most values are clustered in the middle of the range and the rest are tapered off symmetrically towards either extreme.

In addition to the above necessary conditions for the residual, the model must exhibit a high level of R-squared (more than 60 per cent) with at least 50 per cent of the explanatory variables being significant in explaining the dependent variable. The R-squared measures the proportion of the variation in the dependent variable explained by the independent variables. It gives a statistical measure of how close the data are to the fitted regression line model. The adjusted R-squared adjusts the statistic based on the number of independent variables in the model.

Finally, the F-statistic, which indicates how the explanatory variables jointly can influence the dependent variable, must be significant.

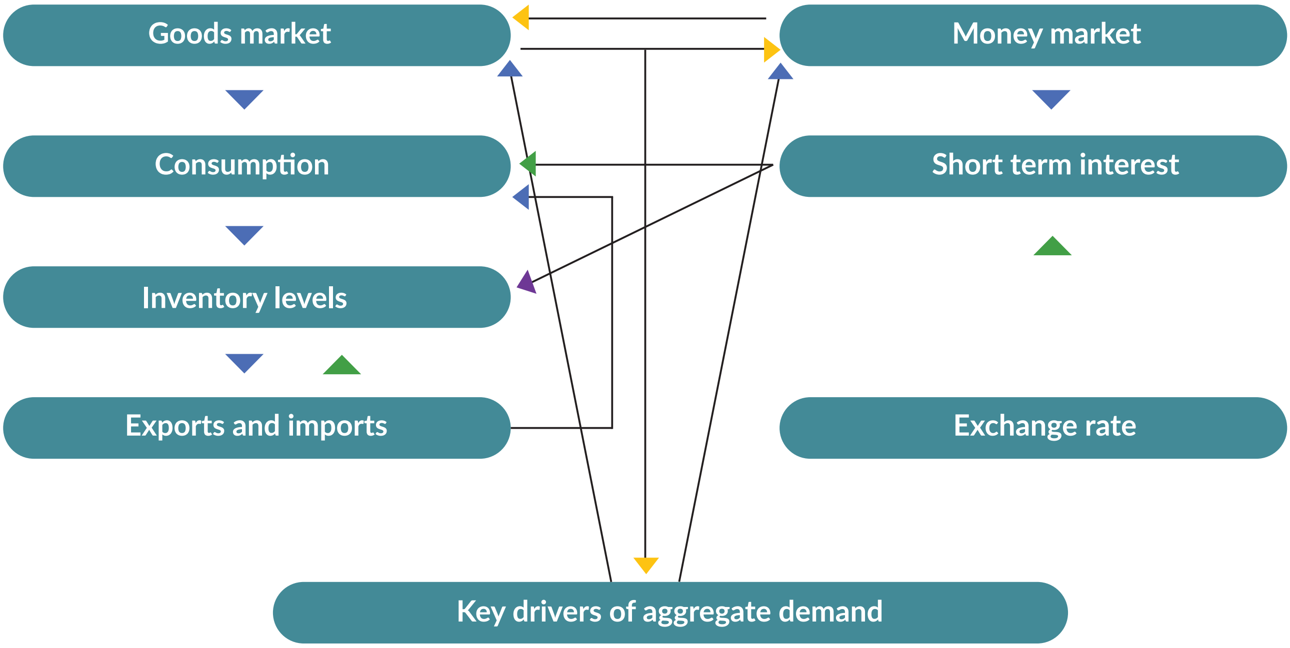
1 One example it Example Introductory Econometrics: A Modern. Approach, Fifth Edition, by Jeffrey Woodbridge.

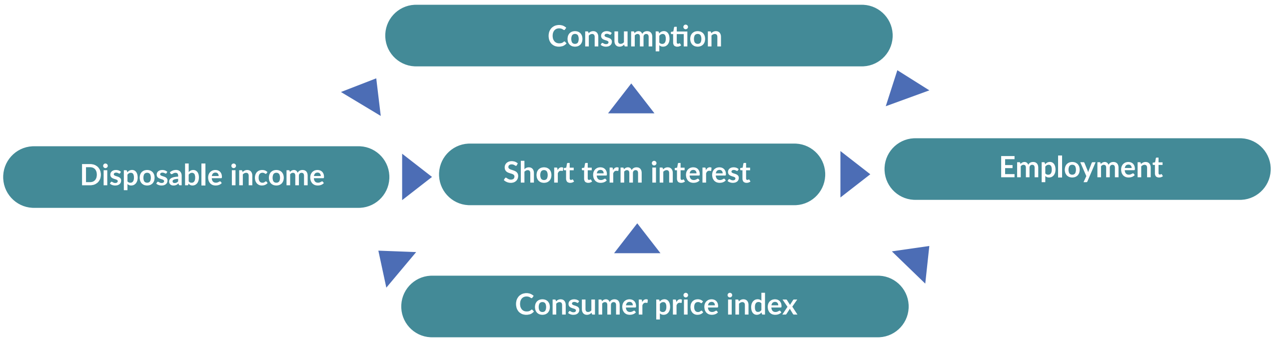
Annex I: Model variables

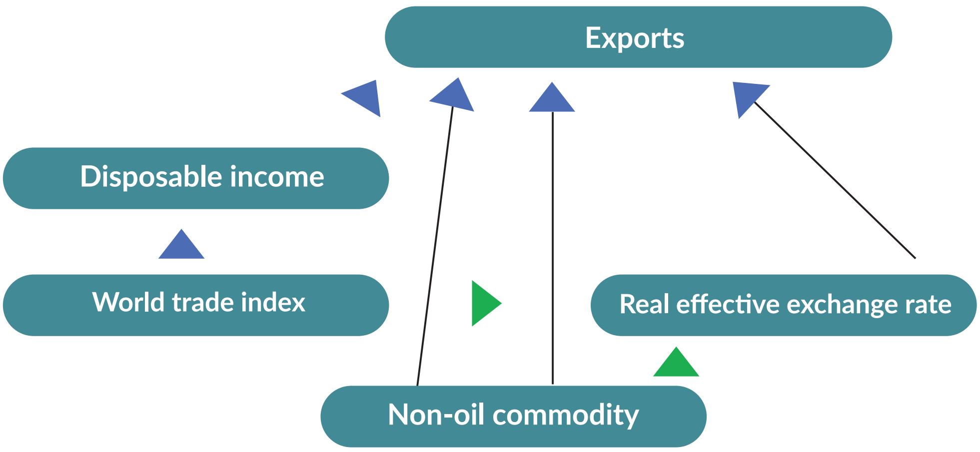
CODE	VARIABLE DEFINITION
AIRTRANS	Air transportation, nominal, local currency unit (LCU) [millions]
ATAX	Average economy-wide tax rate-share of tax revenue to GDP
BCU$1	Current account balance, nominal, US$
BCU$1OTH	Other items-capital and financial (current account balance), nominal, US$
BTN	Trade balance, US$
CMUD	Non-oil import price
CPI	Consumer price index
CUMOD	Output gap (%)
DEBT_GDP	Gross government debt (% of GDP)
DJI_C	Household consumption expenditure, real, LCU [millions: 2012 prices]
ET	Employment, total [thousands]
GDI	Gross domestic income, real, LCU
GDP	GDP, real, LCU [millions: 2012 prices]
GDP1	GDP, nominal, LCU [millions]
GDPGROWTH	Real annual GDP growth
GEXP	Government expenditure, current, LCU [millions]
GEXPOTH	Government expenditure, others, capital, LCU [millions]
GGDEBT	Gross government debt, real, LCU
GLN	General government net lending,(fiscal balance), real, LCU
GREV	Government revenue, total, LCU [Millions]
IF	Gross fixed capital formation, real, LCU
IF_GDP	Gross fixed capital formation as % of GDP
INFL	Inflation measured as CPI growth
LS	Labour force [thousands]
M	Imports, goods and services, real, LCU [millions: 2012 prices]
MARITRANS	Maritime transportation, nominal, LCU [millions]
M1	Imports, goods and services, nominal, LCU [millions]
M2_Growth	M2_growth (annual %)
M2_GDP	Money supply as a % of GDP
NAIRU	Natural rate of unemployment
OMS	Oil share of imports, nominal, US$
OXS	Oil share of export, nominal, US$
PART	Participation ratio
PDC	Public debt (central administration),nominal, LCU [millions]
PDPG	Debt (publicly guaranteed),nominal, LCU [millions]
PDPGB	Debt (publicly guaranteed), nominal, LCU [millions]-bilateral
PDPGM	Debt (publicly guaranteed),nominal, LCU [millions]-multilateral
PEDY	Personal disposable income, total, nominal, LCU [millions]
PGDP	GDP deflator [2012=100]
PGDPNCOM	Non-oil import price deflator, US$ [Index; 2012=100]
PMG	Import deflator, US$ [Index; 2012=100]
POP	Total population
POP15	Population 15+
PROD	Productivity trend, LCU [per emp; 2012 prices]
PX	Export deflator, total [2012=100]

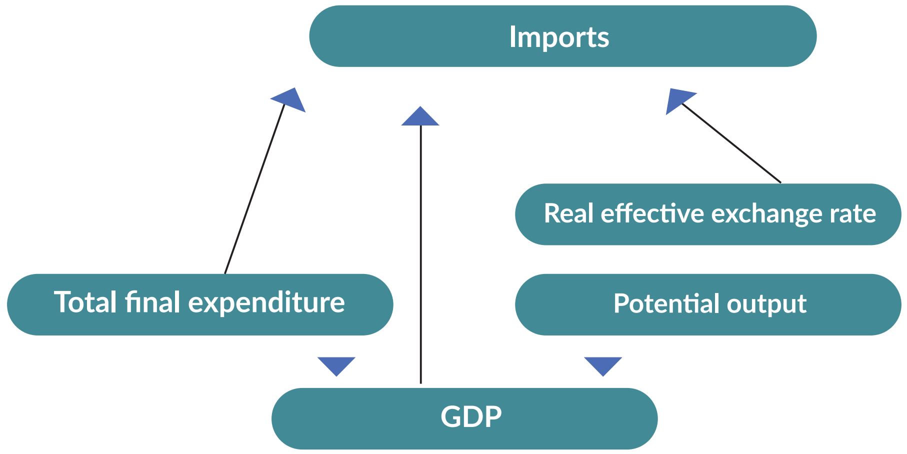
PXGNCOM	Non-oil export price deflator US$ [Index; 2012=100]
RLEND	Lending rate
RSH	Real interest rate, short-term (%)
RXD	Exchange rate, period average [LCU per US$]
SCR	Real inventory change
TFE	Total final expenditure, real, LCU [millions: 2012 prices]
TRANS	Total transportation in LCU (million)
TRANSOTH	Other forms of transportation, nominal, LCU [millions]
TRANS_GDP	Transportation as % of GDP
TRANS_GROWTH	Growth in the transportation sector
U	Unemployment [thousands]
WD_POILU	World oil price, Brent Crude spot, [US$ per barrel]
WDR	Country specific global demand
WT	Global non-oil export price, US$
X	Export of goods and services, constant prices, LCU
X_GDP	Export as a % of GDP
X1	Exports, goods and& services, nominal, LCU [millions]
YHAT	Capacity/potential output, constant prices

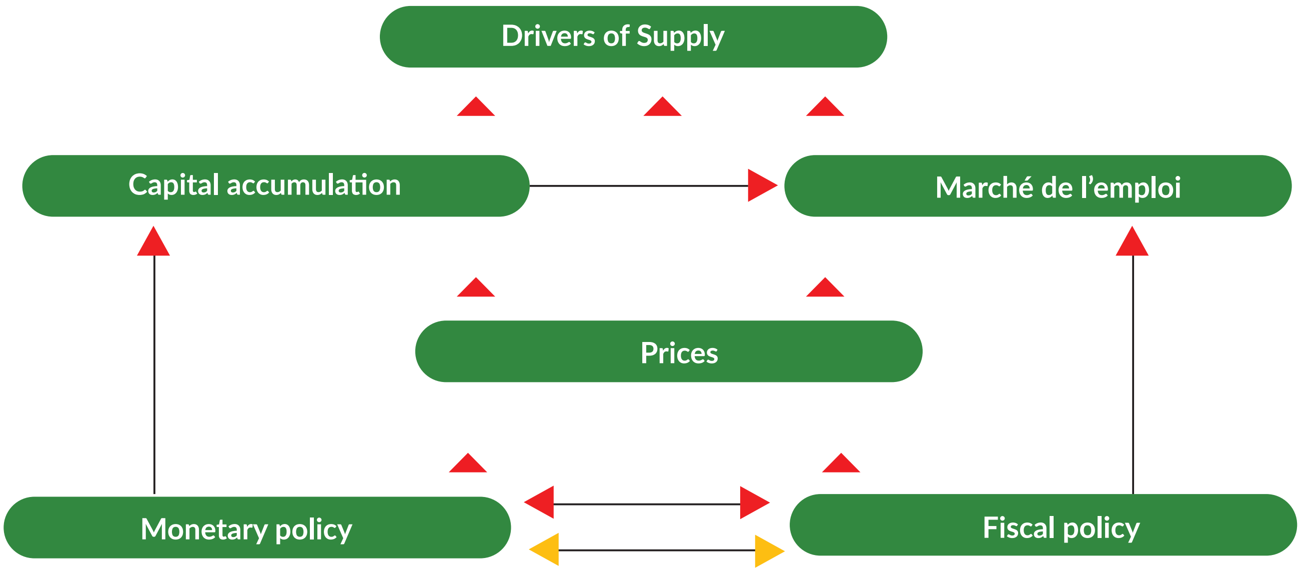
Annex II: Model schema

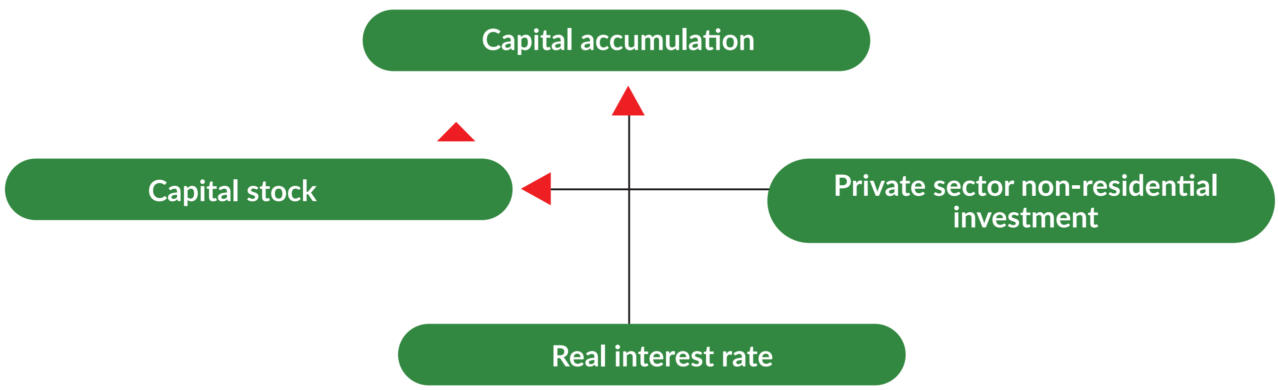


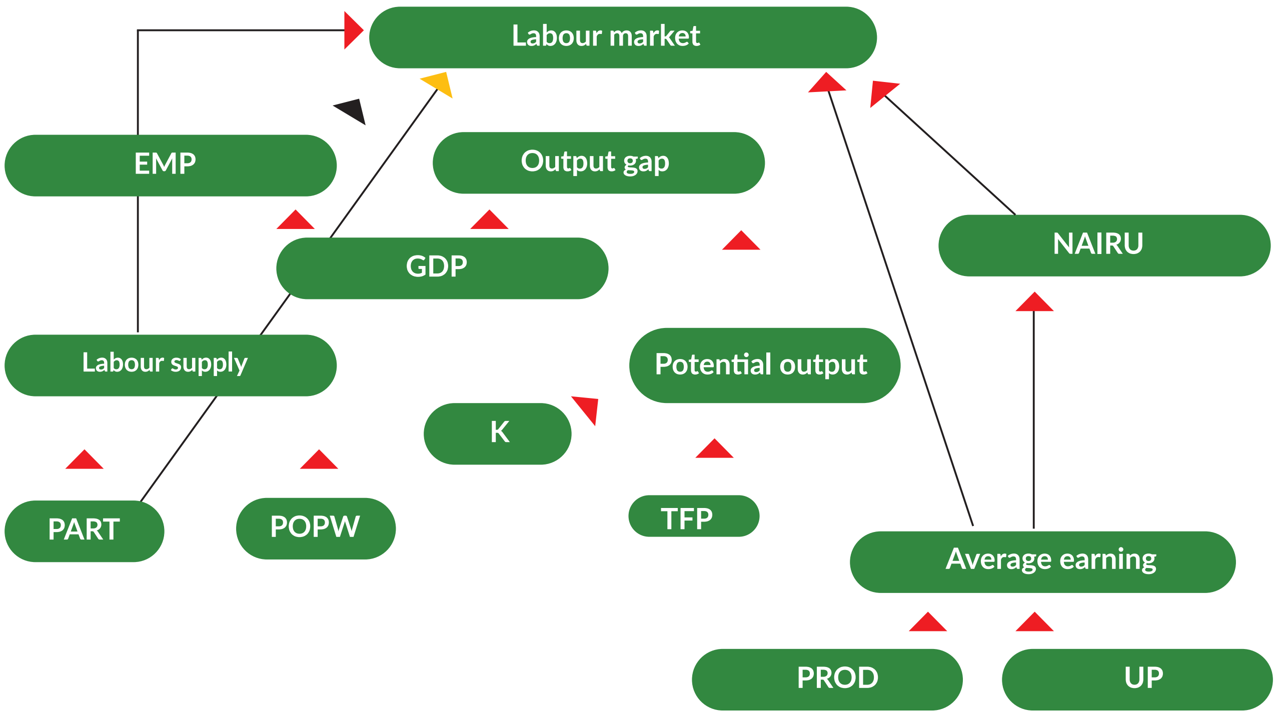


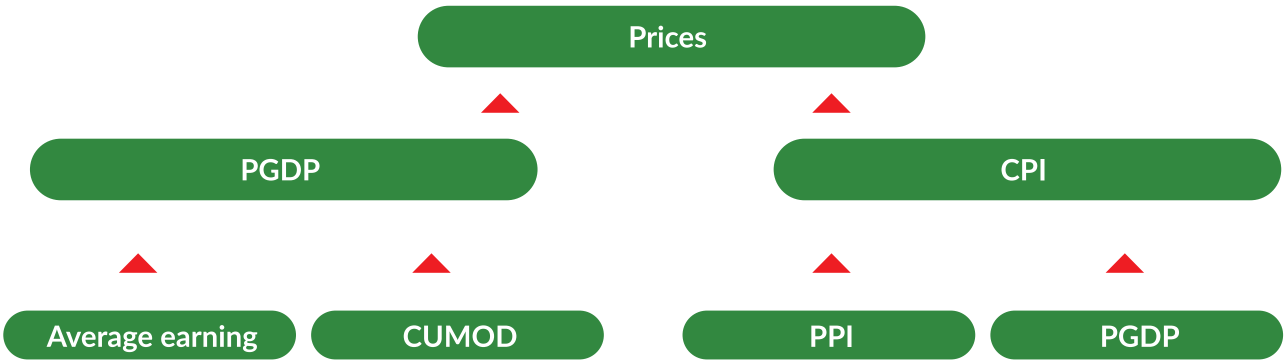


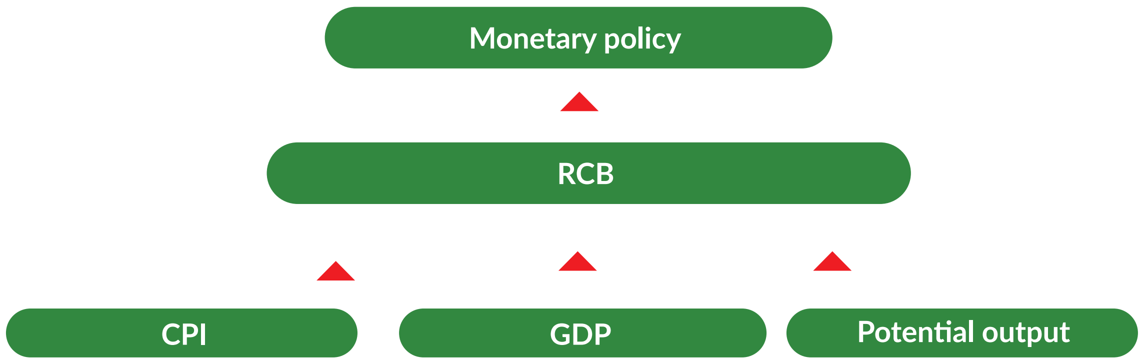

Imports
Real effective exchange rate
Total final expenditure
Potential output
GDP

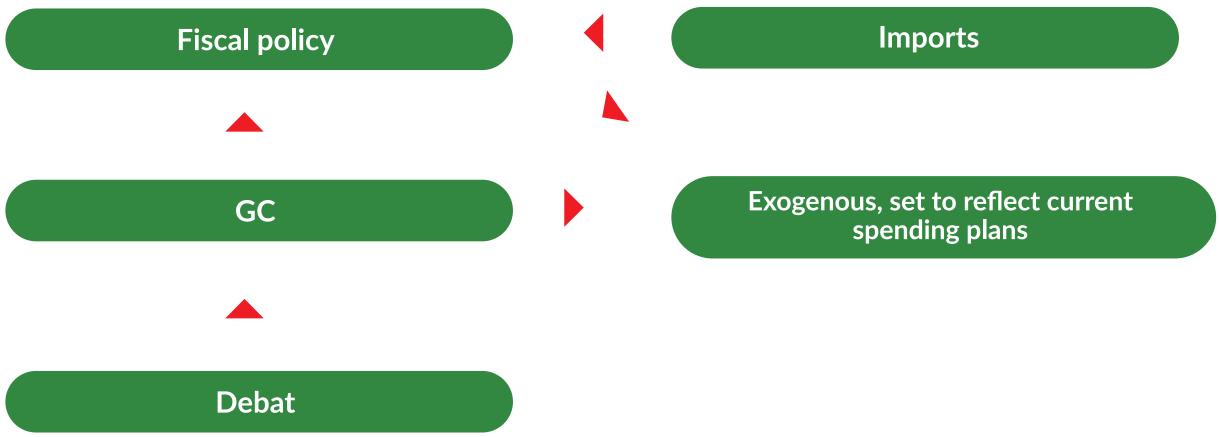

Drivers of Supply
Capital accumulation
Marché de l'emploi
Prices
Monetary policy
Fiscal policy


Capital accumulation
Capital stock
Private sector non-residential investment
Real interest rate


Labour market
EMP
Output gap
GDP
NAIRU
Labour supply
Potential output
K
PART
POPW
TFP
Average earning
PROD
UP


Prices
PGDP
CPI
Average earning
CUMOD
PPI
PGDP


Monetary policy
RCB
CPI
GDP
Potential output


Fiscal policy
Imports
GC
Exogenous, set to reflect current spending plans
Debat

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