

The UN Global Policy Model (GPM):
Technical Description ◊

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May 2014

◊ **This technical overview refers specifically to version 5.2c of the GPM.**

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GPM OVERVIEW

The Global Policy Model (GPM) is a tool for investigation of regional and global policy issues.¹ The model may be used to trace historical developments and simulate potential future impacts of trends, shocks and policy initiatives over medium-term timescales up to 15 or 20 years into the future. The main purpose of the GPM is to provide empirical and rigorously structured insights into problems of policy design and international cooperation. The GPM is not a (short-term) forecasting model.

In common with other macro-models, the GPM comprises a databank of historical time series and a set of computer programs that organize the original data, estimate model parameters and generate scenarios. Both systems, the dataset and the model, are self-contained and distributable. As far as data is concerned, the major challenge is to benefit from the considerable availability of annual data for all countries and compile the various sources in a rigorous manner across fields, countries and time. The GPM enforces strict national accounting consistency, extended into related domains such as trade and balance of payments, banking and government finance, population and employment, income distribution, energy and emissions, etc.

The GPM has been designed to facilitate alternative schemes of geographic disaggregation (flexible geometry) depending on the purposes for which the model is used. A standard decomposition in the current version of the model includes sixteen G20 members and a further nine country groups, amounting to a total of 25 countries and groups covering the world as a whole. Other decompositions have been used to study specific topics, like energy production, use and environmental impact; export diversification and trade agreements, etc.

Regarding the modelling framework, early global empirical investigations of policy issues attempted to ensure consistency by putting together country models provided independently by national governments or think-tanks. This approach, like that formalised in the LINK project under the auspices of the UN, have known limitations

¹ The first version of the GPM was created by the Department of Economic and Social Affairs of the United Nations in 2007. It drew heavily from the experience of more than 30 years of global modelling acquired by the Department of Applied Economics (DAE) of the University of Cambridge, UK. One of the main authors of DAE's global modelling work, Francis Cripps, has been the principal investigator behind all versions of the UN GPM, including this one (5.c). Francis Cripps was joined by Alex Izurieta while at the University of Cambridge, then DESA and at present UNCTAD, and by Rob Vos, then Director of the Department of Policy Analysis of DESA, with whom earlier presentations of the GPM were co-authored. Apart from DESA, other partners have collaborated in the development of the model, most notably UNDP's International Policy Centre (IPC), Cambridge Endowment for Research on Finance (CERF, University of Cambridge), UNCTAD, ILO, and the Global Development and Environment Institute (GDAE) of Tufts University (MA, US). From December 2013 onwards, the responsibility for the maintenance and revisions of the model resides on UNCTAD. UNCTAD is committed to make the databank and model programmes available to a wider audience.

due to the diversity of underlying models and the limits of linking outcomes with fixed trade matrices. The GPM breaks with this pattern as it relies on a fully integrated analytical structure where standardized models of countries or country groups are resolved endogenously through a dynamic trade and financial structure. This facilitates the investigation of global interactions and dynamics over time as well as the simultaneous evaluation of policies and outcomes for individual countries with different economic structures and at different levels of development.

Behavioural specification is homogenous across countries and structural differences are explained endogenously within the model rather than being imposed exogenously by the use of different specifications per country. It is not the only model to employ a common specification of behaviour aided by differentiated fixed effects and 'state' variables as denominators for correction of heteroskedasticity. In addition, continuing investigation is being undertaken to clarify reasons for differences and relate them to structural variables within the model. For example, if research shows that differences in a particular behaviour reflect different degrees of development, a typical variable to include in the specification is the relative or absolute level of income per capita which itself changes dynamically along the period of a model simulation. Likewise, if differences of behaviour across countries or sectors are attributable to some form of financial constraint, explanatory variables that could be included in the specification are the level of public or private debt, the current account position or the level of international reserves, etc. This 'structural' approach opens the door to panel estimation methods which are advantageous when, as in the case of global databanks, there is considerable variation in accuracy of observations for different groups of countries and in different time periods.²

Each variable in the model is specified either by an accounting identity or an econometric specification, while global closure rules and explicit dynamic behaviour ensure model convergence at each point in time. With very limited exceptions, the model is fully endogenous throughout both the historic period and the simulation period.

As in other models, residual terms in behavioural equations over the historical period serve to match 'known' values of the variable being explained.

A more complex task is to generate model values for the period between the last available historical data and the initial period for genuine simulations (typically the 'next year'). Often such data are well known or can be inferred from partial information or short term forecasts but have not yet reached the international statistical sources used in the model. Thus the GPM 'aligns' data for the current year and very recent past

² Additional information and more robust econometric estimates can be obtained using finer country disaggregations. Some work of this kind has been done for the GPM using 50-60 countries to include countries with relatively complete historical data and up to 80 countries to include all countries with substantial population or GDP.

with estimates obtained from short-term forecasting models such as DESA's World Economic Forecasting Model (WEFM), or ILO's Global Employment Trends (GET), or other sets of assumptions about current developments. This alignment that can be extended one or two years into the future is achieved by target-instrument algorithms that adjust residuals in behavioural equations to generate the required values of main indicators such as a world oil price index and GDP, inflation, the current account, employment and unemployment in each country.

A 'plain' projection further into the outlook period can be generated by assuming future residuals to be nil. Neither such a 'plain' projection nor the more informed scenarios explained below have predictive power or probabilities assigned to them. Longer-term outcomes, being subject to unanticipated turning points, policy changes and shocks, are not knowable in a forecasting sense even though underlying trends in different parts of the world are often persistent. Global fluctuations in trade and investment, exchange rates, stock markets, commodity prices etc. continue to make the policy environment unpredictable and crises such as the 2008-9 financial meltdown in the USA and Europe can still derail the world economy in unpredictable ways.

Scenarios for the projection period are thought to be conditional upon assumed patterns imputed by adjustment of residuals in the behavioural relations. In other words, they are 'what if' scenarios, not forecasts. The baseline is typically thought as a continuation of prevailing policies with slowly decaying residuals but it may also include assumptions about future changes that can be anticipated as probable or highly likely. Alternative projections are typically designed as 'policy scenarios' in the broad sense that they embody assumed changes of policy stance that influence behaviour of one equation or a set of equations in a particular manner.

Such policy assumptions can take the form of straightforward 'add factors' in say, the government expenditure equation, or the tax equations, or the interest rate equation, etc. Beyond the straightforward modality of constructing 'what if' scenarios by 'shocks' in one or a set of variables, the main interest of GPM simulations lies in investigating alternative configurations of policy with different degrees of policy coordination. In the tradition of Jan Tinbergen, such policy schemes are defined using rules in which behaviour of an 'instrument' variable is adjusted to aim at achieving a policy 'target', often extended in a nuanced manner to examine the potential impact of behavioural changes at a regional or more global level. Complementary to the use of one instrument for each target, a set of additional instruments can be 'linked' to contribute together in achieving the targets. For example, it is possible to aim at achieving a target of a particular fiscal budget by taking, say direct taxation alone as an instrument, or by linking changes in direct taxation with a proportional effort made by changes in indirect taxes and government spending. Moreover the GPM allows for conditional activation of policies depending on whether outcomes exceed or fall short of a country's targets. This is important because although global trade and financial markets exert a common influence, the predicament facing individual countries at each point in time varies widely implying that priorities and requirements for policy adjustment that are

appropriate for some countries will often be less appropriate or inappropriate for others.

To ensure that model simulations stay within limits of plausibility and have a resonance with historically observed experience, the model can restrict such 'shocks' in a way that outcomes of each behavioural variable do not deviate beyond a specified residual distribution. The modeller can explicitly determine the maximum deviation for each variable separately or for the entire model.

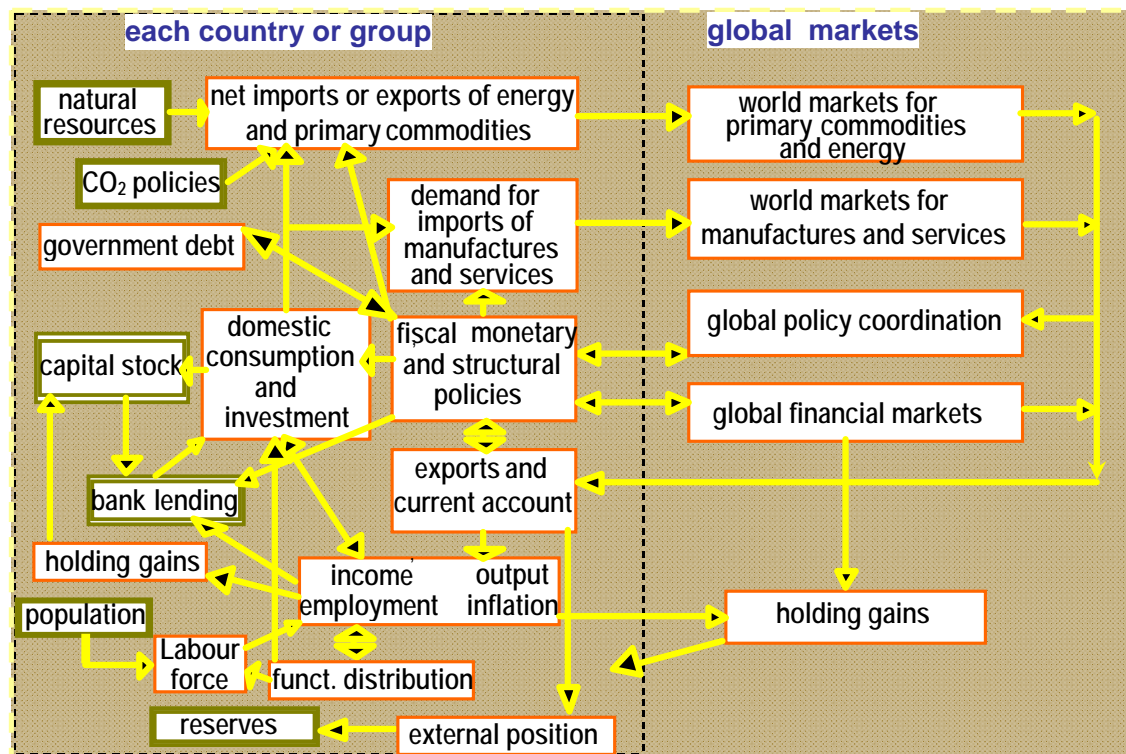
Beyond this the extent to which policies can or could have an effective influence on behaviour in each field is evidently a matter for assumption or judgement. This is true enough for government budgets and even more so for 'trade policies', 'industrial policies', 'environmental policies' etc. What the model can test is the potential consequences if targetted policies do have an influence.

MODEL STRUCTURE AND SPECIFICATION

Domestic and global interactions

The GPM represents relationships between GDP, domestic demand, trade of various types of commodities and services and the balance of payments as feedbacks between flows of expenditure and income, mediated by policies and the financial conditions of main institutional sectors. These relationships are in turn affected endogenously by employment and distributional conditions. Meanwhile, global conditions in financial markets, as well as price formation in international markets tend to play a somewhat more independent role, wherein the influence of the specific country is more limited (see Figure 1).

Figure 1: GPM main modules and interactions



Interpretation of most of the modules represented in this diagram is common to other global models. Worthy of mention here are the role of finance and the flow of funds influencing model closures and the relevance of employment and functional distribution in influencing income and expenditure.

Finance and stock flow closures

In the GPM, finance is not a 'black hole'; the flow-of-funds accounts and balance sheets of the main institutions are explicit and dynamically integrated into the model by accounting rules and behavioural relations. Therefore, changes of income and expenditure of governments, the private sector, and national economies are fully translated into changes of net lending or borrowing positions of these sectors. Such flow 'closures' may directly influence behaviour. In addition, the accumulation of flows on balance sheets of institutions and external assets and liabilities feeds back into the adjustment behaviour of the real economy. Despite the fact that the matrices of flows and of stocks are of a high degree of aggregation, they have proven to be a meaningful factor in model dynamics, particularly when imbalances grow disproportionately, altering historic stock/flow norms.

The GPM provides an explicit if highly approximate treatment of holding gains and changes of volume. Changes of asset prices, physical and financial, are estimated endogenously in relation to portfolio structure, formation of other prices, etc. These include stock market prices and the sometimes sharp increases in the domestic value of foreign-currency debts in countries experiencing large devaluations. Likewise, the

appreciation in value of external assets relative to liabilities of the USA, reflecting the declining international value of the dollar, are also considered. Other examples of such changes at balance sheet level include the impact of so-called 'inflation tax' on the value of outstanding government debt, the effects of privatisations and bail-outs, as well as haircuts that affect the growth of domestic and external debt

The relationship between the real economy (trade, production, income, spending etc.) and the financial system (deposits, debt, stocks and other types of financial asset and liability) in the GPM may be summarised as follows:

- (i) real flows are necessarily matched by opposite financial flows and therefore in the short run may be said to constrain the latter on a net basis (so-called financial balances)
- (ii) gross flows of financial assets are largely determined by what may be described as 'financial' behaviour, subject to the constraints implied by (i) and recognizing that much financial behaviour has its roots in real economy opportunities and requirements
- (iii) gross financial positions (accumulating flows and revaluations) feed back into real behaviour.³

The typical strength and speed of the various feed-backs is largely an empirical matter requiring examination of the design and estimation of individual behavioural equations and checks on the realism of implied dynamics of the model at country level and for the world as a whole.

Although the logical structure of real and financial stocks, flows and holding gains is clear, behavioural feedbacks within the financial system and between the real economy and the financial system require ongoing research. The most critical aspect for international policy is the behaviour of external capital flows and their impacts on international positions and domestic financial markets that too often prejudice policies for the real economy.

Demographics, labour and income distribution

The GPM structure incorporates changing demographics, urbanisation and international migration, patterns of employment and GDP by broad sector and primary income distribution (the division of GDP between profits, mixed income and compensation of employees, and indirect taxation). These variables feed back into overall model dynamics and are important for policy evaluation.

Historical data demonstrate that increased urbanisation and a falling share of employment in agriculture in employment are universal trends that have reached very different stages in each part of the world but continue in all countries, the only

³ GPM equations for savings, investment, government revenue and spending and exchanges rates include balance-sheet feedbacks but estimated coefficients are often too weak to exert any rapid effect and prevent accumulation of increasingly unbalanced positions.

exceptions being short-term reversals with returns to the countryside in times of extreme crisis.

The review of employment data also shows clear trends. Employment in services tends to increase as employment in agriculture falls and as the industrial labour force declines in countries where a large proportion of the labour force was formerly employed in manufacturing industries. Employment rates vary, depending on the level of participation of women and elderly people. Trend adult unemployment rates have remained below 10% in nearly all countries, with short-term unemployment being more sensitive to the macro-economic cycle in high income countries, particularly after the global financial crisis and ensuing deflationary policies. Youth unemployment has been high, rising recently in many countries despite widespread reductions in the number of young people coming into the labour force. Participation of young people in the labour force has fallen in most countries due to extension of secondary and tertiary education and training, facilitated by falling birth rates and reduced numbers of children as a percentage of population.

Differences and trends in primary income distribution in countries at different levels of development are less systematic, with particularly large gaps and some uncertainties about the interpretation of available data. The main generalisation that can be made is that the share of profits and mixed incomes in GDP is typically lower in developed countries and higher in developing countries where wages and salaries take a minor share. Long-term declines in labour income shares (wages plus mixed incomes as proportion of GDP) can be observed over the last 20 to 30 years in many countries although the speed of the decline has somehow slowed-down in recent years. It seems likely that higher monopoly power of corporate business, often linked to state de-regulation, is an important factor for such a historic compression of labour income shares.

The inclusion of employment and primary income distribution makes it possible to model domestic inflation explicitly as an interaction between growth of earnings, aggregate productivity and profit mark-ups and to trace the impact of changes in the share of profits on savings, portfolio and real expenditure. Employment levels, as well as changes in the distribution between profits and labour income may have significant impact on patterns of household consumption and investment spending. Increases in employment levels and economic activity, both in the short and long run, are stimulated by sustained growth of aggregate demand, which is the main trigger of productivity growth (à la Kaldor-Verdoorn).

Patterns of functional income distribution have a strong path-dependency but can adjust in response to various factors including fluctuations in activity and the terms of trade, public policy and incentives and longer-run institutional changes. Changes in functional income distribution have a double effect. Higher profit mark-ups tend to have a positive, albeit moderate and short-term impact on investment. But such shifts also impact labour income, having a negative impact on consumer spending. The net impacts

of increases in the mark-up on growth of final demand and GDP are negative, with different degrees according to the context. Finally, the aggregation of these influences in a global model reveals large cross-border spillovers and synchronised 'confidence' effects, which makes the call for global coordination of demand management particularly relevant.

BEHAVIOURAL EQUATIONS

Domestic macroeconomic and financial variables in equations discussed below are measured in real terms using a deflator for each country that compensates for inflation of the price of total domestic expenditure and for cross-country differences in purchasing power. Meanwhile, international transactions and assets are measured in world-average purchasing power. Volumes of GDP and traded goods and services are measured at constant prices while physical energy series (which can be solid, liquid, gas, electricity and other sources) are expressed in oil-equivalent units. The GPM also models inflation of costs and final prices, nominal interest rates and exchange rate movements. Current dollar values of GDP, domestic income and expenditure, trade and the balance of payments and financial assets and liabilities are derived by multiplying real values by the appropriate deflator.

The GPM ensures global consistency of all external transactions, values of external assets and liabilities and real and nominal exchange rates. This is achieved by dynamic iteration of scaling adjustments on unadjusted values.⁴

Unless otherwise specified, variables in equations discussed below are specific of the country or group of countries, and measured by annual time series. World variables are denominated with the suffix W. Lagged variables are represented by subscripts -1, -2 etc.

Income and expenditure

Gross national income Y is distributed and spent by government on the one hand and the private sector (including households, corporations and state enterprises) on the other. The sources of gross national income are output (GDP), net receipts of external factor income and transfer payments and terms of trade effects.⁵

The private sector

Private disposable income is defined as national income not absorbed by the government ($Yp = Y - Yg$). Three main relations define private spending behaviour. Consumption ($C = Yp - Sp$) is determined by the savings function

⁴ Exceptionally physical energy is balanced for the world as a whole by the endogenous adjustment of the world price of oil. Other scaling adjustments are documented in the addendum, which provides definitions of unadjusted and adjusted versions of each variable.

⁵ Additions to or subtractions from the purchasing power of income generated by domestic output arising from changes in import and export prices

$$(1) \quad \Delta \frac{Sp}{Yp_{-1}} = \Phi \left[\frac{Sp_{-1}}{Yp_{-2}}, \frac{\Delta Yp}{Yp_{-1}}, \frac{\Delta Wp_{-1}}{Wp_{-2}}, \frac{VVem_{-1}}{Yp_{-1}}, \Delta \left(\frac{VVem}{Yp} \right), \log(1 + pi / 100), \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

The *rate of private savings* Sp follows a schedule that is moderately path-dependent, responding to the current growth of private income and in the longer term to the rate of growth of wealth Wp (which incorporates valuation changes measured in real terms). Short- and long- term dynamics of the saving rate are influenced by changes in income distribution, expressed here as the share of labour income $VVem$ in private income Yp . Overall saving rates increase, and thus consumption rates fall as the functional distribution of income shifts away from labour. There are also weak tendencies for savings to rise with inflation pi and with per-capita income of the country relative to the world average YR . Note that growth of wealth reflects holding gains as well as savings. The symbols α_b and ε_b denote country-specific fixed terms and stochastic errors (the same symbols are used in all equations that follow)

$$(2) \quad \Delta \log \frac{Ip}{V_{-1}} = \Phi \left[\log \frac{Ip_{-1}}{V_{-2}}, \Delta \log V, \frac{\Delta VVpr_{-1}}{V_{-1}}, irm, \frac{\Delta(ILX\$/rx)}{V_{-1}}, \frac{\Delta ILN}{V_{-1}}, \alpha_b, \varepsilon_b \right]$$

Private investment Ip expressed as a ratio to lagged GDP shows an accelerator response to the growth of GDP with some additional influence from growth of profits $VVpr$. Financial conditions also matter, with influences from the real bond rate irm , changes in external flows $(ILX\$/rx)$ and changes in lending from the domestic financial sector ILN . The coefficient of the structural term $dlogV$ is obtained from a theoretical model and is imposed on the GPM equations to maintain a stable capital output ratio and avoid excessive current-year feedbacks.

$$(3) \quad \Delta \frac{IV}{V_{-1}} = \Phi \left[\frac{IV_{-1}}{V_{-2}}, \Delta \log V, \frac{\Delta ILN}{V_{-1}}, \frac{ILN_{-1}}{V_{-1}}, irs, \alpha_b, \varepsilon_b \right]$$

Inventory adjustment IV exhibits a similar accelerator response to the growth of GDP. A priori values are imposed on terms that reflect effects of changes in the availability of bank credit ILN and the short-term real interest rate irs whose influence is not well measured by pool estimation.

The government sector

Net financial savings or ‘net lending’ of government represents the difference between net revenue (taxes less subsidies, transfers and debt interest) and spending on goods and services. While the equations below show the factors that influence the outcomes of these variables, it ought to be remembered that these equations, as all other equations in the system, retain an add-factor that represents autonomous policy divergences and shocks.

$$(4) \quad \Delta \log(1 + rtx) = \Phi \left[\log(1 + rtx_{-1}), \frac{XE\$_{-1}}{VV\$_{-2}}, \frac{\Delta XE\$}{VV\$_{-1}}, \alpha_b, \varepsilon_b \right]$$

The share of indirect taxes less subsidies in GDP, rtx , is strongly path dependent and is significantly influenced by the level and increase in the value of energy exports.

$$(5) \quad \Delta \log \frac{Ygd}{Y_{-1}} = \Phi \left[\log \frac{Ygd_{-1}}{Y_{-1}}, \log \frac{Lg_{-1}}{Y_{-2}}, \Delta \log Y, \Delta \log Y_{-1}, \Delta \log \frac{VVtx_{-1}}{Y_{-1}}, \Delta NUL, \alpha_b, \varepsilon_b \right]$$

Direct revenue net of transfers and interest payments Ygd rises or falls with gross national income Y with a lag. A high public debt ratio Lg/Y usually calls for long-term increases in direct tax collection, while increases in proceeds of indirect taxation $VVtx$ reduce the pressure to make savings on transfers or increase direct tax rates. An opposite effect is caused by fluctuations in the unemployment rate NUL .

$$(6) \quad \Delta \log G = \Phi \left[\log G_{-1}, \frac{Yg_{-1}}{Y_{-2}}, \Delta \log \frac{Lg_{-1}}{Y_{-1}}, \Delta \log \frac{AGF_{-1}}{Y_{-1}}, \log N_{-1}, \log YR_{-1}, \frac{CAS_{-1}}{Y\$_{-1}}, \alpha_b, \varepsilon_b \right]$$

Government spending on goods and services G shows a strong path-dependency and is further influenced by financial conditions as well as external sustainability. It mostly responds to the performance of government income Yg and the composition of the balance sheet (Lg , government debt, and AGF , government financial assets). State variables like population, N , and the degree of development captured by relative income per capita YR , also have some influence. Finally, government spending on goods and services tends to respond to external performance, measured by the current account CAS .

Trade and the external current account

The GPM models the current account in some detail, distinguishing the value and volume of exports and imports in four categories of trade -food and raw materials, energy, manufactures and services-, as well as receipts and payments of income and transfers. Trade in manufactures is the clearest short-run driver, responding to prices, exchange rates, growth and fluctuations in expenditure in all countries.

Trade in manufactured goods

Markets for manufactures are modelled on a bilateral basis that reflect the evolving pattern of linkages and network production systems between countries. Imports respond to activity, prices, the real exchange rate, etc, with the price being calculated as a weighted average of export prices of suppliers. Exports are determined by market shares (i.e. shares of each supplier in imports of each importing country). Market shares and export prices respond to relative unit costs, calculated as a weighted average of domestic costs and costs of imports of primary commodities, energy and services as well as manufactures).

$$(7) \quad \Delta \log MM\$ = \Phi \left[\log MM\$_{-1}, \Delta \log MH\$, \log MH\$_{-1}, \log pmm_{0,-1}, \Delta \log rx, \alpha_b, \varepsilon_b \right]$$

The value of imports of manufactures $MM\$$ responds to a weighted sum of expenditures $MH\$$ that attributes relatively high import intensity to investment IP , IV and exports $X\$$, and relatively low import intensity to government spending on goods and services G :

$$MH\$ = rx \cdot (C + 0.4 \cdot G + 2 \cdot (IP + IV)) + X\$ + 2 \cdot XM\$$$

Finally, the value of manufacturing imports is affected by changes in the real exchange rate rx and supplier prices pmm_0 . This equation also includes a long-run trend, representing the momentum of globalisation.

$$(8) \quad \Delta \log \frac{pmm_0 \cdot MM_0}{MM\$} = \Phi \left\{ \log \frac{pmm_{0-1} \cdot MM_{0-1}}{MM\$_{-1}}, \Delta \log(pmm_0), \Delta \log(rx), \alpha_b, \varepsilon_b \right\}$$

Given the value of imports measured in world purchasing power terms, movement of *the volume of imports of manufactures* MM_0 is a question of changes in price. The model assumes a unit long-run elasticity with respect to the weighted-average supplier price, pmm_0 , and estimates short-run coefficients to capture delays in passing through changes in supplier prices and the real exchange rate rx .

Global consistency is enforced by scaling import volumes to match export volumes in the world as a whole.

$$(9) \quad \Delta \log(sxm) = \Phi \left\{ \log(sxm_{-1}), \log(ucx\$_{-1}), \Delta \log(ucx\$_{-1}), \alpha_b, \varepsilon_b \right\}$$

The value of exports $XM\$$ of each country is determined by summing the product of imports by value in each importing market and the country's market share as a supplier. *Market shares* sxm exhibit slow adjustment to unit costs ucx . The estimated long-run elasticity of market share by value with respect to relative unit costs is around 3.⁶ Fixed effects are in this instance bilateral and differ substantially depending on the size and proximity of suppliers and import markets. Estimates generated by the equation above are scaled to sum to unity in each market.⁷

$$(10) \quad \Delta \log \frac{XM_0}{XM\$} = \Phi \left[\log \frac{XM_{0-1}}{XM\$_{-1}}, \log ucx_{-1}, \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

Given the value of exports of manufactures *the volume of exports* XM_0 is again determined by price movements. In the long run aggregate manufacturing export prices

⁶ Coefficients are estimated using a panel that excludes supplier-importer pairs with very low levels of trade for which market shares may exhibit erratic year-on-year proportionate changes.

⁷ This adjustment transforms the country-level equations into an Armington-style system in which market shares depend on trade-weighted relative unit costs of the different suppliers.

rise with unit costs of exports $ucx\$$, while such effects are relatively weaker in more advanced countries (hence the introduction of the variable YR , relative income per capita), presumably reflecting their established presence in world markets through production networks and institutional ties.

Trade in services

The international market for services trade is set up as pool. Net exports of each country measured in international purchasing power depends on the real exchange rate and service requirements of different branches of merchandise trade. Imports are determined as a function of net exports and the same variables, leaving exports (gross) to be calculated as the balancing item. Global service trade is balanced by scaling exports to ensure that the world total is equal to world imports. Export and import volumes at base year dollar prices depend on values and on changes in the real exchange rate.

$$(11) \quad \frac{\Delta BS\$}{V_{-1}} = \Phi \left\{ \Delta \log(rx), \frac{\Delta BA\$}{V_{-1}}, \frac{\Delta BE\$}{V_{-1}}, \frac{\Delta BM\$}{V_{-1}}, \alpha_b, \varepsilon_b \right\}$$

$$(12) \quad \frac{\Delta MS\$}{V_{-1}} = \Phi \left\{ \Delta \log^{(+)}(rx), \frac{\Delta \min\{0, BS\$\}}{V_{-1}}, \frac{\Delta MA\$}{V_{-1}}, \frac{\Delta XE\$}{V_{-1}}, \frac{\Delta MM\$}{V_{-1}}, \alpha_b, \varepsilon_b \right\}$$

$$(13) \quad \Delta \log \frac{MS_0}{MS\$} = \Phi \left[\log \frac{MS_{0-1}}{MS\$_{-1}}, \Delta \log rx, \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

$$(14) \quad \Delta \log \frac{XS_0}{XS\$} = \Phi \left[\log \frac{XS_{0-1}}{XS\$_{-1}}, \Delta \log rx, \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

Trade in primary commodities

World markets for primary commodities are modelled as a pool system with price and quantity adjustments. A country-level equation determines the balance of net exports or imports as an implicit function of domestic supply and demand. Imports of each country are then scaled to match total world exports. The world price index for primary commodities responds to the rate of growth of world imports.

$$(15) \quad \frac{\Delta BA_0}{V_{0-1}} = \Phi \left[\frac{\Delta V_0}{V_{0-1}}, \Delta \log lpa, \alpha_b, \varepsilon_b \right]$$

Net exports of primary commodities at base year prices BA_0 expressed as a ratio to GDP fluctuate with the changes in GDP and tend to increase with a rise in lagged world prices lpa converted into domestic purchasing power terms.

$$(16) \quad \frac{\Delta XA_0}{V_{-1}} = \Phi \left\{ \frac{\Delta(\max\{BA_0, 0\})}{V_{-1}}, \alpha_b, \varepsilon_b \right\}$$

The volume of exports of primary commodities at base year prices XA_0 depends primarily on the availability of a net export surplus. The volume of imports MA_0 is initially derived as a balancing item for each country but is then scaled to balance total imports and exports in the world as a whole. Finally the volume of net exports is adjusted to reflect the adjustment of import volume.

$$(17) \quad \Delta \log \frac{MA\$}{MA_0} = \Phi \left[\Delta \log pa_w, \Delta \log \frac{rx}{pp_0}, \alpha_b, \varepsilon_b \right]$$

Given the volume of imports, the value of imports of primary commodities $MA\$$ is once again a function of price changes. Import prices responds positively to world prices pa_w and the real exchange rate rx . The latter is scaled to have a larger impact in countries with lower base-year parities.

$$(18) \quad \Delta \log \frac{XA\$}{XA_0} = \Phi \left[\Delta \log pa_w, \Delta \log \frac{rx}{pp_0}, \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

The value of exports of primary commodities $XA\$$ responds similarly with an additional term implying slightly lower export prices in high income countries. Finally the value of exports is scaled to match the value of imports for the world as a whole.

Energy trade and environmental considerations

Energy production, demand and trade flows are determined in physical terms with supply and demand cleared by movements of the world price of oil. A distinction is made between carbon sources of supply (oil, gas and coal) and non-carbon sources (mainly hydro and nuclear electricity) which have radically different implications for global emissions.

$$(19) \quad \Delta \log \frac{ED}{N} = \Phi \left\{ \log \frac{ED_{-1}}{N_{-1}}, \Delta \log \frac{V}{N}, \Delta \log lped, \Delta \log tt, \Delta \log X_0, \frac{IV}{V_{-1}}, \log Yr_{-1}, \alpha_b, \varepsilon_b \right\}$$

Primary energy demand ED relative to population N fluctuates in the short run in response to changes in GDP per capita V/N , the terms of trade tt , export volume X_0 and inventory adjustment IV . In the longer term it responds to the level of per capita income

relative to the world average Yr and lagged changes in the world oil price converted to domestic purchasing power terms $lped$.⁸

$$(20) \quad \Delta \log EP_c = \Phi \left[\Delta \log ED \min \left(\frac{ED_{-1}}{EP_{-1}}, 1 \right), \Delta \log lped, \alpha_b, \varepsilon_b \right]$$

Annual changes in *production of carbon energy* EP_c are largely driven by growth of domestic demand ED ⁹ and are influenced by another lagged oil price indicator $lped$.¹⁰ Differences in resources and market access are reflected in country-specific intercepts.

$$(21) \quad \Delta \log \frac{EP_n}{mav(ED_{-1})} = \Phi \left[\log \frac{EP_{n-1}}{mav(ED_{-2})}, \Delta \log ED, lpepc, \alpha_b, \varepsilon_b \right]$$

Production of non-carbon energy EP_n is assumed to adjust to the lagged moving-average level of domestic energy demand as well as short-term fluctuations and a modified lagged oil price indicator that can take account of 'carbon-taxes' when applicable $lpepc$.¹¹

(22)

$$\Delta \log (EM - \max(ED - EP, 0)) = \Phi \left[\log (EM_{-1} - \max(ED_{-1} - EP_{-1}, 0)), \Delta \log EP_w, \alpha_b, \varepsilon_b \right]$$

Energy imports EM in excess of the amount required to fill the gap between domestic demand and supply are assumed to increase with growth of global supply EP_w . Exports are derived as the balancing item in energy supply and demand for each country.

$$(23) \quad \Delta \log \frac{CO_2}{ED - EP_n} = \Phi \left[\log \frac{CO_{2-1}}{ED_{-1} - EP_{n-1}}, \log Y_n, \log lttco2, \alpha_b, \varepsilon_b \right]$$

Carbon emissions CO_2 are modelled as a function of carbon energy use ($ED - EP_n$) and imputed carbon taxes ($tttco2$), with trends also influenced by the level of income per capita Y_n .

The world oil price pe_w is solved endogenously to find the value that equalizes total world supply and demand for energy expressed in tons of oil equivalent. Auxiliary

⁸ This term is a moving average of prior-year values and incorporates a transform to introduce the notion of a real oil price ceiling with energy demand and supply becoming increasingly price-elastic as the ceiling is approached.

⁹ In case of a country with very large non-carbon sources, this equation is modified to suppress the linkage between carbon energy supply and domestic energy demand.

¹⁰ See the footnote for energy demand.

¹¹ In simulations this variable may be loaded with a carbon tax to simulate penalties on use of fuels that generate high CO2 emissions.

equations convert physical imports and exports into imports and exports measured at base-year dollar prices ME_0 and XE_0 and the world oil price is used to estimate values of imports and exports $ME\$$ and $XE\$$ in international purchasing power terms.

External income and transfers

$$(24) \quad \frac{\Delta BIT\$}{Y\$_{-1}} = \Phi \left\{ \frac{BIT\$_{-1}}{Y\$_{-1}}, im_{US} \cdot \frac{NX\$_{-1}}{Y\$_{-1}}, \frac{\Delta NX\$}{Y\$_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Net income and transfers, $BIT\$$, is estimated as a balance to improve stability responding to the inherited net external position $NX\$$ which when multiplied by the interest rate of US Treasuries, im_{US} , serves as a proxy for flows of factor revenue.

Movements of *receipts* $XIT\$$ and *payments* $MIT\$$ on the external income and transfers account, are estimated by generating a proxy $NIT\$$, termed “covered” income and transfers, that represents the minimum of the two:

$$NIT\$ = \begin{cases} XIT\$ & \text{if } XIT\$ \leq MIT\$ \\ MIT\$ & \text{if } XIT\$ > MIT\$ \end{cases}$$

The model can then impute receipts and payments separately using the figure for net income and transfers from the equation above.¹²

$$(25) \quad \Delta \log NIT\$ = \Phi \left[\log NIT\$_{-1}, \log NXN\$_{-1}, \Delta \log X\$_{-w}, \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

The “covered” flow so defined is moderately path-dependent and is correlated with the level of net external assets and liabilities $NXN\$$ (defined as a “covered” position in similar fashion) and global trade, $X\$_{-w}$. These relations depend on the degree of development, again captured by relative income per capita YR .

Specification of exports and imports in value and volume terms and flows of external income and transfers completes modelling of the trade balance and current account. Together with the modules covering government and non-government income and expenditure and standard national accounting identities, these equations are sufficient to determine GDP (output), the terms of trade and gross national income.

The financial sector: flow of funds, holding gains and balances

Modelling of assets and liabilities, even if at very high degree of aggregation, provides a method for monitoring the plausibility of ongoing financial imbalances (flows) that may or may not result in acceptable accumulation of assets and liabilities (stocks) as time goes by. Also, it adds an anchor to the adjustments in the real economy by allowing balances of institutions to feed back into spending behaviour and policy reactions. The main difficulty, apart from paucity and unreliability of data, is that stocks may also be

¹² $XIT\$ = NIT\$ + \max(BIT\$, 0)$ $MIT\$ = NIT\$ + \max(-BIT\$, 0)$

strongly influenced by holding gains and losses. The GPM does not attempt a detailed asset pricing model or sophisticated analysis of portfolio behaviour of households, corporations, financial institutions etc. but the simplified price functions and balance sheet closures represented in the model serve to trace movements of the main financial variables on annual basis. Non-government sectors including state enterprises are aggregated into a single group, the private sector, which excludes the domestic banking sector for which separate data are available for virtually all countries. External assets and liabilities are modelled on a gross basis. Together with government balances these balance sheets provide a consistent breakdown of national wealth for each country or country group.

The matrix below shows assets and liabilities considered from the perspective of a single country. The matrix format makes it evident that every asset has an issuer for which it is a liability as well as a holder. For consistency the model ensures that total external assets and liabilities shown in the row for the rest of the world, measured in international purchasing power, are equal when summed over all countries. Net worth of the banking system is assumed to be zero (capital of banks is included in assets held by government, *AGF*, and other sectors, *DP*).

Matrix of assets and liabilities

	Assets (held by)				Net worth
	Banks	Government	Non-government	Rest of world	
Capital stock			KP		
Liabilities of					
Banks		Agf	DP		0
Government	Lgf		Lgo	(1)	
Non-government	LN			Lx\$/rx	WP
Rest of world	R\$/rx		Axo\$/rx	(1)	-Nx\$/rx

(1) A portion of *Lgo* and *Lx\$/rx* represents government debt held by non-residents and a portion of *Axo\$* represents external assets held by government. This does not invalidate the wealth identities ($Nx\$ = Lx\$ - R\$ - Axo\$$ and $WP = DP + Lgo + Axo\$/rx - LN - Lx\$/rx$).

For each asset identified in the matrix, the GPM tracks cash flows and holding gains or losses. The flow of funds matrix in the next table below shows the cash flows and savings by which they are financed.¹³ Again, every asset transaction has a buyer and seller so that all cash is accounted for, at least on a net basis.

¹³ The table includes one cash flow, *Iago*, for which there is no corresponding asset in the matrix above due to lack of data on the value of government-owned equity and lending to state enterprises and the private sector. By necessity these items that represent liabilities of the non-government sector are omitted from the calculation of private wealth, *WP*.

Summary flow-of-funds matrix

Sources of funds	Uses of funds / net acquisition of assets				Net lending
	Banks	Government	Non-government	Rest of world	
Capital stock			Ip + IV		
Issuers					
Banks		I _{Agf}	IDP		0
Government	IL _{gf}		IL _{go}	(1)	Y _g - G
Non-government	IL _N	I _{Ago}		IL _x \$/rx	Sp-Ip-IV
Rest of world	IR\$/rx		I _{Axo} \$/rx	(1)	-CA\$/rx

(1) See the note to the preceding table.

The following sub-sections show how the GPM models asset holdings, gains and losses and cash flows for each sector identified in these tables.

Government debt and asset transactions

The determination of changes in outstanding government debt Lg starts with net lending NLg which represents the difference between government income Yg and spending G discussed above.

The accumulation of government debt is affected by asset transactions, debt write-offs and, in the case of foreign currency debt, exchange rate movements.¹⁴ Historical data often show large discrepancies between government net lending and changes in outstanding debt that cannot readily be explained by revaluation effects. The discrepancy is usually the result of asset transactions such as lending and capital transfers to state enterprises, the private sector and foreign governments and proceeds of privatisation. To track the accumulation of government debt it is necessary to model the aggregate of these transactions as well as any debt forgiveness or write-offs.

The GPM divides government asset transactions between deposits and investment in the banking sector and transactions with the rest of the economy. Injections or accumulation of deposits with the banking sector I_{Agf} are treated as consequence of balance sheet requirements of government and banks, discussed further below. Net asset transactions with the rest of the economy I_{Ago} are modelled directly as a cash flow since data on corresponding assets are not available. Historical estimates of the cash flow are derived as a residual of government accounts after an approximate estimation of holding gains¹⁵ and the net figure is treated as a contribution to changes in private wealth Wp but not income.

¹⁴ Measured in real terms outstanding debt is also affected by inflation which reduces its value or deflation (a falling price level) which increases its value.

¹⁵ Since historical series on debt write-offs are not available, write-offs are implicitly included with asset transactions.

$$(26) \quad \frac{IAgo}{Y_{-1}} = \Phi \left\{ \frac{Lg_{-1}^{(-)}}{Y_{-1}}, \frac{NLg^{(+)}}{Y_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Government asset transactions with the rest of the economy $IAgo$ are negatively correlated with outstanding debt Lg and positively correlated with government net lending NLg .

Given net lending, holding gains¹⁶ and asset transactions with the rest of the economy, there is an implied change in the government's financial position Ngf defined as the value of deposits and investments in the domestic banking system less outstanding debt. This may be positive or negative depending on whether the government is a net creditor or debtor and the net figure is not sufficient by itself to determine each side of the balance sheet. Therefore the GPM sets a floor using a proxy variable termed *covered government debt* Ngj defined as the minimum of assets Agf and debt liabilities Lg . If sustained cash surpluses reduce outstanding debt to the minimum level further net cash receipts accumulate as deposits in the banking system. If on the other hand government is short of cash and deposits with the banking system are at a minimum level, further cash outlays must be financed by increases in outstanding debt.

$$(27) \quad \Delta \log Ngj = \Phi \left[\log Ngj_{-1}, \log \frac{R\$_{-1}}{rx_{-1}}, \Delta \log Y, \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

Covered government debt, so defined, is positively correlated with national income Y , the accumulated stock of foreign exchange reserves measured in domestic purchasing power $R\$/rx$ and the degree of development represented by the YR variable

Given the level of covered debt and the government's net financial position, the derivation of assets Agf and liabilities Lg follows. Calculation of the net cash flow $IAgf$ required to maintain government's investment and deposits with the banking system Agf requires estimation of capital gains or losses. The GPM makes the somewhat heroic assumption that government ultimately absorbs 70% of losses arising from abnormal debt write-offs by banks as well as gains or losses on exchange reserves held by the central bank which from an accounting perspective is part of the domestic banking system.

The remaining task to complete the government's balance sheet is estimation of the split between government debt held by the domestic banking system and other holders.

$$(28) \quad \Delta \log \frac{Lgo}{Lg} = \Phi \left[\Delta \log \frac{DP_{-1}}{Y_{-1}}, \log YR_{-1}, \alpha, \varepsilon_b \right]$$

¹⁶ Holding gains or losses in government accounts depend on changes in the real value of deposits and investments in the banking system as well as changes in the real value of outstanding debt.

Non-bank holdings of government debt Lg_0 as a share of total debt outstanding Lg ¹⁷ respond weakly to prior-year growth of bank deposits DP and are also influenced by the degree of development again represented by relative income per capita YR .

Cash flows ILg_0 and ILg_f follow from changes in values of outstanding debt after allowing for holding gains or losses.¹⁸

The external position and exchange rates

The external position may be understood as representing the accumulation of current account surpluses and deficits and holding gains or losses on external assets and liabilities. Changes in market positions are also influenced by acquisition or sale of exchange reserves by the monetary authority.

$$(29) \quad \Delta \log \frac{R\$}{rx \cdot Y_{-1}} = \Phi \left\{ \log(rpr\$), \frac{CA\$}{Y\$_{-1}}, \frac{CA\$_{-1}}{Y\$_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Exchange reserves, denominated in domestic purchasing power dollars, $R\$/rx$, are modelled as a ratio to national income.¹⁹ The reserve ratio responds to valuation changes $rpr\$$ and is positively correlated with the current account outturn $CA\$$. The equation has large residuals reflecting changes in central bank policy.

Given the movement of exchange reserves, changes in the *net market position* $Nxf\$$ are fully determined by the balance on current account, together with holding gains and losses. The *covered market position* $Nxi\$$ defined as the minimum of non-reserve assets and liabilities, is modelled as follows.

$$(30) \quad \Delta \log \frac{Nxi}{rxY_{-1}} = \Phi[\log Y_{-1}, \Delta \log R\$_{-1}, \Delta \log Y_{-1}, \alpha, \varepsilon_b]$$

The covered position which may also be viewed as an indicator of 'openness' of the external capital account has historically increased in an uneven and highly path-dependent manner. Countries with major global financial centres such as the US and the UK have far higher levels of external assets and liabilities relative to the size of their domestic economies than others and countries with managed exchange regimes may have very low levels of recorded non-reserve assets. Beyond these country-specific factors the covered position typically responds to the level and growth of national income Y and reserves $R\$$. Together with the net market position Nxf representing the

¹⁷ A slightly more complex transform is used in the model to keep the share below unity.

¹⁸ When historical time series are lacking or incomplete, the GPM assumes that government debt denominated in foreign currency diminishes with a rising level of per capita GDP. Erosion of the value of domestic currency debt is determined by domestic price inflation.

¹⁹ Once again the model uses a slightly more complex function to impose a ceiling on exchange reserves relative to annual income.

accumulation of current account and reserve transactions and revaluations, the degree of openness determines total external assets $Axo\$$ and liabilities $Lx\$$.

Exchange rates

The real exchange rate represents the combined effect of changes in domestic and external price levels and changes in nominal exchange rates. The real exchange rate that results is critical for the determination of relative prices of domestic and external goods and services and unit costs in each country relative to competitors. Since participants in exchange markets can be assumed to be well aware of the need for nominal exchange rate movements to compensate for differences in inflation, the GPM models the real exchange rate directly, leaving nominal exchange rate movements to be inferred as the consequence of changes in the real exchange rate and differential rates of inflation.

$$(31) \quad \Delta \log rx = \Phi \left[\log rx_{-1}, \Delta \log (1 + rxna), \Delta^2 \log ph_w, \Delta \log \frac{V}{V_{-5}}, \log YR_{-1}, \alpha, \varepsilon_b \right]$$

The *real exchange* rx rises in the long run with sustained GDP growth and increases in relative income per capita YR . In the short run it fluctuates in response to nominal exchange rate changes $rxna$ and changes in global inflation ph_w . Inevitably there are significant fixed effects and large residuals reflecting differences in financial systems and exchange regimes as well as changing market expectations about future economic growth and trade prospects of individual countries.²⁰

Revaluation of external assets and liabilities

$$(32) \quad \log(1 + rpr\$) = \Phi[\Delta \log ph_w, \alpha_b, \varepsilon_b]$$

$$(33) \quad \log rpaxo\$ = \Phi[\Delta \log ph_w, \log YR_{-1}, \alpha_b, \varepsilon_b]$$

$$(34) \quad \log rplx\$ = \Phi[\Delta \log ph_w, \Delta \log pkp, \alpha_b, \varepsilon_b]$$

The real value of external assets in international purchasing power (reserves $rpr\$$, other assets $rpaxo\$$ and liabilities $rplx\$$) is eroded by world inflation $\Delta \log(ph_w)$. Liabilities appreciate with a rise in the real price of capital assets pkp in each country while gains in the real value of other assets tends to be lower in countries with higher relative income YR .

Real values in domestic terms are further affected by movements in the real exchange rate giving rise to additional holding gains or losses in the balance sheets of domestic residents.

²⁰ Exchange rates whether nominal or real have one less degree of freedom than the number of countries since they represent relative rather than absolute prices. The GPM determines the real exchange rate for each country independently in the first instance and makes a scaling correction for all countries to maintain consistency for the world as a whole.

An important issue for open economies with large financial sectors is the movement of asset prices relative to liabilities which may, as in the case of the USA when the dollar experiences a significant depreciation, generating net holding gains as foreign-currency assets appreciate relative to dollar liabilities on a scale sufficient to compensate substantial current account deficits. By implication other countries experience holding losses as their dollar assets depreciate relative to non-dollar liabilities. These effects which make the relationship between international positions and current accounts highly uncertain in the longer run are another subject of continuing research.

The domestic banking system

The final component of domestic balance sheets is assets and liabilities of the banking system. Exchange reserves $R\$/rx$, government investment in banks Agf and liabilities to banks Lgf have already been discussed. The remaining components of the balance sheet of the domestic banking system are domestic lending LN and, as a balancing item, other liabilities DP including capital and net external liabilities as well as domestic deposits. The two items LN and DP are again modelled by considering the net position, Nff , which may in principal be positive or negative, and the covered position, Nfi , formally defined as the minimum of lending to the private sector LN and liabilities DP . In practice Nfi nearly always represents lending as the banking system's net position with the private sector Nff is positive and deposits are the larger of the two. In periods of credit expansion loans and deposits rise together, represented by increasing Nfi .

The net position of the domestic banking system with the private sector Nff is given by the three factors mentioned earlier - reserves R , government assets Agf and government debt held by banks Lgf .

Expansion or contraction of the covered position Nfi representing lending to the private sector is modelled as follows:

(35)

$$\Delta \log \frac{Nfi}{Y_{-1}} = \Phi \left\{ \log \frac{Nfi_{-1}}{Y_{-1}}, \log Y_{-1}, \Delta \log Y, \frac{Nff}{Nfi_{-1}}, \frac{\Delta Nff}{Nfi_{-1}}, \frac{\Delta Lgf}{Y_{-1}}, \frac{R\$_{-1} + Nxi\$_{-1}}{Y\$_{-1}}, \frac{WLNA}{LN_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Thus, the ratio of *covered bank lending to income* $Nfi/Y(-1)^{21}$ responds positively to income Y , excess deposits Nff , liquidity in the form of government debt LGF , and the size of the external position $R\$ + Nxi\$$. Past debt write-offs $WLNA$ are included as an

²¹ This ratio is written in a form that imposes a ceiling equal to 2.5 times annual income.

exogenous variable whose value can be specified in scenarios to simulate the impact of a financial crisis.²²

The net position and covered lending determine loans LN and liabilities DP . Cash flows are again derived by subtracting estimated holding gains from balance sheet changes.²³

Capital stock and private wealth

Financial components of private wealth have now been fully accounted for. It remains to consider the value of the capital stock which includes land, produced capital goods and IPR. Like many other macro-models the GPM calculates the stock of produced capital goods KI by the perpetual inventory method, accumulating investment in capital goods and inventory, $IP + IV$, in each period and deducting an estimate for capital consumption.

$$(36) \quad \Delta \log(pkp) = \Phi \left\{ \log(pkp_{-1}), \Delta \log(pkp_{-1}), \log \frac{V}{VT}, \alpha_b, \varepsilon_b \right\}$$

The *real price of capital* pkp is modelled as a path-dependent variable with momentum represented by the lagged $d\log(pkp)$ term, responding to the level of capacity utilization V/VT . The *value of the capital stock* is then calculated as the product of the stock of produced capital goods KI and the real price of capital.

Private wealth Wp is defined as the sum of the real value of capital and net financial assets of the private sector. Changes in private wealth are identically equal to the sum of savings, net receipts from government asset transactions and holding gains and losses less capital consumption.

Interest rates²⁴

The GPM models two interest rates for each country a short-term 'policy' rate is and a longer-term bond rate im .

²² In this case again the lack of historical time series means that modelling has to be based on a priori assumptions that cannot be tested systematically.

²³ This time holding gains or losses exclude items such as gains on exchange reserves and 70% of losses on abnormal debt write-offs that are absorbed by government.

²⁴ A comment is necessary on the measurement procedure and significance of series for interest rates and inflation for countries that comprise countries using different currencies. The GPM measures nominal interest rates and inflation as weighted averages using ppp expenditure in each country as the weighting factor. This procedure has some drawbacks when very different rates of inflation are experienced in countries belonging to a group of countries in the GPM. These are familiar problems affecting regional currency agreements as well.

$$(37) \quad \Delta \log(is) = \Phi \left\{ \log^{(-)}(is_{-1}), \log^{(+)}(pi_{-1}), \Delta \log^{(+)}(pi), \log^{(+)} \frac{V}{VT}, \alpha_b, \varepsilon_b \right\}$$

Changes in the policy rate is ²⁵ follow a Taylor rule determined by domestic inflation pi and capacity utilization, V/VT .

$$(38) \quad \log im = \Phi \left[\log is_{-1}, \Delta \log is, \log pvi_{-1}, \Delta \log pvi, \log \frac{VV_{-1}}{N_{-1}}, \alpha_b, \varepsilon_b \right]$$

The bond rate im responds to the level and rate of change of the policy rate is and cost inflation pvi with a tendency to be lower in countries with higher GDP per capita VV/N .

Inflation and employment

Price formation

Domestic cost inflation pvi is modelled as the outcome of increases in unit labour cost, determined by changes in average money earnings ei and output per person employed V/NE with a variable profit markup mu and a further markup for indirect taxes less subsidies rtx discussed in the section of government income and expenditure. Thus

$$1 + pvi = (1 + ei) \left[\frac{V_{-1}/NE_{-1}}{V/NE} \frac{1 + mu}{1 + mu_{-1}} \frac{1 + rtx}{1 + rtx_{-1}} \right]$$

$$(39) \quad \Delta \log ei = \Phi \left[\log ei_{-1}, \log pi_{-1}, \Delta \log \frac{V}{NE}, \log rx_{-1}, \log YR_{-1}, \alpha_b, \varepsilon_b \right]$$

Average earnings per person employed ei ²⁶ respond to increases in output per person employed V/NE and, with some lag, to price inflation pi , with negative pressure exerted by a higher real exchange rate rx , influenced by the relative income per capita YR

(40)

$$\Delta \log(1 + mu) = \Phi \left[\log(1 + mu_{-1}), \log(1 + ei), \Delta \log \frac{V}{NE}, \Delta \log \frac{LN}{VV_{-1}}, \Delta \frac{G}{VV_{-1}}, \Delta \log tt, \Delta \frac{XE\$}{rxVV}, \alpha_b, \varepsilon_b \right]$$

The profit markup on average unit labour cost mu is strongly path dependent and in the short run responds to the interaction between forces driving wage costs, ei on the one hand and productivity growth V/NE , on the other. The mark-up is also affected by credit

²⁵ The GPM uses a modified transform that allows negative interest rates as these are sometimes found in estimated historical data. This problem should be eliminated by data improvements.

²⁶ The model includes a constant that allows for reductions in average earnings per person in case of deflation or economic crisis.

conditions LN/VV , government policies including social protection and government employment G/VV , movements of the terms of trade tt and energy exports $XE\$$.

The distribution of GDP between labour income $VVEM$ and profits $VVPR$ ²⁷ is largely determined by the profit markup.

Domestic price inflation, pi , measured as annual changes in the domestic expenditure deflator, is the outcome of cost inflation and movements of the terms of trade and is derived by an identity which is a consequence of national accounting definitions. If the terms of trade move in a country's favour, a greater proportion of domestic costs are passed through to exports and/or import prices fall to the benefit of the domestic market. However higher export prices do not by themselves reduce domestic inflation. Indeed an increase in export prices usually implies higher costs or profits of producers which may result in higher domestic prices. The terms of trade benefit to domestic price inflation only takes effect if and when import prices fall or rise less than export prices while domestic costs (including profit) fall or remain unchanged.

Employment

Employment is analyzed separately for male and female members of the labour force, distinguishing young persons aged 15-24 and adults aged 25 and over. The starting point is participation in the labour force, generally represented as a percentage of the relevant population. Unemployment rates are modelled explicitly as functions of economic activity and employment is derived by identity as the number of persons in the labour force less those unemployed.

$$(41) \quad \Delta \log NLNga = \Phi [\log NLNga_{-1}, NONga, NCNga, NURN, \log YR_{-1}, \alpha_b, \varepsilon_b]$$

Labour force participation for each gender "g" and age-group "a" $NLNga$ tends to reduce with urbanisation $NURN$ but may increase slightly with GDP per capita. Adult participation defined relative to the entire population aged 25 or over falls with ageing $NONga$ while participation of young persons is higher in countries with larger numbers of children $NCNga$. Adult male participation rates tend to be slightly higher, and adult female rates lower, in countries with higher income YR .

In the GPM panel labour force participation does not show a significant cyclical component. The clearest longer-term trend is a reduction in participation of young persons as the number of children declines and secondary and tertiary education are extended.

²⁷ In the GPM labour income includes the national accounting categories 'compensation of employees' and 'mixed income' and profits are represented by the 'operating surplus'. Employment includes employees, self-employed and family workers.

(42)

$$\Delta \log NULga = \Phi \left[\log NULga_{-1}, \Delta \log Nga, \beta \Delta \log V, \beta \Delta \log V_{-1}, \beta \Delta \log IP, \frac{IVw}{Vw}, NURN, \alpha_b, \varepsilon_b \right]$$

The unemployment rate for each gender 'g' and age group 'a' $NULga$ increases with faster growth of population Nga and fluctuates in response to growth of activity V and investment IP with a significant impact of the global cycle represented by world inventory changes IVw . Unemployment rates also tend to rise with urbanisation. The coefficient β multiplying activity and investment terms in the equation above represents a response that increases with the relative income level YR .

Aggregate employment $NEga$ for each gender 'g' and age group 'a' is obtained by multiplying population by the participation rate and subtracting the number of unemployed. Total employment NE is the sum of employment for each gender and age group.

$$(43) \quad \Delta \log NURN = \Phi \left[(\log VV / VV_{-3}) / 3, \alpha_b, \varepsilon_b \right]$$

Urbanization $NURN$ is a long-term ongoing process that shows some response to GDP growth.²⁸

$$(44) \quad \Delta \log \left(1 + \frac{NIM}{NE_{-1}} \right) = \Phi \left[\log \left(1 + \frac{NIM_{-1}}{NE_{-2}} \right), YR_{-1}, \Delta \log NE, \alpha_b, \varepsilon_b \right]$$

Growth of population of working age is affected by *net migration* NIM responding to the relative income level and growth of employment in the country.²⁹

The GPM includes a provisional analysis of employment by gender and broad sector with estimates of GDP by broad sector for comparison. Another preliminary development is a breakdown of total employment between employees and other categories of worker (self-employed and family workers) with a matching breakdown of labour income between compensation of employees and mixed income.

SELECTED MULTIPLIER TABLES

Apart from econometric properties of the equations specified above, which are captured by the usual tests, an important quality of a complex model is its ability to generate plausible results when shocks to behavioural equations play out through the model as a whole. This is the essence of 'multiplier analysis', which highlights the model's ability to capture not only feedbacks internal to a particular economy but also those which result

²⁸ The LHS is formulated to constrain the share of urban population to the range zero to 1.

²⁹ The increase in population in each age group is exogenous (based on UN projections).

from spill-overs to the rest of the world and back to each economy, including the one where the shock originated.

In the following pages selected multiplier tables are presented, showing the more common shocks and calculated outcomes of such shocks on critical variables. The results here show the impact of a single shock in one country and one year.

To examine composition effects when confidence shocks or policy changes occur in more than one country and cumulative effects when they are sustained over extended time periods it is necessary to specify full-scale scenarios. As is well known the impact of some shocks and policies is reinforced when they are implemented simultaneously in many countries but in other cases the impact may be weakened or even neutralised. A similar caution may be made about the time-scale over which shocks or policy changes are sustained. In some cases impacts cumulate in a way that changes longer-term dynamics but in other cases they generate contrary tendencies that limit their ultimate effects.

Africa Low Income

Impact of the shock on:	Resulting from:			
	government expenditure	net direct taxes	rate of indirect taxation	profit markup
<i>\$bn if shock in \$bn</i>	\$1bn shock	\$1bn shock	1% change	1% change
<i>% change if shock in %</i>				
	<i>[nb: for net lending & CA, % change is measured as % of GDP]</i>			
GDP	1.68	-0.21	-0.40	-0.17
consumption	0.48	-0.23	-0.60	-0.26
fixed private investment	0.16	-0.02	-0.12	-0.01
govt exp. on goods & services	1.00	0.05	0.23	-0.01
government net lending	-0.61	0.91	0.75	-0.03
current account	-0.10	0.05	0.17	0.03

North Africa

Impact of the shock on:	Resulting from:			
	government expenditure	net direct taxes	rate of indirect taxation	profit markup
<i>\$bn if shock in \$bn</i>	\$1bn shock	\$1bn shock	1% change	1% change
<i>% change if shock in %</i>				
	<i>[nb: for net lending & CA, % change is measured as % of GDP]</i>			
GDP	1.66	-0.12	-0.26	-0.16
consumption	0.49	-0.18	-0.70	-0.35
fixed private investment	0.20	-0.02	-0.02	0.01
govt exp. on goods & services	1.00	0.06	0.24	-0.01
government net lending	-0.65	0.92	0.79	-0.03
current account	-0.13	0.04	0.19	0.03

Argentina**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.67	-0.11	-0.44	-0.31
consumption	0.43	-0.16	-0.76	-0.49
fixed private investment	0.20	-0.02	-0.15	-0.08
govt exp. on goods & services	1.00	0.05	0.21	-0.02
government net lending	-0.61	0.92	0.69	-0.07
current account	-0.11	0.01	0.05	0.03

Brazil**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.62	-0.12	-0.73	-0.37
consumption	0.39	-0.12	-0.79	-0.52
fixed private investment	0.14	-0.01	-0.28	-0.06
govt exp. on goods & services	1.00	0.02	-0.65	-0.14
government net lending	-0.56	0.94	0.79	-0.07
current account	-0.13	0.02	0.09	0.04

Canada**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.53	-0.02	-0.25	-0.18
consumption	0.41	-0.09	-0.67	-0.43
fixed private investment	0.16	-0.00	0.15	0.13
govt exp. on goods & services	1.00	0.08	0.23	-0.01
government net lending	-0.64	0.93	0.74	-0.03
current account	-0.25	0.05	0.14	0.06

Central America and Caribbean

Impact of the shock on:

\$bn if shock in \$bn

% change if shock in %

[nb: for net lending & CA, % change is measured as % of GDP]

Resulting from:

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.57	-0.23	-0.46	-0.16
consumption	0.46	-0.26	-0.72	-0.27
fixed private investment	0.13	-0.02	-0.09	0.02
govt exp. on goods & services	1.00	0.05	0.21	-0.01
government net lending	-0.65	0.91	0.69	-0.03
current account	-0.18	0.05	0.10	0.03

China

Impact of the shock on:

\$bn if shock in \$bn

% change if shock in %

[nb: for net lending & CA, % change is measured as % of GDP]

Resulting from:

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	2.22	-0.19	-0.30	-0.13
consumption	0.46	-0.19	-1.10	-0.55
fixed private investment	0.56	-0.07	0.00	0.09
govt exp. on goods & services	1.00	0.05	0.21	-0.01
government net lending	-0.23	0.88	0.63	-0.04
current account	-0.20	0.05	0.08	0.02

CIS and other

Impact of the shock on:

\$bn if shock in \$bn

% change if shock in %

[nb: for net lending & CA, % change is measured as % of GDP]

Resulting from:

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.06	-0.29	-0.73	-0.35
consumption	0.22	-0.15	-0.96	-0.62
fixed private investment	0.14	-0.04	-0.26	-0.05
govt exp. on goods & services	1.00	0.05	0.18	-0.03
government net lending	-0.73	0.85	0.60	-0.10
current account	-0.32	-0.11	-0.12	0.01

France

Impact of the shock on:*\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.61	0.09	-0.27	-0.38
Consumption	0.38	-0.02	-0.66	-0.66
fixed private investment	0.13	0.01	0.08	0.04
govt exp. on goods & services	1.00	0.08	0.21	-0.03
government net lending	-0.59	0.94	0.67	-0.09
current account	-0.20	0.04	0.08	0.01

Germany

Impact of the shock on:*\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.64	0.02	-0.16	-0.31
consumption	0.40	-0.05	-0.60	-0.59
fixed private investment	0.13	-0.00	0.12	0.05
govt exp. on goods & services	1.00	0.06	0.24	-0.02
government net lending	-0.61	0.95	0.77	-0.06
current account	-0.19	0.03	0.22	0.06

India

Impact of the shock on:*\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.92	0.33	1.41	0.05
consumption	0.51	-0.15	-0.17	-0.17
fixed private investment	0.29	0.05	0.97	0.11
govt exp. on goods & services	1.00	0.39	6.41	0.58
government net lending	-0.54	0.78	0.39	-0.06
current account	-0.10	-0.00	-0.04	0.00

Indonesia

Impact of the shock on:*\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.87	-0.25	-0.43	-0.17
consumption	0.56	-0.26	-0.87	-0.34
fixed private investment	0.28	-0.04	-0.10	0.01
govt exp. on goods & services	1.00	0.04	0.24	-0.01
government net lending	-0.60	0.91	0.68	-0.03
current account	-0.13	0.04	0.09	0.02

Italy

Impact of the shock on:*\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.72	-0.03	-0.36	-0.32
Consumption	0.45	-0.11	-0.72	-0.54
fixed private investment	0.13	-0.01	0.02	0.04
govt exp. on goods & services	1.00	0.06	0.19	-0.03
government net lending	-0.57	0.93	0.63	-0.08
current account	-0.19	0.04	0.04	0.00

Japan

Impact of the shock on:*\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.82	-0.13	-0.43	-0.26
Consumption	0.44	-0.16	-0.83	-0.47
fixed private investment	0.17	-0.02	0.00	0.06
govt exp. on goods & services	1.00	0.07	0.22	-0.01
government net lending	-0.65	0.91	0.71	-0.05
current account	-0.26	0.03	0.08	0.05

Other East Asia**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.08	-0.35	-0.89	-0.14
consumption	-0.14	-0.43	-1.87	-0.29
fixed private investment	0.22	-0.02	0.16	0.05
govt exp. on goods & services	1.00	0.05	0.21	-0.01
government net lending	-0.74	0.89	0.66	-0.02
current account	-0.06	0.07	0.18	0.02

Other East Asia High Income**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.58	-0.07	-0.32	-0.20
consumption	0.41	-0.11	-0.64	-0.45
fixed private investment	0.19	-0.01	0.03	0.07
govt exp. on goods & services	1.00	0.06	0.26	-0.01
government net lending	-0.68	0.93	0.79	-0.03
current account	-0.26	0.05	0.20	0.05

Other North & West Europe**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.64	0.09	-0.14	-0.34
consumption	0.41	-0.01	-0.60	-0.73
fixed private investment	0.16	0.01	0.17	0.07
govt exp. on goods & services	1.00	0.08	0.24	-0.03
government net lending	-0.58	0.96	0.78	-0.08
current account	-0.13	0.07	0.28	0.01

Other South Asia**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.86	-0.35	-0.53	-0.16
consumption	0.58	-0.37	-0.76	-0.23
fixed private investment	0.17	-0.03	-0.15	0.01
govt exp. on goods & services	1.00	0.03	0.20	-0.01
government net lending	-0.66	0.90	0.70	-0.03
current account	-0.10	0.04	0.06	0.02

Other South America**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.40	-0.33	-1.00	-0.22
consumption	0.15	-0.38	-1.64	-0.35
fixed private investment	0.21	-0.03	-0.18	-0.02
govt exp. on goods & services	1.00	0.04	0.19	-0.01
government net lending	-0.67	0.88	0.64	-0.05
current account	-0.08	0.06	0.20	0.04

Other South & East Europe**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.66	-0.02	-0.28	-0.26
consumption	0.43	-0.12	-0.70	-0.48
fixed private investment	0.13	-0.01	0.08	0.06
govt exp. on goods & services	1.00	0.07	0.22	-0.02
government net lending	-0.57	0.93	0.68	-0.07
current account	-0.17	0.05	0.08	0.00

Other West Asia**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.31	-0.21	-2.99	-0.31
consumption	0.18	-0.23	-4.84	-0.64
fixed private investment	0.17	-0.02	-0.60	-0.02
govt exp. on goods & services	1.00	0.06	-0.06	-0.02
government net lending	-0.80	0.87	-0.22	-0.08
current account	-0.25	-0.05	-1.00	-0.01

South Africa**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.60	-0.11	-0.35	-0.16
consumption	0.41	-0.19	-0.69	-0.28
fixed private investment	0.14	-0.01	-0.03	0.02
govt exp. on goods & services	1.00	0.08	0.22	-0.01
government net lending	-0.64	0.90	0.73	-0.03
current account	-0.14	0.03	0.07	0.02

Turkey**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.73	-0.15	-0.22	-0.16
consumption	0.49	-0.22	-0.65	-0.28
fixed private investment	0.18	-0.02	0.01	0.00
govt exp. on goods & services	1.00	0.05	0.23	-0.01
government net lending	-0.65	0.92	0.70	-0.03
current account	-0.22	0.06	0.17	0.04

United States of America**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.85	-0.16	-0.38	-0.24
consumption	0.50	-0.19	-0.71	-0.40
fixed private investment	0.16	-0.02	0.01	0.05
govt exp. on goods & services	1.00	0.05	0.20	-0.02
government net lending	-0.46	0.90	0.66	-0.07
current account	-0.16	0.04	0.14	0.05

United Kingdom**Impact of the shock on:***\$bn if shock in \$bn**% change if shock in %**[nb: for net lending & CA, % change is measured as % of GDP]***Resulting from:**

	government expenditure	net direct taxes	rate of indirect taxation	profit markup
	\$1bn shock	\$1bn shock	1% change	1% change
GDP	1.55	0.02	-0.18	-0.24
consumption	0.38	-0.07	-0.59	-0.49
fixed private investment	0.10	-0.00	0.15	0.12
govt exp. on goods & services	1.00	0.07	0.22	-0.02
government net lending	-0.64	0.93	0.70	-0.05
current account	-0.25	0.04	0.18	0.08

APPENDIX: NOTATION, DEFLATORS AND MODEL VARIABLES

1. NOTATION AND MEASUREMENT CONVENTIONS

Domestic income and expenditure

Variables measured in real terms are denoted by an upper-case symbol followed by a 2 or 3 character country or country code or **W** for the world total:

e.g. v_{JA} Japan's GDP
 $v_W = \text{sum}(v_?)$ world GDP (where ? denotes each country)

GDP is measured at base-year dollar prices divided by a different base-year purchasing power parity adjustment pp_0 for each country. Real incomes and expenditures in each country are measured by dividing current dollar values by the domestic expenditure deflator for the country to convert the figures to base-year values and further dividing by the base-year purchasing power adjustment to make them more comparable across countries.

It follows that current dollar values, denoted with a leading underscore, are equal to real values multiplied by the dollar price of domestic expenditure ph for each country:

e.g. $_Y_{EU} = ph_{EU} * Y_{EU}$ income of Europe in current dollars

International trade and other external transactions

International transactions denoted by a \$ suffix are measured in terms of world purchasing power. The deflator used is the deflator for world expenditure aggregated over all countries in purchasing power parity terms. The value of this deflator is set to 1 in the base year (2005) to facilitate comparison of \$ variables with current price series.

e.g. $x\$_{CN} = _x_{CN}/ph_w$ China's exports (international value)

The real exchange rate rx for each country is defined as the ratio between the local price deflator ph and the world price deflator ph_w . Thus international values may be converted to domestic purchasing power by dividing by the real exchange rate:

e.g. $rx_{CN} = ph_{CN}/ph_w$ China's real exchange rate
 $x_{CN} = x\$_{CN}/rx_{CN}$ China's exports (domestic value)

The latter figure x_{CN} represents the buying power of China's exports in terms of goods and services within China. This is considerably larger than the buying power of the same exports in terms of globally-consumed goods and services $x\$_{CN}$ which, taking an average for the world as a whole, are more expensive than in China.

Conversely the income of each country, normally measured in domestic purchasing power, is converted to world purchasing power by multiplying by the real exchange rate.

e.g. Y_{IN} India's income (domestic purchasing power)
 $Y\$_{IN} = Y_{IN} * rx_{IN}$ India's income (world purchasing power)

The definitions above imply that the weighted average real exchange rate for the world as a whole is a constant (equal to the base-year value of the world expenditure deflator before the latter is set to 1). Thus with n countries there are only $n-1$ degrees of freedom for real exchange rates just as there are only $n-1$ degrees of freedom for nominal exchange rates.

The 'volume' of exports and imports measured at base-year prices and market exchange rates is denoted by suffix 0:

e.g. $XE0_{WA}$ West Asia's energy exports at base-year international prices.

The contribution of West Asia's energy exports to West Asia's GDP measured in constant ppp units is given by

$$XE0_{WA}/pp0_{WA}$$

where $pp0_{WA}$ is the base-year purchasing-power adjustment for West Asia.

World exports are equal to world imports in value and volume terms for each commodity group and for goods and services as a whole:

e.g. $X\$_W = M\$_W = \text{sum}(X\$_?) = \text{sum}(M\$_?)$
 $X0_W = M0_W = \text{sum}(X0_?) = \text{sum}(M0_?)$
 $XA\$_W = MA\$_W = \text{sum}(XA\$_?) = \text{sum}(MA\$_?)$
 etc.

Similar identities hold for other components of balance of payments current and capital accounts and for cross-border holdings of assets and liabilities when the latter are valued in terms of the same global purchasing-power standard. But when international transactions and assets are valued in terms of their purchasing power within each country or country group, it is no longer true that totals balance out.

e.g. $CA_W = \text{sum}(CA\$_?/rx_?)$

where CA represents the current account surplus (+) or deficit (-), is not equal to zero, although the same total valued in world purchasing power

$$CA\$_W = \text{sum}(CA\$_?)$$

is equal to zero for the world as a whole.

One implication is that when excess savings are transferred from one country to another, the value of the savings in terms of purchasing power in each country is not the

same. Thus if savings are transferred from a low-income country where goods and services are cheap to a high-income country where goods and services are more expensive, the volume of expenditure foregone in the low-income country is greater than the volume of additional expenditure in the high-income country. Evidently the reverse is the case when savings are transferred from high-income to low-income countries.

Prices and rates

Prices, rates of inflation, interest rates and exchange rates are denoted with lower-case symbols:

e.g.	<code>pvi_EU</code>	Europe's average local currency cost inflation rate (% p.a.)
	<code>is_EU</code>	Europe's average local ccy. short-term interest rate (% p.a.)
	<code>irs_w</code>	world average 'real' short-term interest rate (% p.a.)

Values for a country group are weighted averages of values for countries in the group.³⁰

Assets and liabilities

Assets and liabilities at end year are converted from current dollars to real values by dividing by the period expenditure deflator (the same deflator that is used for income and expenditure in the period). The real value of assets and liabilities may rise or fall from year to year on account of changes in their price or nominal value in the currency in which they are quoted or denominated, as well as changes in the dollar exchange rate for that currency and changes in the purchasing power of the dollar as measured by the domestic or world expenditure deflator.

Holding gains measured in real terms are denoted with the prefix \mathfrak{H} and cash flows (net acquisition or sale) of assets are denoted with the prefix \mathfrak{I} . For example

<code>AGF_US</code>	US government investment in banks
<code>HAGF_US</code>	holding gains or losses on US government investment in banks
<code>IAGF_US</code>	net cash proceeds of US government transactions in bank liabilities

The relationship between stocks and flows may be written as

$$\mathbf{AGF_US} = \mathbf{AGF_US}(-1) + \mathbf{HAGF_US} + \mathbf{IAGF_US}$$

³⁰ Expenditure weights are used to average domestic price inflation and nominal interest rates across countries within a country group. GDP weights are used to average cost inflation. Implicitly, group-level real interest rates are expenditure-weighted averages of rates in each country.

The valuation of assets and liabilities brought forward from the previous year is represented by a variable whose name begins with **rp**.

e.g. **LG_IN** India government debt at end-year
rpfa_IN valuation for prior-year assets
LG_IN(-1)*rpfa_IN value of debt brought forward
ILG_IN proceeds of debt issues less redemptions

End-year debt is equal to debt brought forward plus issues less redemptions:³¹

$$LG_IN = LG_IN(-1)*rpfa_IN + ILG_IN$$

External assets and liabilities are treated in a similar fashion using variable names suffixed with \$ to indicate an international value:

e.g.	R\$_{JA}	Japan's exchange reserves at end year
	rpr\$_{JA}	valuation ratio for exchange reserves brought forward
	IR\$_{JA}	net purchases less sales of exchange reserves

Actual and simulated values

Historical series (extended to include current-year estimates) are designated by the variable name and country code with no additional suffix. Baseline series projected into the future by the model have suffix **_o**. Series simulated in alternative scenarios have the relevant scenario suffix, e.g. **_1** or **_3a**.

Residuals and instruments

Values of behavioural variables simulated by the model may be influenced by residual terms or 'instruments' that modify the typical pattern of behaviour. In GPM simulations instruments are specified as country-specific intercept shifts in behavioural equations, denoted by the variable name and country code with suffix **_ins**. Values of **_ins** series may be defined exogenously or set by policy rules that depending on the rule may also create series suffixed with **_tar** (target values) or **_sav** (saved values of instruments).

Example: primary energy production in Europe (million tons of oil equivalent)

ED_EU	historical values and current year estimates
ED_EU_0	values in the baseline projection
ED_EU_1	values in scenario 1
ED_EU_ins	instrument (may take different values in each scenario)

³¹ Holding gains or losses may occur on purchases and sales in the current year. Therefore the interpretation of **rpfa** given here is not strictly precise. A more accurate definition would be that **(rpfa-1)** represents the ratio of holding gains and losses on current-year transactions and prior-year assets to the real value of prior-year assets at the end of the preceding year. In general the valuation **rp** is defined such that holding gains or losses $H = (rp-1)*A(-1)$ where **A** represents the end-year value of an asset.

2. REAL VALUES, VOLUMES AND PRICE DEFLATORS

<i>Series</i>	<i>Description</i>	<i>Source or formula</i>
1. Expenditure and expenditure deflators		
APT	GDP in current dollars	databank
APT1	GDP at current purchasing power parity	databank
AXD	domestic expenditure in current dollars	databank
AXD0	domestic expenditure at base-year prices	databank
PXA	index of world prices for primary commodities	databank
PXE	index of world price of oil	databank
<i>Model variables - country level</i>		
pp0	base-year purchasing power parity adjustment	$APT(\text{base}) / APT1(\text{base})$
H	domestic expenditure, base-year purchasing power	$AXD0 / pp0$
ph	domestic expenditure deflator	$AXD / H = AXD \cdot pp0 / AXD0$
_H	domestic expenditure in current dollars	$H \cdot ph$
<i>Model variables – global</i>		
HW	world expenditure, base-year purchasing power	$\text{sum}(H)$
pp0w	base-year PPP adjustment	$\text{sum}(AXD(\text{base})) / \text{sum}(H(\text{base}))$
phw	world expenditure deflator	$\text{sum}(AXD) / (pp0w \cdot \text{sum}(H))$
paw	world price of primary commodities, base-year world value	PXA / phw
pew	world price of oil, base-year world value	PXE / phw
2. Real exchange rate, current account, national income and GDP		
APT0	GDP at base-year prices	databank
AXX	exports in current dollars	databank
AXX0	exports at base-year prices	databank
AXM	imports in current dollars	databank
AXM0	imports at base-year prices	databank
BCA	current account in dollars	databank
<i>Model variables - country level</i>		
rx	real exchange rate	ph / phw
CA\$	current account, base-year world value	BCA / phw
TB\$	trade balance, base-year world value	$(AXX - AXM) / phw$
TB0	net exports at base-year prices	$TB0 = AXX0 - AXM0$
BIT\$	balance on income and transfers, base-year world value	$CA\$ - TB\$$
Y	national income, base-year purchasing power	$(AXD + BCA) / ph$
V	GDP volume, base-year purchasing parity	$APT0 / pp0$
VV	expenditure on GDP	$H + TB\$ / rx$
tt	terms of trade effect (ratio of GDP value to volume)	$(H + TB\$ / rx) / V$

<i>Series</i>	<i>Description</i>	<i>Source or formula</i>
<i>Country level theorems</i>		
T1	Income, domestic expenditure and current a/c	$H = C + IP + IV + G$ $Y = H + CA\$/rx$ $= H + TB\$/rx + BIT\$/rx$
T2	GDP, expenditure and net export volume	$V = H + TB0/pp0$ $VV = H + TB\$/rx$
T3	Income, GDP and the terms of trade	$Y = V.tt + BIT\$/rx$
<i>Theorem - world level</i>		
T4	Weighted average real exchange rate	$sum(H.rx)/sum(H) = pp0w$
<i>Proof</i>	$H.rx = H.ph/ph_w$ $= AXD.pp0_w.sum(H)/sum(AXD)$ $sum(H.rx) = pp0_w.sum(H)$	definition of rx defns of ph and ph_w sum over countries
3. Inflation and nominal exchange rate appreciation		
APT3	GDP in domestic currency units	(databank - internal)
AXD3	domestic expenditure in domestic currency units	(databank - internal)
PPT	cost of constant dollar GDP in domestic currency units	APT3/APT0
PXD	price of constant dollar domestic expenditure in domestic currency units	AXD3/AXD0
RXN	exchange rate - dollars per domestic currency unit	APT/APT3 = AXD/AXD3
<i>Model variables - country level</i>		
pvi	domestic cost inflation (% p.a.)	$100(PPT/PPT(-1) - 1)$
pi	domestic price inflation (% p.a.)	$100(PXD/PXD(-1) - 1)$
rxna	nominal exchange rate appreciation (% p.a.)	$100(RXN/RXN(-1) - 1)$
<i>Country level theorems</i>		
T5	Price inflation, cost inflation and the terms of trade	$(1+pi/100) = (1+pvi/100)$ $.tt(-1)/tt$
<i>Proof</i>	$PXD/PPT = (AXD/APT) . (APT0/AXD0)$ $= ph.V / (AXD+AXX-AXM)$ $= V/(H + TB\$/rx) = 1/tt$	defns of PPT, PXD and RXN defns of ph,V and APT defns of H, rx and tt
T6	Nominal exchange rate appreciation	$(1+rxna/100) = (ph/ph(-1))$ $/(1+pi/100)$
<i>Proof</i>	$RXN.PXD = AXD/AXD0$ $= ph/pp0$	defns of RXN, PXD definition of ph
<i>Theorem - world level</i>		
T7	Movement of global dollar prices relative to US prices and real exchange rate movements	$ph_w = ph_w(-1) .$ $(1+pi_us/100) .$ $rx_us(-1)/rx_us$

3. VARIABLES AND IDENTITIES

Variables with no suffix represent domestic purchasing power values, variables suffixed with \$ are measured in terms of world purchasing power, and variables suffixed with 0 denote volumes or quantities measured at base-year prices and exchange rates.

Variables suffixed with _w represent world indexes or totals.³²

Model variables

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
AGF	Bank deposits and capital held by government at end year	\$m	$AGF = NGI + \max(NGF, 0)$
AX\$	External assets at end year	\$m	$AX\$ = R\$ + AXO\$$
AXO\$	Other external assets at end year (adjusted)	\$m	$AXO\$ = AXO\$U \cdot AXO\$_W / AXO\U_W
AXO\$U	Other external assets at end year (unadjusted)	\$m	$AXO\$U = NXI\$ + \max(NXF\$U, 0)$
BA\$	Net exports of primary commodities	\$m	$BA\$ = XA\$ - MA\$$
BA0	Net exports of primary commodities at base-year prices (adjusted)	\$m	$BA0 = XA0 - MA0$
BA0U	Net exports of primary commodities at base-year prices (unadjusted)	\$m	behavioural [structural policy]
BE\$	Net exports of fuels	\$m	$BE\$ = XE\$ - ME\$$
BE0	Net exports of fuels at base-year prices	\$m	$BE0 = XE0 - ME0$
BIT\$	Net income and transfers from abroad	\$m	$BIT\$ = XIT\$ - MIT\$$
BIT\$U	Net income and transfers from abroad (unadjusted)	\$m	behavioural [structural policy]
BM\$	Net exports of manufactures	\$m	$BM\$ = XM\$ - MM\$$
BM0	Net exports of manufactures at base-year prices	\$m	$BM0 = XM0 - MM0$
BS\$	Net exports of services (adjusted)	\$m	$BS\$ = XS\$ - MS\$$
BS0	Net exports of services at base-year prices	\$m	$BS0 = XS0 - MS0$
BS\$U	Net exports of services (unadjusted)	\$m	behavioural [structural policy]
C	Consumers expenditure	\$m	$C = YP - SP$
CA\$	Current account balance of payments	\$m	$CA\$ = TB\$ + BIT\$$
CO2	CO2 emissions	m tons	behavioural [energy policy]
DNNVF	Natural increase in female population 25+	millions	exogenous
DNNVM	Natural increase in male population 25+	millions	exogenous

³² Most variables are also available in current US dollars (variable name prefixed by _).

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
DNNYF	Natural increase in female population 15-24	millions	exogenous
DNNYM	Natural increase in male population 15-24	millions	exogenous
DP	Bank deposits at end-year	\$m	$DP = NFI + \max(NFF, 0)$
EB	Energy balance	mtoe	$EB = EX - EM$
ED	Energy demand	mtoe	behavioural [structural policy]
ei	Increase in average earnings	% p.a.	behavioural [incomes policy]
EM	Primary energy imports	mtoe	behavioural [trade policy]
EPC	Primary carbon energy production	mtoe	behavioural [energy policy]
EPN	Primary non-carbon energy production	mtoe	behavioural [energy policy]
EX	Primary energy exports	mtoe	$EX = EPC + EPN + EM - ED$
G	Government expenditure	\$m	behavioural [fiscal policy]
GSS	Government service standard	index	$100 * (G / (NCP + NYF + NYM + NOP)) / YN$
H	Domestic expenditure	\$m	$H = C + IP + IV + G$
HAGF	Holding gain or loss on government investment in banks	\$m	$HAGF = R(-1).rpr\$/rx + (LN(-1) + LGF(-1) - DP(-1)).rpfa - AGF(-1) - \lnbail.LN(-1).wln.rpfa$
HAXO	Holding gain on other external assets	\$m	$HAXO = AXO\$/rx - AXO\$/(-1)/rx(-1) - IAXO\$/rx$
HDP	Holding gain or loss on other sectors' investment and deposits with banks	\$m	$HDP = DP - DP(-1) - IDP$
HKP	Holding gain or loss on capital stock at end year	\$m	$HKP = KP - KP(-1) - KI + KI(-1)$
HLGO	Holding gain or loss on other government debt	\$m	$HLGO = LGO - LGO(-1) - ILGO$
HLN	Holding gain or loss on bank lending	\$m	$HLN = LN - LN(-1) - ILN$
HLX	Holding gain or loss on external liabilities	\$m	$HLX = LX\$/rx - LX\$/(-1)/rx(-1) - ILX\$/rx$
HWP	Holding gain or loss on private wealth	\$m	$HWP = HKP + HDP - HLN + HLGO + HAXO - HLX$
IAG	Government asset transactions	\$m	$IAG = IAGF + IAGO$
IAGF	Government injections to banks	\$m	$IAGF = AGF - AGF(-1) - HAGF$
IAGO	Other government asset transactions	\$m	behavioural [financial policy]
IAXO\$	Other external capital outflow	\$m	$IAXO\$ = ILX\$ - IR\$ + CA\$$
IDP	Acquisition of bank deposits	\$m	$IDP = ILN - ILGO + IAGO - (IAXO\$ - ILX\$) / rx + NLP$
ILG	Net issues of government debt	\$m	$ILG = IAG - NLG$
ILGF	Acquisition of government debt by banks	\$m	$ILGF = ILG - ILGO$
ILGO	Non-bank acquisition of government debt	\$m	$ILGO = LGO - LGO(-1).rpfa$
ILN	Net lending by banks to non-government sectors	\$m	$ILN = LN - LN(-1).rpfa.(1-wln)$
ILX\$	Other external borrowing	\$m	$ILX\$ = LX\$ - LX\$/(-1).rplx\$$
im	Bond rate	% p.a.	behavioural [confidence]

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
IP	Private investment	\$m	behavioural [confidence]
IR\$	Net acquisition of exchange reserves	\$m	$IR\$ = R\$ - R\$\text{(-1)}.rpr\$$
irm	Real bond rate	% p.a.	$irm = 100((1+im/100)/(1+pi/100)-1)$
irs	Short term interest rate	% p.a.	$irs = 100((1+is/100)/(1+pi/100)-1)$
is	Short-term interest rate	% p.a.	behavioural [monetary policy]
IV	Change in inventories	\$m	behavioural [confidence]
KI	Produced capital stock at end year	\$m	$KI = (1-rdp)*KI\text{(-1)} + IP + IV$
KID	Capital consumption	\$m	$KID = rdp KI\text{(-1)}$
KP	Value of capital at end year	\$m	$KP = pkp.KI$
LG	Government debt at end year	\$m	$LG = AGF - NGF$
LGF	Government debt held by banks at end year	\$m	$LGF = LG - LGO$
LGO	Non-bank holdings of government debt at end year	\$m	behavioural [monetary policy]
LN	Bank loans outstanding at end year	\$m	$LN = DP - NFF$
lnbail	Government bail-out losses as proportion of abnormal loan write-offs by banks	ratio	constant [assumption]
lpa	Domestic impact of world price of primary commodities	log	$lpa = 0.3 \log(pa_w/rx) + 0.7 lpa\text{(-1)}$
lped	Demand impact of user price of energy	log	$lped = 0.3 \log(ped*rx/(pepmax-400*pe_w)) + 0.7 lped\text{(-1)}$
lpep	Production impact of producer price of carbon energy	log	$lpep = 0.15 \log(pep*rx/(pepmax-400*pe_w)) + 0.85 lpep\text{(-1)}$
lpepc	Production impact of producer price of non-carbon energy	log	$lpepc = 0.05 \log(pepc*rx/(pepmax-400*pe_w)) + 0.95 lpepc\text{(-1)}$
LX\$	External liabilities at end year	\$m	$LX\$ = AXO\$U - NXF\$U$
M\$	Imports of goods and services	\$m	$M\$ = MA\$ + ME\$ + MM\$ + MS\$$
M0	Import of goods and services at base-year prices	\$m	$M0 = MA0 + ME0 + MM0 + MS0$
MA\$	Imports of primary commodities	\$m	behavioural [volume, prices]
MA0	Imports of primary commodities at base-year prices (adjusted)	\$m	$MA0 = MA0U XA0_W/\text{sum}(MA0U)$
MA0U	Imports of primary commodities at base-year prices (unadjusted)	\$m	$MA0U = XA0 - BA0U$
ME\$	Imports of energy products	\$m	behavioural [volume, prices]
ME0	Imports of energy products at base-year (adjusted)	\$m	$ME0 = ME0U XE0_W/\text{sum}(ME0U)$
ME0U	Imports of energy products at base-year (unadjusted)	\$m	behavioural [product mix]
mh	Import content of domestic expenditure	ratio	$mh = M0/(pp0.H + vx.X0)$
MIT\$	Income paid abroad	\$m	$MIT\$ = XIT\$U - BIT\$U$
MM\$	Imports of manufactures	\$m	behavioural [trade policy]
MM0	Imports of manufactures at base-year prices (adjusted)	\$m	$MM0 = MM0U XM0_W/\text{sum}(MM0U)$
MM0U	Imports of manufactures at base-year prices (unadjusted)	\$m	behavioural [prices, value]
MS\$	Imports of services	\$m	behavioural [trade policy]
MS0	Imports of services at base-year	\$m	$MS0 = MS0U XS0_W/\text{sum}(MS0U)$

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
	prices (adjusted)		
MSOU	Imports of services at base-year prices (unadjusted)	\$m	behavioural [prices, value]
mu	profit markup	%	behavioural [incomes policy]
N	Total population	millions	$N = NCP + NP$
NCP	Child population	millions	exogenous
NE	Employment	millions	$NE = NEF + NEM$
NEA	Employment in agriculture	millions	$NEA = NEAF + NEAM$
NEAF	Female employment in agriculture	millions	behavioural [labour market]
NEAM	Male employment in agriculture	millions	behavioural [labour market]
NEEF	Female employees	millions	behavioural [labour market]
NEEM	Male employees	millions	behavioural [labour market]
NEF	Female employment	millions	$NEF = NEYF + NEVF$
NEI	Employment in industry	millions	$NEI = NEIF + NEIM$
NEIF	Female employment in industry	millions	behavioural [labour market]
NEIM	Male employment in industry	millions	behavioural [labour market]
NEM	Male employment	millions	$NEM = NEYM + NEVM$
NEN	Non-agricultural employment	millions	$NEN = NENF + NENM$
NENF	Female non-agric employment	millions	$NENF = NEF - NEAF$
NENM	Male non-agricultural employment	millions	$NENM = NEM - NEAM$
NES	Employment in services	millions	$NES = NESF + NESM$
NESF	Female employment in services	millions	$NESF = NENF - NEIF$
NESM	Male employment in services	millions	$NESM = NENM - NEIM$
NEVF	Female employment 25+	millions	$NEVF = NLVF - NUVF$
NEVM	Male employment 25+	millions	$NEVM = NLVM - NUVM$
NEYF	Female employment 15-24	millions	$NEYF = NLYF - NUYF$
NEYM	Male employment 15-24	millions	$NEYM = NLYM - NUYM$
NFF	Bank deposits less loans at end year	\$m	$NFF = R\$/rx + LGF - AGF$
NFI	Covered bank lending	\$m	behavioural [confidence]
NGF	Government investment and deposits with banks less outstanding debt at end year	\$m	$NGF = NLG + AGF(-1) + HAGF - IAGO - LGO(-1).rplgo - LGF(-1).rpfa$
NGI	Covered government debt	\$m	behavioural [monetary policy]
NIM	Net migration (adjusted)	millions	$NIM = NIMU + NIMU_W * (NIMU - abs(NIMU)) / (sum(abs(NIMU)) - NIMU_W)$
NIMU	Net migration (unadjusted)	millions	behavioural [labour market]
NIT\$	Net income and transfers (adjusted)	\$m	$NIT\$ = min(XIT\$, MIT\$)$
NIT\$U	Net income and transfers (unadjusted)	\$m	behavioural [external policy]
NL	Total labour force	millions	$NL = NLF + NLM$
NLF	Female labour force	millions	$NLF = NLYF + NLVF$
NLM	Male labour force	millions	$NLM = NLYM + NLVM$
NLG	Government net lending	\$m	$NLG = YG - G$
NLP	Private net lending	\$m	$NLP = SP - IP - IV$
NLVF	Female labour force 25+	millions	behavioural [labour market]

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
NLVM	Male labour force 25+	millions	behavioural [labour market]
NLYF	Female labour force 15-24	millions	behavioural [labour market]
NLYM	Male labour force 15-24	millions	behavioural [labour market]
NOF	Female elderly population	millions	exogenous
NOM	Male elderly population	millions	exogenous
NOP	Elderly population	millions	$NOP = NOF + NOM$
NP	Total population 15+	millions	$NP = NPF + NPM$
NPF	Female population 15+	millions	$NPF = NYF + NVF$
NPM	Male population 15+	millions	$NPM = NYM + NVM$
NU	Total unemployment	millions	$NU = NUF + NUM$
NUF	Total female unemployment	millions	$NUF = NUYF + NUVF$
NUM	Total male unemployment	millions	$NUM = NUYM + NUVM$
NUVF	Female unemployment 25+	millions	behavioural [labour market]
NUVM	Male unemployment 25+	millions	behavioural [labour market]
NUYF	Female unemployment 15-24	millions	behavioural [labour market]
NUYM	Male unemployment 15-24	millions	behavioural [labour market]
NUR	Urban population	millions	behavioural [trend]
NVF	Female population 25+	millions	$NVF = NVF(-1) + DNNVF + NIM/4$
NVM	Male population 25+	millions	$NVM = NVM(-1) + DNNVM + NIM/4$
NWP	Working age population	millions	$NWP = N - NCP - NOP$
NX\$	External position	\$m	$NX\$ = R\$ + NXF\$$
NXF\$	External position at end year excluding exchange reserves (adjusted)	\$m	$NXF\$ = AXO\$ - LX\$$
NXF\$U	External position at end year excluding exchange reserves (unadjusted)	\$m	$NXF\$U = CA\$ - IR\$ + AXO\$(-1) . rpaxo\$u - LX\$(-1) . rplx\$$
NXI\$	Covered external position excluding exchange reserves	\$m	behavioural [confidence]
NXN\$	Covered external position including exchange reserves	\$m	$NXN\$ = \min(R\$ + AXO\$, LX\$)$
NYF	Female population 15-24	millions	$NYF = NYF(-1) + DNNYF + NIM/4$
NYM	Male population 15-24	millions	$NYM = NYM(-1) + DNNYM + NIM/4$
pa_w	World price of primary commodities	index	behavioural [global markets]
pa\$_w	World dollar price of primary commodities	index	$pa\$_w = pa_w . ph_w$
ped	User price of energy	\$/ton	$800 \text{ rx } EPN/ED + pep(1 - EPN/ED) + ttco2 \text{ CO2}/ED$
pep	Producer price of carbon energy	\$/ton	$400 \text{ pe}_w/\text{rx}$
pepc	Producer price of non-carbon energy	\$/ton	$pep + ttco2 \text{ CO2}/ED$
pepmax	Oil price ceiling	\$/ton	constant (assumed level at which demand and supply elasticities become infinite)
pe_w	World price of oil	index	market-clearing price (equalizes ED_w and EP_w)
pe\$_w	World dollar price of oil	index	$pe\$_w = pe_w . ph_w$
ph	Dollar price of domestic expenditure	ratio	$ph = \text{rx} . ph_w$

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
phd	Domestic price index	index	$phd = phd(-1)(1+pi/100)$
ph_w	World dollar price of expenditure	ratio	$ph_w = ph_w(-1) \cdot (1+pi_{us}/100) \cdot rx_{us}(-1)/rx_{us}$
pi	Domestic currency price inflation	% p.a.	$pi = 100((1+pvi/100) \cdot tt(-1)/tt-1)$
pi\$	Dollar price inflation		$pi\$ = 100 \cdot (ph/ph(-1))-1$
pi_w	World average domestic currency price inflation	% p.a.	$pi_w = \text{sum}(pi.H)/H_W$
pi\$_w	World dollar price inflation	% p.a.	$pi\$_w = 100 (ph_w/ph_w(-1) - 1)$
pkp	Price of capital (ratio of value of capital including land to produced capital stock)	deflator	behavioural [confidence]
pmm	Price of imports of manufactures	deflator	$ppm = MM\$ / MM0$
pmm0	Average supplier price for imports of manufactures	deflator	$ppm0 = 1/\text{sum}(\text{suppliers: } sxm \cdot (XM0/XM\$))$
pp0	Base-year ppp adjustment	ratio	constant
pp0_w	World base-year ppp adjustment	ratio	constant
pvd	Domestic cost index	index	$pvd = pvd(-1)(1+pvi/100)$
pvi	Domestic cost inflation	% p.a.	$pvi = 100((1+ei/100)((1+\mu/100)/(1+\mu(-1)/100))((1+rtx/100)/(1+rtx(-1)/100))(V(-1) \cdot NE/(V \cdot NE(-1)))-1)$
pxm	Price of exports of manufactures	index	$pxm = XM\$ / XM0$
R\$	Exchange reserves at end year	\$m	behavioural (monetary policy)
ralx\$	External asset/liability ratio	%	$ralx\$ = 100 \cdot AX\$ / LX\$$
rax	External asset ratio	%	$rax = 100 \cdot AX\$ / (RX \cdot DP)$
rax0	Non-reserve asset ratio	%	$rax0 = 100 \cdot AX0\$ / (RX \cdot DP)$
rlx	External liability ratio	%	$rlx = 100 \cdot LX\$ / (RX \cdot DP)$
rmx\$	Reserves as % of annual imports	%	$rmx\$ = 100 \cdot R\$ / M\$$
rpaxo\$	Valuation ratio for other external assets brought forward (adjusted)	ratio	$rpaxo\$ = (AXO\$ - IAXO\$) / AXO\$(-1)$
rpaxo\$u	Valuation ratio for other external assets brought forward (unadjusted)	\$m	behavioural [price movements]
rpfa	Valuation ratio for domestic financial assets brought forward	ratio	$rpfa = 1/(1+spvi)$ [assumption]
rpkp	Valuation ratio for capital stock brought forward	ratio	$rpkp = pkp/pkp(-1)$
rplgo	Valuation ratio for non-bank holdings of government debt brought forward	ratio	$rplgo = slgx \cdot ph(-1)/ph + (1-slgx) \cdot rpfa$
rplx\$	Valuation ratio for external liabilities brought forward	ratio	behavioural [price movements]
rpr\$	Valuation ratio for exchange reserves brought forward	ratio	behavioural [price movements]
rtx	Indirect tax markup	% p.a.	behavioural [fiscal policy]
rx	Real exchange rate (adjusted)	ratio	$rx = rxu / rxadj$
rxd	Nominal exchange rate	index	$rxd = rxd(-1)(1+rxna/100)$
rxna	Nominal exchange rate appreciation	% p.a.	$rxna = 100((ph/ph(-1)) / ((1+pi/100)-1))$

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
rxu	Real exchange rate (unadjusted)	ratio	behavioural [monetary policy, confidence]
slgx	Proportion of government debt financed in foreign currency	ratio	$slgx = 1 - \log(1+YR)/2$ [assumption]
SP	Private saving	\$m	behavioural [confidence]
SPV	Private saving as % of GDP	% p.a.	$SPV = 100*SP/VV$
spvi	Inflation indicator	log	$spvi = \log(-0.718 + 3.436(1+pvi/100) / (2+pvi/100))$
sxm	Market share of exports of manufactures in imports of each destination (adjusted)	ratio	$sxm = sxmu / \text{sum}(sxmu)$
sxmm	Percent share of world exports of manufactures	% p.a.	$sxmm = 100 \text{ XM\$} / \text{MM\$}_W$
sxmu	Market share of exports of manufactures in imports of each destination (unadjusted)	ratio	behavioural [trade policy]
TB\$	Trade balance	\$m	$TB\$ = X\$ - M\$$
TB0	Trade balance at base year prices	\$m	$TB0 = X0 - M0$
tt	Terms of trade effect	ratio	$tt = (H+TB\$/rx) / (H+TB0/pp0)$
ttco2	Carbon tax	\$/ton	exogenous [energy policy]
ucx\$	Real unit cost of exports	index	$ucx\$ = mh*vx*M\$/M0 + (1 - mh*vx)*rx/pp0$
ulc\$	Unit labour cost	index	$ulc\$ = rx*VVEM*pp0/V0$
uva\$	Unit factor cost	index	$uva\$ = RX*(VVEM+VVPR)*pp0/V0$
V0	GDP at base-year exchange rates	\$m	$V0 = V.pp0$
V	GDP volume	\$m	$V = H + TB0/pp0$
VGA	Productivity gap in agriculture	%	$VGA = 100*(NEA/NE-WA/VV)/(1-NEA/NE)$
VNE	GDP per employed person	\$	$VNE = V / NE$
VT	Productive capacity	\$m	$VT = 1.05 \text{ movav}(V, 6) \cdot (V/V(-6))^{0.3}$
VV	Domestic purchasing power of GDP	\$m	$VV = H + TB\$/rx$
VV\$	External purchasing power of GDP	\$m	$VV\$ = H*rx + TB\$$
VVA	GDP in agriculture	\$m	behavioural (demand/supply)
VVE	GDP in extraction and utilities	\$m	behavioural (demand/supply)
VVEE	Compensation of employees	\$m	behavioural (labour market)
VVEM	Labour and mixed income	\$m	$VVEM = VV - VVPR - VVTX$
VVI	GDP in industry	\$m	behavioural (demand/supply)
VVPR	Profits and rent	\$m	$VVPR = \mu(VV - VVTX)/(100 + \mu)$
VVN	GDP per capita	\$	$VVN = VV/N$
VVS	GDP in services	\$m	$VVS = VV - VVA - VVE - VVI$
VVT	Capacity utilization	% p.a.	$VVT = 100*(V/VT - 1)$
VVTX	Indirect taxes less subsidies	\$m	$VVTX = rtx \text{ VV} / (100 + rtx)$
vx	Import content of exports relative to import content of domestic expenditure	ratio	$vx = 2 + (X0-M0)/(pp0.V)$ [assumption]
wln	Write-off rate for bank loans	% p.a.	exogenous [confidence]
WLNA	Lagged loan write-offs	\$m	$WLNA = 0.8 \text{ LN}(-1).wln.rpfa + 0.2 \text{ WLNA}(-1)$

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
WP	Private wealth at end-year	ratio	$WP = KP + LGO + NFF + NXF\$ / rx$
X\$	Exports of goods and services	\$m	$X\$ = XA\$ + XE\$ + XM\$ + XS\$$
X0	Exports of goods and services at base-year prices	\$m	$X0 = XA0 + XE0 + XM0 + XS0$
XA\$	Exports of primary commodities (adjusted)	\$m	$XA\$ = XA\$U \text{ MA\$}_W / \text{sum}(XA\$U)$
XA0	Exports of primary commodities at base-year prices	\$m	behavioural [trade policy]
XA\$U	Exports of primary commodities (unadjusted)	\$m	behavioural [price behaviour]
XE\$	Exports of energy products	\$m	$XE\$ = XE\$U \text{ ME\$}_W / \text{sum}(XE\$U)$
XE\$U	Exports of energy products (unadjusted)	\$m	behavioural [price behaviour]
XE0	Exports of energy products at base-year prices	\$m	behavioural [trade policy]
XIT\$	Income and transfers from abroad (adjusted)	\$m	$XIT\$ = XIT\$U \cdot \text{MIT\$}_W / XITU\$_W$
XIT\$U	Income and transfers from abroad (unadjusted)	\$m	$XIT\$U = NIT\$U + \max(\text{BIT\$U}, 0)$
XM\$	Exports of manufactures	\$m	$XM\$ = \text{sum}(\text{partners: } s_{xm} \text{ MM\$})$
XM0	Exports of manufactures at base-year prices	\$m	behavioural [price behaviour]
XS\$	Exports of services (adjusted)	\$m	$XS\$ = XS\$U \text{ MS\$}_W / \text{sum}(XS\$U)$
XS0	Exports of services at base-year prices	\$m	behavioural [price behaviour]
XS\$U	Exports of services (unadjusted)	\$m	$XS\$U = BS\$U + MS\$$
Y	National income (domestic purchasing power)	\$m	$Y = H + CA\$ / rx$
Y\$	National income (international purchasing power)	\$m	$Y\$ = Y / rx$
YG	Government net income	\$m	$YG = YGD + VVTX$
YGD	Direct taxes less transfers	\$m	behavioural [fiscal policy]
YN	Income per capita	\$ pp	$YN = Y / N$
YN\$	Income per capita at market rates	\$ wpp	$YN\$ = Y\$ / N$
YP	Private disposable income	\$m	$YP = Y - YG$
YPN	Private income net of capital consumption	\$m	$YP - KID$
YR	Relative income per capita	Ratio	$YR = YN / YN_W$

Additional variables for policy evaluation

Variables listed below are calculated after solution of the core model. In addition to these variables, many growth rates and ratios are computed for display in graphs.

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
GY	Population-weighted Gini coefficient for distribution of income between countries	Index	computed on countries in ascending sequence by income per capita
NER	Employment rate	%	$NER = 100 \text{ NE} / \text{NP}$
NUL	Unemployment rate	%	$NUL = 100 \text{ NU} / \text{NL}$

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
psbdyn	Country performance measure for per capita income growth	Index	$psbdyn = movav(10/(1+0.3 \max(movav(DYN(-1), pslag) - DYN, 0)), psmav)$
psbner	Country performance measure for activity rate	Index	$psbner = movav(10/(1+0.5 \max(movav(NER(-1), pslag) - NER, 0)), psmav)$
psbpi	Country performance measure for inflation	Index	$psbpi = movav(10/(1+0.1 \max(pi - movav(pi(-1), pslag), 0)), psmav)$
psbrx	Country performance measure for exchange rate stability	Index	$psbrx = movav(10/(1+10*abs(\log(rx) - movav(\log(rx(-1)), pslag))), psmav)$
psbt	Overall country performance measure	Index	$psbt = 1/(\sqrt{(pbpi/psbpi)^2 + pbdyn/psbdyn^2 + pbrx/psbrx^2 + pbnar/psbnar^2})$
pslag	Country performance comparison basis (no of years)	Years	constant [assumption]
psmav	Smoothing (no of year)	Years	constant [assumption]
pbdyn, pbnar, pbpi, pbrx	Weights for overall country performance measure	fractions	constant [assumption]
psed_w	Global performance measure for energy use	Index	$psed_w = movav(10/(1 + \max(ED_W - movav(ED_W(-1), pslag), 0)), psmav)$
psdx_w	Global performance measure for stability of export markets	Index	$psdx_w = movav(10/(1+100 \abs(dlog(X\$_W) - movav(dlog(X_W(-1), pslag))), psmav)$
pspae_w	Global performance measure for stability of commodity and oil prices	Index	$pspae_w = movav(10/(1+abs(\log(pa_w) - movav(\log(pa_w(-1)), pslag))), psmav)$
psynl_w	Global performance measure for catch-up of low income countries	Index	$psynl_w = movav(10*exp(10*(rylow/movav(rylow(-1), pslag) - 1)) / (1+exp(10*rylow/movav(rylow(-1), pslag) - 1))), psmav)$
pswt_w	Overall global performance measure	Index	$pswt = 1/(\sqrt{(psed/psed_w^2 + psdx/psdx_w^2 + pspae/pspae_w^2 + psynl/psynl_w^2})$
psed, psdx, pspae, psynl	Weights for overall global performance measure	fractions	constant [assumption]
rylow_w	Average income of bottom quartile as a fraction of global average income	Ratio	$rylow_w = \frac{\sum(Q1, Y)NW}{(\sum(Q1, N)YW)}$ where Q1 is the first quartile by population of between-country income distribution
TH_CO2	Theil inequality coefficient for CO2 emissions	Index	$TH_CO2 = 100(1 - \exp(-\sum(CO2/CO2_W \log(N/N_W))))$
TH_ED	Theil inequality coefficient for energy absorption	Index	$TH_ED = 100(1 - \exp(-\sum(ED/ED_W \log(N/N_W))))$
TH_EP	Theil inequality coefficient for energy production	Index	$TH_EP = 100(1 - \exp(-\sum(EP/EP_W \log(N/N_W))))$

<i>Symbol</i>	<i>Name</i>	<i>Units</i>	<i>Exogenous, behavioural or determined by identity</i>
TH_G	Theil inequality coefficient for government expenditure	Index	$TH_G = 100(1 - \exp(-\sum(G/G_W \log(N/N_W))))$
TH_XM\$	Theil inequality coefficient for exports of manufactures	Index	$TH_XM\$ = 100(1 - \exp(-\sum(XM\$ / XM\$_W \log(N/N_W))))$
TH_XS\$	Theil inequality coefficient for exports of services	Index	$TH_XS\$ = 100(1 - \exp(-\sum(XS\$ / XS\$_W \log(N/N_W))))$
TH_Y	Theil inequality coefficient for income	Index	$TH_Y = 100(1 - \exp(-\sum(Y/Y_W \log(N/N_W))))$