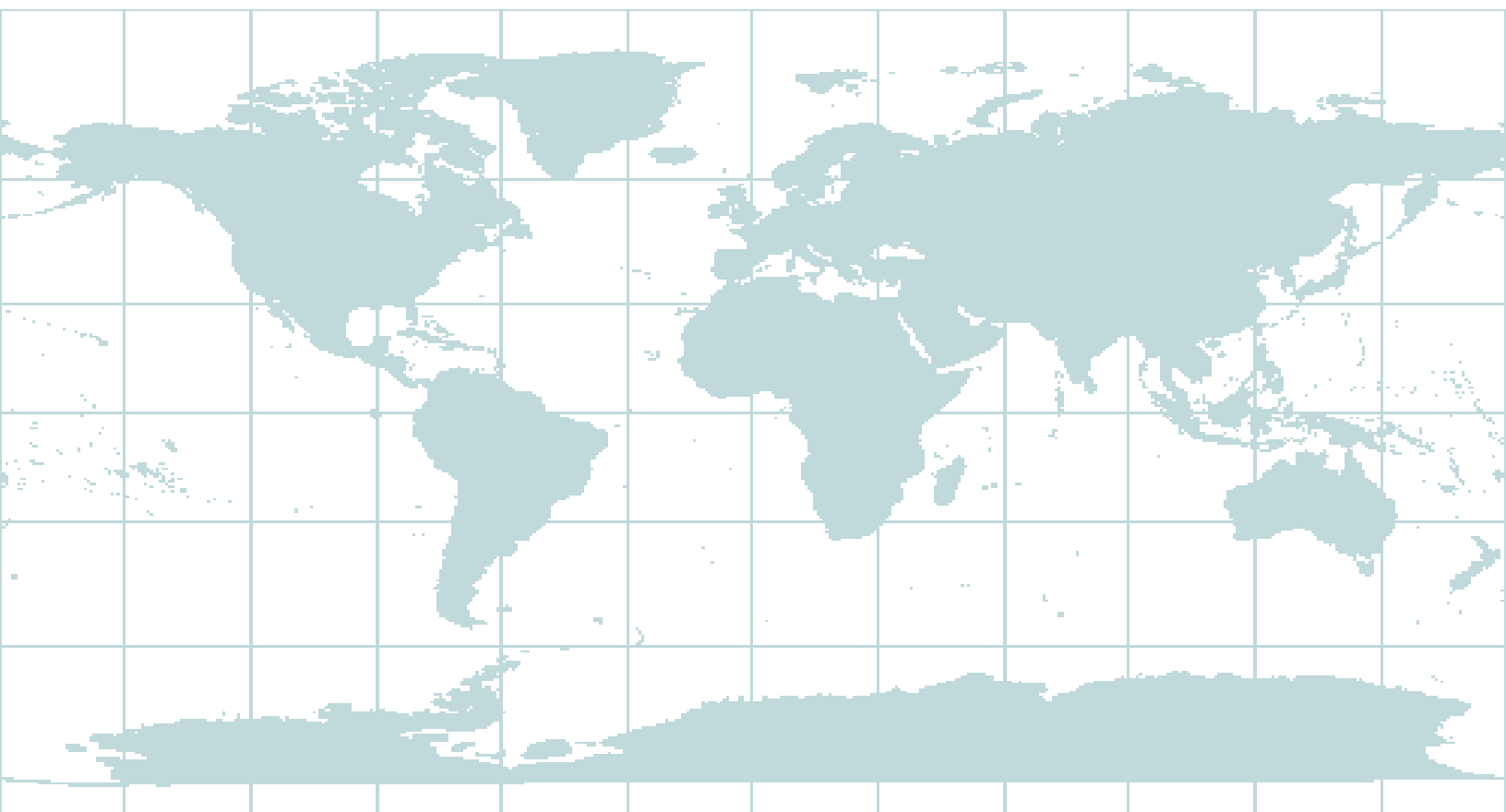


Development Policy and Analysis Division
Department of Economic and Social Affairs

Global Policy Model

Technical Description of GPM



United Nations
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**The UN DESA Global Policy Model (GPM):
Technical Description of GPM version 3.0**

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PRELIMINARY DRAFT

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This paper describes the structure of equations of the GPM with short explanations of methods for specifying new policy rules, scoring policy outcomes and measuring dynamic multipliers. Appendices describe (A) notation and measurement conventions, (B) derivation of series used in the model, (C) a listing of main variables and identities, (D) details of estimated equations, (E) functions used to specify policy rules and (F) dynamic multipliers showing local and external effects of shocks transmitted through the model.

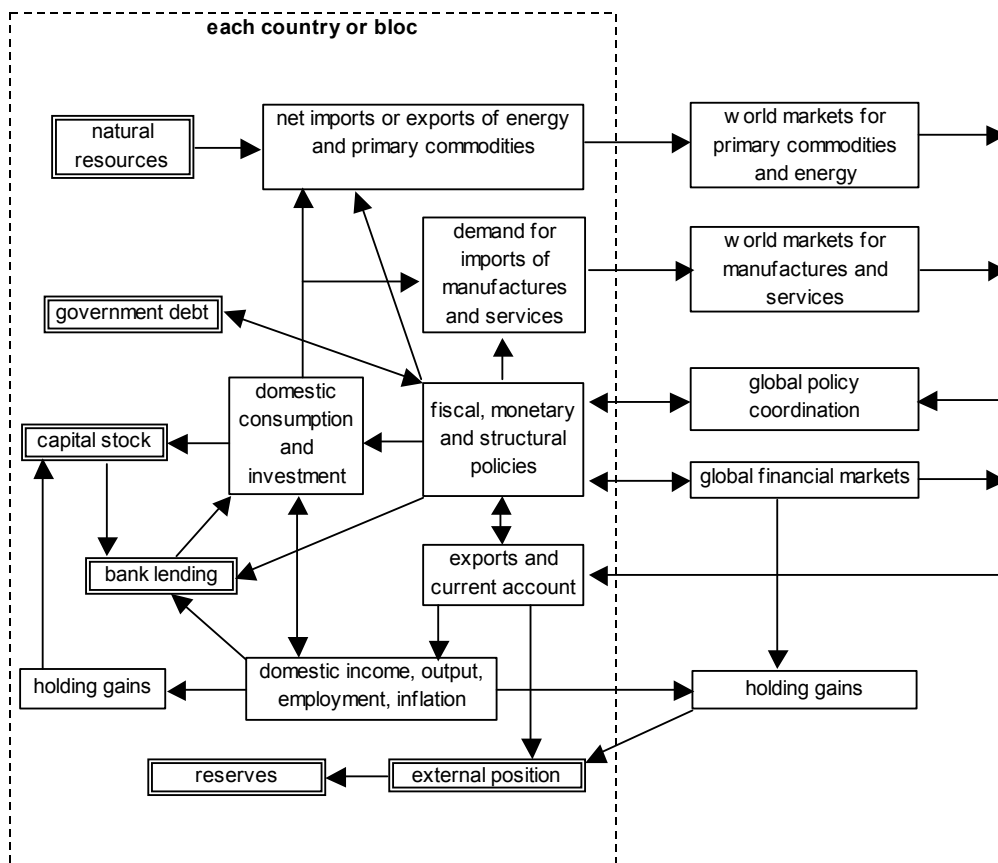
This paper is complementary to 'The UN/DESA Global Policy Model. Underlying Concepts and Empirical Illustrations', by the same authors. Discussion of methodology, concepts, scenario construction and empirical illustrations of policy scenarios are referred to this paper (henceforth referred to as 'GPM concepts').

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OVERVIEW OF SECTORS AND POLICY ARENAS

The main sectors (or modules) of the GPM are private sector demand and income; government demand and income; international trade in manufactured goods (bilateral); international trade in primary commodities, energy and services (world pools); international factor payments and transfers, external positions, exchange rates and capital flows (world pools); government and domestic banking sector flows and balances; prices; output, capacity, inflation, employment and migration.



Policies may operate either as targeted functions or in a looser, reactive mode. The main explicit policies are 'fiscal policy', 'monetary policy' and 'exchange rate, trade and industrial policy'. Targeted policies directly impact specific macro variables. Policy reactions are triggered by changes in model outcomes caused either by other policies or by exogenous shifts in behaviour. The GPM includes functions that score the effectiveness of policy against historical patterns. Other cases, like employment, migration and urbanization may be affected by policy intervention at present these have little feedback into the main sectors. Policies not explicitly modelled such as those affecting income distribution may be reflected by assumed changes in behaviour of macro variables such as savings and relative costs. Formal methods for specifying policies are explained in the section on construction of scenarios and their evaluation.

BEHAVIOURAL EQUATIONS

Equations discussed below need to be understood together with the full set of identities and variable definitions listed in Appendix C. The system is fully consistent with national accounting standards and inconsistencies and gaps in data are resolved by the usual methods, both for historical series and across model solutions (RAS, Armington systems, etc).

It is essential to take into account the scaling used for the variables in the system, which is based on standards established by the 2005 International Comparison Program.¹ Appendices A and B explain the notation used and demonstrate how the scaling system is made fully consistent with national accounting identities. In essence, most domestic macroeconomic variables are measured in constant domestic purchasing power, equivalenced across blocs to equalise purchasing power in the base year (currently 2005); energy volumes are measured in oil-equivalent terms; volumes of other goods and services are measured in the standard manner at base-year prices; and international transactions and assets are measured in world-average purchasing power. Finally, after each model solution is run, the system calculates current dollar values of main aggregates at market exchange rates.

Consistent scaling in IPC terms and through time, facilitates panel estimation of parameters of behavioural equations by maximizing comparability across blocs.

Unless otherwise specified, variables in equations discussed below are bloc-specific and measured by annual time series. World variables are denominated with the suffix W. Lagged variables are represented by subscripts $-1, -2, \dots$ etc).

Income and expenditure

Gross national income 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 additions to or subtractions from domestic purchasing power arising from changes in the external terms of trade.

The private sector

Three main relations define private spending behaviour while private disposable income is defined as national income not absorbed by the government ($Y_p = Y - Y_g$). Private consumption is resolved in the model by the savings function ($C = Y_p - S_p$)

¹ See World Bank. 2008. *Global Purchasing Power Parities and Real Expenditures*. Washington DC.: The World Bank.

$$(1) \quad \Delta \frac{Sp}{Yp_{-1}} = \Phi \left\{ \frac{(-)}{Yp_{-2}}, \frac{(+)}{Yp_{-1}}, \frac{(-)}{Wp_{-2}}, \frac{(+)}{spvi}, \frac{(+)}{irs_{-1}}, \alpha_b, \varepsilon_b \right\}$$

The *rate of savings* on the LHS follows a schedule that targets an optimal wealth to income ratio and is moderately path-dependent. The model can operate in two modes. In one mode there is a stock/flow adjustment that fully drives spending and saving decisions over the long run. In the other mode, the one discussed here, there is a savings function that is influenced, though not fully determined, by a wealth objective. The wealth objective relates to disposable income and the adjustment in each period is inevitably incomplete because wealth is typically four or five times larger than annual income. Changes in wealth, $\Delta Wp_{-1}/Wp_{-2}$, are the result either of savings or of price changes (holding gains). The first element in the RHS of the econometric relation above specifies a correction along the path-dependent pattern. The second element, $\Delta Yp/Yp_{-1}$, introduces a short-term lag in the response of consumption to changes in real income. In addition inflation, $spvi$, and the lagged real interest rate, irs_{-1} , have their own effects on savings. The symbols α_b and ε_b denote bloc-specific fixed terms and stochastic errors (the same symbols are used in all equations that follow)

$$(2) \quad \Delta \log \frac{Ip}{V_{-1}} = \Phi \left\{ \log \frac{(-)}{Ip_{-1}}, \Delta \log V, \frac{(+)}{ILN_{-1}}, \frac{(-)}{V_{-1}}, irm, \alpha_b, \varepsilon_b \right\}$$

Private investment, Ip shows a standard accelerator pattern responding to $d \log V$, the rate of growth of GDP, with some degree of path-dependency, hence the lagged term, first variable in the RHS. Further, investment is influenced by financial conditions such as the rate of bank lending, ILN , and the long term interest rate, represented by the real bond rate, irm .

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

Inventory adjustment exhibits an accelerator response similar to the investment function with the short-term real interest rate, irs , replacing the bond rate.

Government

Net 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.

$$(4) \quad \frac{\Delta Y_g}{Y_{-1}} = \Phi \left\{ \frac{Y_{g-1}}{Y_{-1}}, \frac{\Delta Y}{Y_{-1}}, \frac{\Delta Y_{-1}}{Y_{-1}}, \frac{Lg_{-1}}{Y_{-1}}, irm_{-1} \cdot \frac{Lg_{-1}}{Y_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Y_g , *government income* (net of subsidies, transfers and interest payments), is moderately path dependent, which is captured by the first term in the RHS expression, following the growth of gross national income with some lag. The inherited stock of government debt, Lg_{-1}/Y_{-1} , usually calls for increased efforts to raise taxation, while interest on accumulated debt will erode government receipts..

$$(5) \quad \Delta \log G = \Phi \left\{ \log G_{-1}, \Delta \log Y_g, \frac{Y_{g-1}}{Y_{-1}}, \log N_{-1}, \log \frac{Lg_{-1}}{Y_{-1}}, \frac{CA\$_{-1}}{Y\$_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Government spending on goods and services, G , is strongly path-dependent (captured by the first element of the RHS), responds to the level and rate of change of government income and tends to rise with population, N . Government spending is also adjusted in response to the inherited debt burden, Lg_{-1}/Y_{-1} , and the external balance as a ratio to GDP $CA\$_{-1}/Y\$_{-1}$ (consistent with dominant views among policy makers according to which external imbalances require correction through contraction of domestic demand).

The external current account

Trade in manufactured goods

The international market for manufactures is modelled on a bilateral basis. 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 driven by market shares (i.e. share of imports of each bloc) responding 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). Domestic inflation, which enters the unit cost calculation, is influenced by the output gap. Market shares estimated on a bilateral basis are dynamic and strongly path dependent. The main equations are therefore the following:

$$(6) \quad \Delta \log MM\$ = \Phi \left\{ \log MM\$_{-1}, \Delta \log MH\$, \log(MH\$_{-1}), \Delta \log(rx), \log(rx_{-1}), \log(pmm_{0-1}), \alpha_b, \varepsilon_b \right\}$$

Imports of manufactures measured in international purchasing power terms $MM\$$ respond to a weighted sum of final expenditure components $MH\$$ that attributes relatively high import intensity to investment IP , IV and exports of manufactures $XM\$$,

and relatively low import intensity to government spending on goods and services G . Based on I/O tables, the following approximation is proposed:

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

As $MH\$$ is denominated in terms of external purchasing power, it correlates strongly with the real exchange rate. The term for changes in the real exchange rate $d\log(rx)$ is expected to have a negative sign, partially offsetting the positive effect on domestic purchasing power $MH\$$ in the short run. Supplier prices pmm_0 exert a negative long-run influence.

$$(7) \quad \Delta \log \frac{pmm_0 \cdot MM_0}{MM\$} = \Phi \left\{ \log \frac{pmm_{0-1}^{(-)} \cdot MM_{0-1}}{MM\$_{-1}}, \Delta \log^{(+)}(pmm_0), \Delta \log^{(-)}(rx), \alpha_b, \varepsilon_b \right\}$$

Given the value of imports measured in world purchasing power terms, the movement of *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 the supplier price and the real exchange rate rx .

Import volumes are eventually scaled to ensure the world total matches export volumes (see below).

$$(8) \quad \Delta \log(sxm) = \Phi \left\{ \log^{(-)}(sxm_{-1}), \log^{(-)}(ucx\$_{-1}), \Delta \log^{(-)}(ucx\$_{-1}), \alpha_b, \varepsilon_b \right\}$$

Market shares of each supplier in each import market sxm are path-dependent with negative short and long run impacts from unit costs ucx . Shares predicted by the equation above are scaled to sum to 1, transforming the result into an Armington-style constant-elasticity function in which market shares depend on trade-weighted relative unit costs of the different suppliers. The estimated long-run elasticity of market share by value with respect to relative unit costs is around 2.5. Intercepts and error terms are in this instance bilateral and intercepts differ substantially as would be expected given size, geographical and cultural relationships between different groups of countries.

Elasticities in the bilateral market share equation are estimated using a panel with a reduced cross-section of bilateral market shares excluding very small market shares that frequently exhibit large and erratic year-on-year proportionate changes.

Given market shares, export values of each supplier, $XM\$$, are determined by summing the product of import value in each market and the supplier's market share.

$$(9) \quad \Delta \log \frac{XM_0}{XM\$} = \Phi \left\{ \log \frac{XM_{0,-1}^{(-)}}{XM\$_{-1}}, \log(ucx\$_{-1}), \alpha_b, \varepsilon_b \right\}$$

The *volume of exports of manufactures* given export value measured in world purchasing power terms is again determined by price movements. Path-dependency means that changes in unit costs, $ucx\$_$, are only gradually passed through and the oligopolistic nature of industrial international markets implies that the pass-through is incomplete even in the long run.

Energy trade

Energy production, demand and trade flows are determined in physical terms. A world pool for traded energy products is cleared by movements of the world price of oil. The oil price is treated as a benchmark and other kinds of energy (gas, coal and primary electricity) are measured in ‘tons of oil equivalent’ (toe).

$$(10) \quad \Delta \log \frac{ED}{N} = \Phi \left\{ \log \frac{ED_{-1}^{(-)}}{N_{-1}}, \Delta \log \frac{V^{(+)}}{N}, \Delta \log(lped)^{(-)}, \Delta \log(tt)^{(+)}, \Delta \log(X_0)^{(+)}, \frac{IV^{(+)}}{V_{-1}}, \log(1+Yr_{-1})^{(+)}, \alpha_b, \varepsilon_b \right\}$$

Primary energy demand, ED , relative to population, N , is clearly path dependent, hence the expected negative sign of the first element in the RHS. In the long run per capita energy absorption responds to the level of per capita income relative to the world average Yr and changes in a constructed moving lagged real price of oil, $lped = \delta \log(pew) + (1-\delta) \log(pew_{-1})$.² In the short run it fluctuates with growth of per capita GDP V/N , the terms of trade tt , export volume $X0$ and inventory adjustment IV .

$$(11) \quad \Delta \log EP = \Phi \left\{ \Delta \log(ED) \cdot \min \left\{ \frac{ED_{-1}^{(+)}}{EP_{-1}}, 1 \right\}, \log(lpep)^{(+)}, \alpha_b, \varepsilon_b \right\}$$

Growth of *primary production of energy*, EP , is to a considerable extent driven by growth of domestic demand and is influenced by another constructed moving lagged real price, $lpep = \lambda \log(pew) + (1-\lambda) \log(pew_{-1})$.³ Differences in resources and market access are reflected in bloc-specific intercepts. The current version of the model does not capture potential exhaustion of resources such as oil and gas in each bloc.

² The model identity is slightly more complex as it must take account of the real exchange rate in each bloc and it introduces the notion of a real oil price ceiling with energy demand and supply becoming increasingly price-elastic as the ceiling is approached.

³ See the footnote for energy demand.

$$(12) \quad \Delta \log EM' = \Phi \left\{ \log^{(-)}(EM'), \Delta \log^{(+)}(EPW), \alpha_b, \varepsilon_b \right\}$$

Imports in excess of the amount required to fill the gap between domestic demand and supply, EM' , tend to increase with growth of global energy production EPW . By definition such imports are reflected in exports, calculated as the balancing item in energy supply and demand of each bloc.

The world oil price pew is solved endogenously to find the value that equalizes total world supply and demand for energy or equivalently, total imports and exports, in tons of oil equivalent. Auxiliary equations convert imports and exports in tons of oil equivalent into imports and exports measured at base-year dollar prices ME_0 and XE_0 . Subsequently the world oil price, pew , is used to determine values of imports and exports $ME\$$ and $XE\$$ in international purchasing power terms.

Trade in primary commodities

The market for primary commodities functions as a price-clearing pool with some friction resulting in partial quantity adjustment. Bloc equations, given world prices and domestic demand, determine net exports or imports. Exports of each bloc are scaled to ensure that world exports will equal world imports and the world price responds to growth of world imports.

The estimated equations for this market are as follows:

$$(13) \quad \frac{\Delta BA_0}{V_{-1}} = \Phi \left\{ \Delta^{(+)}(lpa), (lpa_{-1})^{(+)}, \frac{\Delta V}{V_{-1}}^{(-)}, \alpha_b, \varepsilon_b \right\}$$

Domestic demand for food and raw materials increases with GDP. Therefore *net exports of primary commodities* at base year prices, BA_0 , expressed as a ratio to lagged GDP, tends to increase with a rise in world prices, $lpa = \lambda \log(paw) + (1-\lambda) \log(paw_{-1})$, and diminish with a faster increase in GDP.

$$(14) \quad \frac{\Delta XA_0}{V_{-1}} = \Phi \left\{ \frac{\Delta (\max\{BA_0, 0\})^{(+)}}{V_{-1}}, \alpha_b, \varepsilon_b \right\}$$

The *volume of exports of primary commodities* at base year prices XA_0 depends primarily on the net export surplus. The volume of imports MA_0 follows as a balancing item.

$$(15) \quad \Delta \log \frac{MAS}{MA_0} = \Phi \left\{ \Delta \log^{(+)}(paw), \Delta \log^{(+)}(rx/pp_0), \alpha_b, \varepsilon_b \right\}$$

Given the volume of imports, import value expressed in international purchasing power, $MA\$$, is a function of prices. Relative to imports at the base year price, MA_0 , import value responds positively to world prices, paw , and the real exchange rate, rx .

$$(16) \quad \Delta \log \frac{XA\$}{XA_0} = \Phi \left\{ \Delta \log^{(+)}(paw), \Delta \log^{(+)}(rx / pp_0), \alpha_b, \varepsilon_b \right\}$$

The value of exports of primary commodities responds similarly.

Trade in services

The international market for services trade is another pool. Net exports of each bloc 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.

$$(17) \quad \frac{\Delta BS\$}{V_{-1}} = \Phi \left\{ \Delta \log^{(-)}(rx), \frac{\Delta BAS}{V_{-1}}, \frac{\Delta BES}{V_{-1}}, \frac{\Delta BMS}{V_{-1}}, \alpha_b, \varepsilon_b \right\}$$

$$(18) \quad \frac{\Delta MS\$}{V_{-1}} = \Phi \left\{ \Delta \log^{(+)}(rx), \frac{\Delta \min\{0, BS\$\}}{V_{-1}}, \frac{\Delta MAS}{V_{-1}}, \frac{\Delta XES}{V_{-1}}, \frac{\Delta MMS}{V_{-1}}, \alpha_b, \varepsilon_b \right\}$$

$$(19) \quad \Delta \log \frac{MS_0}{MS\$} = \Phi \left\{ \log \frac{MS_0}{MS\$}, \Delta \log^{(-)}(rx), \alpha_b, \varepsilon_b \right\}$$

$$(20) \quad \Delta \log \frac{XS_0}{XS\$} = \Phi \left\{ \log \frac{XS_0}{XS\$}, \Delta \log^{(-)}(rx), \alpha_b, \varepsilon_b \right\}$$

External income and transfers

$$(21) \quad \frac{\Delta BIT\$}{Y\$_{-1}} = \Phi \left\{ \frac{BIT\$_{-1}}{Y\$_{-1}}, im_{US} \cdot \frac{NX\$_{-1}}{Y\$_{-1}}, \frac{\Delta NX\$}{Y\$_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Net income and transfers, $BIT\$$, is estimated as a balance to improve stability. The lagged variable absorbs the error correction dynamic process. $NX\$$ is the inherited net external position, which when multiplied by the interest rate of reference of the reserve

currency bonds, im_{US} , serves as a proxy for factor revenues. Net receipts may correlate directly with changes in the external position.

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 estimates the proxy variable which is always positive and can then impute receipts and payments separately using the figure for net income and transfers from the equation above. ⁴

$$(22) \quad \Delta \log NIT\$ = \Phi \left\{ \log NIT\$_{-1}^{(-)}, \log NXN\$_{-1}^{(+)}, \Delta \log XW\$^{(+)}, \alpha_b, \varepsilon_b \right\}$$

The “covered” flow so defined is moderately path-dependent, hence the expected negative sign of the first variable on the RHS, is correlated with the size of net external assets and liabilities $NXN\$$ (defined as a “covered” position in similar fashion) and depends also on global trade, $XW\$$.

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 spending 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 incomplete, is important in any medium or long-term macro model because it 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. The main difficulty, apart from paucity and unreliability of data, is that stocks may also be strongly influenced by holding gains and losses. The GPM does not attempt a detailed asset model for households, corporations, financial institutions etc. but aggregates non-government sectors including state enterprises into a single group, excluding only the domestic banking sector for which separate data are available for virtually all countries.

The following matrix shows how the GPM tracks assets and liabilities for one bloc., divided between government, non-government, banks and the rest of the world. The important point is that every asset has an issuer for which it is a liability as well as a

⁴ $XIT\$ = NIT\$ + \max(BIT\$, 0)$ $MIT\$ = NIT\$ + \max(-BIT\$, 0)$

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 blocs. 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*).

Identified assets and liabilities

	Assets (held by)				Net worth
	Non-government	Government	Banks	Rest of world	
Capital stock	KP				
Liabilities of					
Non-government			LN	LX\$/rx	WP
Government	LGO		LGF		
Banks	DP	AGF			0
Rest of world	AXO\$/rx		R\$/rx		-NX\$/rx

For each asset identified in the matrix, the GPM models related 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.⁵ Again every asset transaction has a buyer and seller so that all cash is accounted for, at least on a net basis.

Summary flow of funds

Sources of funds	Uses of funds / net acquisition of assets				Savings
	Non-government	Government	Banks	Rest of world	
Capital stock	IP + IV				
Issuers					
Non-government		IAGO	ILN	ILX\$/rx	SP
Government	ILGO		ILGF		YG - G
Banks	IDP	IAGF			0
Rest of world	IAXO\$/rx		IR\$/rx		-CAS\$/rx

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

⁵ It will be noted that the table includes one cash flow for which there is no corresponding asset in the matrix above. This cash flow, *IAGO*, representing net asset transactions of government with other sectors (excluding banks) is discussed further in the section on government debt and asset transactions below. The main point is that the available data do not provide sufficient evidence to track the total value of corresponding assets such as the value of government ownership of and loans to state enterprises and lending to the private sector. By necessity therefore, the corresponding liabilities are omitted from the calculation of private wealth, *WP*.

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 and spending for which equations were provided above.

In addition to budget surpluses or deficits the accumulation of debt in nominal terms is affected by asset transactions while the real value of debt carried forward is affected by domestic inflation and, if debt is financed externally, exchange rate movements. In the GPM government asset transactions are divided between those related to deposits and investment in the banking sector and other government asset transactions in aggregate. Finally, given total debt outstanding, it is necessary to establish the division of holdings of government debt between the domestic banking system (which affects bank liquidity and deposits) and the private sector including non-residents.

$$(23) \quad \frac{IAgo}{Y_{-1}} = \Phi \left\{ \frac{Lg_{-1}^{(-)}}{Y_{-1}}, \frac{NLg^{(+)}}{Y_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Other government asset transactions, $IAgo$, encompass a variety of financial flows including lending and capital transfers to state enterprises, the private sector and foreign governments and proceeds of privatisation. This series is estimated as a residual of government accounts and, perhaps unsurprisingly, does not accumulate in any systematic way to generate a corresponding stock variable representing government assets. Therefore in the GPM it is treated as a capital transfer affecting non-government wealth, WP , but not income. Empirically, it is found to be negatively correlated with debt outstanding, Lg , and positively correlated with government net lending (financial savings), NLg .

Given net lending and other asset transactions as well as holding gains⁶, there is an implied change in the government's financial position, NGF , defined as deposits and investments in the domestic banking system less outstanding debt. This may be positive or negative as the government may be a net creditor or net debtor but the net figure is not sufficient to determine assets and liabilities on each side of the balance sheet. To do this the GPM uses a proxy variable, NGI , that measures "covered" debt, meaning the minimum of government holdings of financial sector assets, Agf , and debt liabilities, Lg .

⁶ The imputation of holding gains is set out in Appendix C. Government gains or losses depends on changes in the value of government deposits and investment in the banking system as well as outstanding debt. The GPM makes the assumption that government ultimately absorbs gains or losses on exchange reserves which are an asset of the domestic banking system and takes responsibility for 70% of losses arising from abnormal debt write-offs by banks.

$$(24) \quad \Delta \log NGI = \Phi \left\{ \log^{(-)} NGI_{-1}, \log \frac{R\$_{-1}}{rx_{-1}}, \Delta \log^{(+)} Y, \alpha_b, \varepsilon_b \right\}$$

where $NGI = Agf$ if $Agf \leq Lg$ or Lg if $Agf > Lg$

Covered government debt, so defined, is historically determined (hence the first element in the RHS) and is correlated with national income, $dlogY$, and the accumulated stock of foreign exchange reserves measured in domestic purchasing power (divided by the effective exchange rate), $R\$/rx$.

Given the net position and the covered position, the derivation of assets Agf and debt Lg follows.⁷ The remaining task is to estimate how holdings of government debt are split between the domestic banking system and other holders.

$$(25) \quad \Delta \log \frac{Lg_0}{Lg} = \Phi \left\{ \log \frac{Lg_{0-1}}{Lg_{-1}}, \Delta \log \frac{Dp_{-1}}{Y_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Non-bank holdings of government debt, Lg_0 , are expressed as a share of total debt outstanding, Lg .⁸ This series follows a time-dependent path, captured in the first variable on the RHS, and appears as a weak portfolio alternative to deposits in the banking system, Dp .

The external position

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.⁹ Changes in market positions are also influenced by changes in exchange reserves held by the monetary authority.

$$(26) \quad \Delta \log \frac{R\$}{rx \cdot Y_{-1}} = \Phi \left\{ \log^{(+)}(rpr\$), \frac{CAS_{-1}}{Y_{-1}}, \frac{CAS_{-1}}{Y_{-1}}, \alpha_b, \varepsilon_b \right\}$$

Exchange reserves, denominated in domestic purchasing power dollars, $R\$/rx$, are estimated as a ratio to national income.¹⁰ Reserves are path-dependent, rising or falling

⁷ $AGF = NGI + \max(NGF, 0)$ $LG = NGI + \max(-NGF, 0)$

⁸ A slightly more complex transform is used in the model to ensure that the ratio lies between zero and 1.

⁹ See Appendix C for modelling of holding gains.

¹⁰ Once again the model uses a slightly more complex RHS function to impose a ceiling on exchange reserves relative to annual income.

with valuation changes, $rpr\$$, and are positively correlated with the level and rate of change of the current account, $CA\$/Y\$$. Inevitably the equation has large standard errors reflecting variations 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 (see Appendix C for the relevant identities). The *covered market position*, $NXI\$$, defined as the minimum of assets and liabilities, is modelled as follows.

$$(27) \quad \frac{NXI\$}{rx \cdot Y_{-1}} = \Phi \left\{ \log Y_{-1}, \Delta \log Y_{-1}, \Delta \log \frac{R\$_{-1}}{rx_{-1} \cdot Y_{-1}}, \Delta \log (1 + Yr_{-1}), \alpha_b, \varepsilon_b \right\}$$

$$\text{where} \quad Nxi\$ = \begin{cases} Axo\$ & \text{if } Axo\$ \leq Lx\$ \\ Lx\$ & \text{if } Axo\$ > Lx\$ \end{cases}$$

The covered position tends to fall relative to national income when income itself, Y , relative income, YR , and reserves, $R\$$, increase. Given the net market position and the covered position, external assets $AXO\$$ and liabilities $LX\$$ are determined by identities.¹¹

The real exchange rate and valuation of external assets and liabilities

The real exchange rate represents the combined effect of changes in domestic and external price levels and changes in nominal exchange rates, themselves responding to supply and demand in markets for goods and services and international financial markets. It is particularly important to track the real exchange rate as a basis for understanding changes in relative prices of domestic and external goods and services (current account) and assets (capital account). Therefore the GPM models the real exchange rate directly, leaving nominal exchange rate movements to be inferred as consequences of changes in the real exchange rate and rate of inflation.

$$(28) \quad \Delta \log (rx) = \Phi \left\{ \log (rx_{-1}), \frac{CA\$_{-1}}{NXI\$_{-1} + M\$_{-1}}, \frac{NX\$_{-1}}{rx_{-1} \cdot Y_{-1}}, \Delta (spvi_{-1}), \Delta \log (phw), \alpha_b, \varepsilon_b \right\}$$

The *real exchange*, rx , is path dependent, being expected to rise as the current account, $CA\$$, and external position, $NX\$$, improve. Domestic inflation, $spvi$, and world inflation,

¹¹ $AXO\$ = NXI\$ + \max(NXF\$, 0)$ $LX\$ = NXI\$ + \max(-NXF\$, 0)$

$d\log(phw)$, have short-run effects as the nominal exchange rate cannot be relied upon to adjust immediately to compensate for relative inflation.¹²

The valuation of external assets (reserves, $rpr\$$; external assets, $rpax\$$, and external liabilities, $rplx\$$) in terms of international purchasing power, captured in the equations below, is eroded by world inflation, $\Delta\log(phw)$. External liabilities, which represent holdings of domestic assets, appreciate with a rise in the real price of capital. Changes in these valuations give rise to holding gains or losses for external parties that issue the assets or hold the liabilities. Valuations for domestic issuers and asset holders are further affected by changes in the real exchange rate, giving rise to additional holding gains or losses.

$$(29) \quad \log(rpr\$) = \Phi \left\{ \Delta \log^{(-)}(phw), \alpha_b, \varepsilon_b \right\}$$

$$(30) \quad \log(rpax\$) = \Phi \left\{ \Delta \log^{(-)}(phw), \alpha_b, \varepsilon_b \right\}$$

$$(31) \quad \log(rplx\$) = \Phi \left\{ \Delta \log^{(+)}(pkp), \Delta \log^{(-)}(phw), \alpha_b, \varepsilon_b \right\}$$

The domestic banking system

The final component of financial balance sheets is assets and liabilities of the domestic banking system. We have already provided equations for exchange reserves (asset) and government deposits and investment (liability). Another asset of the domestic banking system, holding of government debt LGF , is the difference between total debt LG and debt held by other institutions LGO . The remaining components of the balance sheet of the domestic banking system are domestic lending LN and a residual or balancing item DP that represents not only domestic deposits but capital not held by government and net external liabilities of domestic banks. Again these items are modelled by considering the net position, NFF , which may in principal be positive or negative, and the covered position, NFI , which is the minimum of assets LN and liabilities DP .

First note that changes in the net position NFF (defined as deposits minus advances) may be determined as the residual of the balance sheet.¹³ Implicitly changes arise from

¹² Whatever the number of blocs identified in the model, exchange rates whether nominal or real, have one less degree of freedom since they represent relative rather than absolute prices. The GPM deals with this by determining the real exchange rate for each bloc independently in the first instance and then making a scaling correction to the calculated rate for all blocs in order to maintain accounting identities that imply a constant world-average figure

¹³ $NFF = R\$.rx + Lgf - Agf$

financial flows and holding gains and losses in the usual manner.¹⁴ Changes in the covered position representing expansion or contraction of the balance sheet are modelled as follows:

$$(32) \quad \Delta \log \frac{NFI}{Y_{-1}} = \Phi \left\{ \log \frac{NFI_{-1}}{Y_{-1}}, \log Y_{-1}, \Delta \log Y, \frac{NFF}{NFI_{-1}}, \frac{\Delta NFF}{NFI_{-1}}, \frac{\Delta LGF}{Y_{-1}}, \frac{R\$_{-1} + NXI\$_{-1}}{Y\$_{-1}}, \frac{WLNA}{LN_{-1}}, \alpha_b, \varepsilon_b \right\}$$

$$\text{where} \quad NFI = \begin{cases} Dp & \text{if } Dp \leq LN \\ LN & \text{if } Dp > LN \end{cases}$$

Thus the ratio of *covered bank lending to income* $NFI/Y(-1)$ ¹⁵ responds positively to income Y , excess deposits NFF , liquidity in the form of government debt LGF , and the size of the external position $R\$ + NXI\$$. On the other hand the model assumes that past debt write-offs $WLNA/LN(-1)$ have a restrictive impact on credit policy.

Given the net position and covered lending, loans and deposits are determined by the usual identities.¹⁶

The 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 by the perpetual inventory method, accumulating investment in capital goods and inventory, $IP + IV$, in each period and deducting an estimate for capital consumption. The *value of the capital stock* is calculated as the product of the stock of produced capital goods and the real price of capital.

$$(33) \quad \Delta \log (pkp) = \Phi \left\{ \log (pkp_{-1}), \Delta \log (pkp_{-1}), \log \frac{V}{VT}, \alpha_b, \varepsilon_b \right\}$$

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 .

¹⁴ 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.

¹⁵ In the model this ratio is written in a form that imposes a ceiling equal to 2.5 times annual income (see Appendix D).

¹⁶ $DP = NFI + \max(NFX, 0)$ $LN = NFI + \max(-NFX, 0)$

Private wealth WP is defined as the sum of the real value of capital and net financial assets of the private sector comprising holdings of government debt, deposits less borrowing from the domestic banking system, and the external market position. Changes in private wealth are identically equal to the sum of savings and holding gains and losses less capital consumption and government capital transfers.

Interest rates, capacity utilization and inflation

A comment is necessary on the measurement procedure and significance of series for interest rates and inflation for blocs that comprise countries using different currencies as is the case for most blocs in the standard GPM decomposition. The approach that has been followed is to measure interest rates and inflation as weighted averages using ppp expenditure in each country as the weighting factor.¹⁷ This procedure has some drawbacks when very different rates of inflation are experienced in countries belonging to the same bloc. Thus for example, an annual inflation rate of 100% in a country accounting for one-tenth of real expenditure would be sufficient to raise the imputed inflation rate for the bloc as a whole by 10% even though the remaining 90% of countries had not been affected. A similar problem arises for interest rates on non-indexed financial instruments since these may also rise to very high values under conditions of hyper-inflation. GPM estimates of bloc-level nominal exchange rate changes are affected indirectly since they are inferred from changes in real exchange rates adjusted for relative rates of inflation.

An alternative method for averaging inflation, currently under consideration, would be based on an index of the level of pain or distortion induced rather than inflation itself. The justification for this approach is that the impact of very high rates of inflation is typically mitigated by extensive indexation or use of external currencies.¹⁸ If an improved method is used to average inflation, interest rates will be averaged on a real-terms basis. Nominal interest rates and exchange rate movements will be calculated by adjusting real rates for the imputed inflation rate.

The GPM models two interest rates for each bloc. The ‘policy’ rate is a short term rates, *is*. The long-term interest rate, called the ‘bond’ rate *im*, is mainly influenced by market conditions and expectations.

$$(34) \quad \Delta \log(is) = \Phi \left\{ \log^{(-)}(is_{-1}), \log^{(+)}(pi_{-1}), \Delta \log^{(+)}(pi), \log \frac{V^{(+)}}{VT}, \alpha_b, \varepsilon_b \right\}$$

¹⁷ In the case of domestic cost inflation, country values are weighted by ppp GDP.

¹⁸ The GPM does make use of an index of inflation impact, *spvi*, whose value increases from 0 to 1 as inflation increases from low rates to very high rates.

Changes in the policy rate, is ,¹⁹ follow a schedule that is weakly path dependent and strongly determined by domestic inflation, pi , and capacity utilization, V/VT . Thus, the equation resembles a ‘Taylor rule’ which may be said to represent the underlying views of central banks around the globe and shows a robust econometric fit.

$$(35) \quad \log(im) = \Phi \left\{ \log^{(+)}(is_{-1}), \Delta \log^{(+)}(is), \log^{(+)}(pi_{-1}), \Delta \log^{(+)}(pi), \alpha_b, \varepsilon_b \right\}$$

The bond rate, im ,²⁰ responds to the level and rate of change of the policy rate is and inflation pi .

Domestic cost inflation, pvi , is modelled as a path-dependent phenomenon influenced by capacity utilisation and changes in the real exchange rate and price of oil.

$$(36) \quad \Delta \log(pvi) = \Phi \left\{ \log^{(-)}(pvi_{-1}), \Delta \frac{V^{(+)}}{VT}, \Delta \log^{(-)}(rx), \Delta \log^{(+)} \frac{pew}{rx}, \alpha_b, \varepsilon_b \right\}$$

An increase in the real exchange rate puts downward pressure on cost inflation by reducing prices of external goods and services in the domestic market and cutting profits of exporters and producers of import substitutes. Increases in the domestic price of oil have a pass-through effect.

$$(37) \quad VT = (1 + \sigma) \cdot \text{mavg}(V, 6) \cdot e^{\left\{ \delta \cdot \log \frac{V}{V_{-6}} \right\}}$$

Productive potential, VT , is modelled by an extrapolation of GDP growth over the past six years with coefficients s and δ that determine the typical level of spare capacity as a function of the growth rate.

Domestic price inflation, pi , measured as annual changes in the domestic expenditure deflator, is determined by cost inflation and movements of the terms of trade using an identity which is a straightforward consequence of national accounting definitions.²¹ If the terms of trade moves in a country’s favour, a greater proportion of domestic costs has been passed through to exports and/or import prices have reduced 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

¹⁹ 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.

²⁰ See the preceding footnote.

²¹ See Appendix B.

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, urbanization and migration

Employment, NE, is modelled as a path-dependent proportion of potential labour supply, *LS*, represented by the working age population plus 20% of older people. A transform is applied to ensure that the proportion employed lies within the range 40-80%.²²

$$(38) \quad \Delta \log \frac{NE}{LS} = \Phi \left\{ Y_{r-1} \cdot \Delta \log V^{(+)}, Y_{r-1} \cdot \Delta \log V_{-1}^{(+)}, \Delta \log (NUR_{-1} / N_{-1})^{(-)}, \alpha_b, \varepsilon_b \right\}$$

The equation captures Okun's law with a dynamic adjustment to GDP growth over two years, the elasticity of adjustment being proportionate to the relative income level. In other words the adjustment of employment to changes in output growth is strong in high-income blocs and weak in low-income blocs. This finding may reflect greater measurement difficulties in middle and low income countries but it also has substance to the extent that greater flexibility is essential for survival in lower-income countries.

The employment rate is further influenced by the speed of *urbanization, dlog(NUR/N)*.

$$(39) \quad \Delta \log \frac{NUR}{N} = \Phi \left\{ \log V_{-1}^{(-)} / N_{-1}, \alpha_b, \varepsilon_b \right\}$$

Urbanization itself appears to be a largely independent, ongoing process, with some slow-down at higher levels of GDP per capita, V/N .²³

Finally, the growth of population of working age is affected by *net migration, NIM*, treated as exogenous to the model.²⁴

$$(40) \quad \Delta \log \left(1 + \frac{NIM}{NE_{-1}} \right) = \Phi \left\{ \Delta \log NWP_{-1}^{(+)}, \Delta \log NE_{-1}^{(+)}, \alpha_b, \varepsilon_b \right\}$$

Net migration correlates with the lagged rate of growth of working-age population, $dlog(NWP(-1))$, and growth of employment, $dlog(NE)$.

²² In the model the LHS is written as $\log(1/((0.8-0.4)/(NE/LS-0.4) - 1))$

²³ In the model the LHS is formulated to constrain the share of urban population to the range zero to 1.

²⁴ The natural increase in population in each age group is exogenous (based on UN projections).

PANEL ESTIMATION

As noted in ‘GPM concepts’, macroeconomic data often lack the properties required for straightforward estimation and clean interpretation of econometric results. The main concerns, even if data have been checked and reconciled carefully, are the scale and irregular pattern of measurement errors, non-stationarity and multi-collinearity. These problems are prevalent or even acute in annual time series that provide global coverage.

Currently, the GPM is implemented in EViews 6 and panel regressions are performed using the EViews ‘pool’ object with bloc-specific intercepts and covariances. The general specification of behavioural equations is based on the following reformulation of the autoregressive distributed lag model – ARDL(1, 1, ..., 1):

$$\Delta y_{i,t} = \mu_i - \phi \cdot y_{i,t-1} + \delta \cdot \Delta x_{i,t} + \beta \cdot x_{i,t-1} + \varepsilon_{i,t}$$

where X is a vector of cointegrated explanatory variables, β contains information about their long-run impact, ϕ is the error correction term, and δ measures the short-run influence of (weakly) exogenous variables. The μ_i capture time-invariant group-specific differences (fixed effects).

Using this general form and EViews pool estimation with cross-section variances and one degree of autocorrelation, four different models for each equation are tested and tabulated: with or without fixed effects and with or without covariant SUR error terms. Finally one of the models is re-estimated for use in simulations. This may have imposed values for certain coefficients and may have fixed effects and variances recalibrated on more recent data if these are believed to be more relevant than values estimated on the full set of historical data. The ability of the final equation to track historical data is tested by constructing a dynamic simulation and graphing results against actual values (see Appendix D). Note that the schema for each equation results from more extensive tests for robustness and model properties using different geographical disaggregations including finer geographical disaggregations distinguishing up to 70 individual countries.

The SUR model with estimated cross-section error covariances has not proved very successful. Therefore in most cases the GPM currently relies on pool estimation with independent shocks in each bloc, generally termed DFE or dynamic fixed effects.

Summarized in the table below²⁵, there are a set of alternative models currently under consideration, including PMG or pooled mean group and DOLS or dynamic least squares.

²⁵ Borrowing from inputs provided by Pedro Martins (SOAS, London) at a workshop in Thailand, May 2010.

Alternative estimation models under consideration

Method	Advantages	Disadvantages
DFE: dynamic fixed effects	Few parameters to compute Robust for small samples	Error-correction term may be downward-biased Sensitive to endogeneity on the right- hand side Sensitive to outliers
SUR: seemingly unrelated regression	Allows for cross-section covariance of error terms	Not robust with annual data and a substantial number of blocs
PMG: pooled mean groups	Allows noisy short-run behaviour to be group-specific, improving efficiency of long-run coefficients Fairly robust to outliers.	More parameters to estimate Sensitive to endogeneity on the right- hand side
DOLS: dynamic OLS	More robust to endogeneity	More parameters to estimate No information about short-run adjustment

See DFE: Banerjee et al, 1998
 SUR: Zellner, 1962 and Swamy, 1970
 PMG: Pesaran et al., 1999
 DOLS: Kao and Chiang, 2000

SCENARIO RULES AND POLICY EVALUATION²⁶

GPM scenarios are defined by rules superimposed on a baseline projection. The rules may specify shocks such as shifts in confidence that represent risks facing policy-makers as well as changes in the conduct of policy.²⁷

The main categories of rule, in increasing order of complexity, are

- Exogenous changes: usually be applied to behavioural variables,²⁸ these rules may effectively exogenise a variable or perturb its value in a predefined way
- Lagged adjustment: a policy variable is adjusted each year in response to differences between the desired value and actual value of an objective in the prior year
- Target-instrument: a policy variable is adjusted each year in such a way that the specified objective achieves a given value in the same year.
- Conditional regime switch: a policy variable is adjusted if any only if an objective function approaches or hits a target value or trajectory.

The target-instrument rule type is evidently the most demanding since it requires that the instrument be effective and that the target value specified for the objective is feasible. The GPM provides a shock simulation function that helps users to evaluate the effect of any instrument on the proposed objective as a basis for judging whether the rule will work out in practice. A dynamic multiplier program is also provided to allow a user to examine the impact of shock to one variable on a list of other variables in the same bloc or other blocs (see below)

Exogenous changes

Shocks may be introduced to simulate changes in confidence or expectations or to simulate policy innovations whose magnitude can be fixed in advance.

It is also possible to fix the future values or growth trajectory of a behavioural variable, effectively making it exogenous. In this case the GPM keeps track of the implied deviation of the variable from 'normal' behaviour specified by the model equation estimated on historical data. The size of the deviation may have a bearing on the plausibility or realism of the assumed values or growth trajectory.

²⁶ This section draws heavily from "GPM User Guide, version 3", produced by Francis Cripps and Naret Khurasee.

²⁷ See Appendix E for details of rule definitions and examples of their use in scenarios.

²⁸ It is also possible to modify the assumed values of the small number of explicit exogenous variables used in GPM. The most important of these is the write-off rate for bank lending which may potentially have a significant effect on future availability of credit.

Lagged adjustment

A lagged adjustment rule modifies values of an instrument in the light of differences between the target value and actual value of an objective in the prior year. The objective may be the value of a variable or the value of a formula such as a percentage growth rate or ratio to GDP.

This type of rule is relatively safe from a modelling perspective since the size of the instrument adjustment in each year can be calculated in advance using the target value given by the rule and the actual value of the objective in the prior year.

The rule may or may not be effective in bringing the objective near to its target value. The main risk is that if the rule has perverse effects, the gap between target and actual values will increase over time, provoking increasingly large adjustments to the policy variable.

Target-instrument

A target-instrument rule adjusts a policy variable (the instrument) in such a way that the current-period value of the objective moves a specified fraction of the distance from its prior-year value to a given target value. The effect is different from lagged adjustment because the policy setting is adjusted in the light of the current-year result, being iterated until the specified outcome is achieved.

Fractional movement of the objective towards the target value or trajectory is specified as a number in the range 0 to 100. The higher the fraction, the more rapidly the objective will converge to the target. If it is 100, the instrument will be adjusted as necessary in order for the target path to be tracked exactly in each year. If the value is very small, the objective will move only a small distance from its prior-year value.

Regime-switching

Conditional target-instrument rules are defined by specifying a ceiling or floor. So long as the value of the objective is below the ceiling or above the floor, no adjustment is made to normal behaviour of the policy instrument. Adjustments of the policy instrument commence when the objective hits the ceiling (floor) and the adjustments are sufficient to prevent the objective from exceeding the ceiling (falling below the floor).²⁹

In the case of a regime switch, the transition can be made less dramatic by specifying a fractional adjustment process in which the effective ceiling or floor each year is fixed at level somewhere between the prior-year value of the objective function and the target level or trajectory specified ex ante in the scenario definition.

²⁹ The assumption that the policy variable will be adjusted to any necessary extent may be relaxed by restricting adjustments to lie within a given range of probability.

Links

Additional variables may be associated with a policy rule by specifying links that define the direction and size of adjustments of the linked variable relative to adjustments of the variable to which it is linked. When policy variables are linked the implication is that policy makers in different blocs or different policy fields will respond in a synchronised manner to a common stimulus. Thus links may be used to specify a bloc-level policy package in which a combination of policy instruments is to be used in pursuit of a given objective, or for an internationally coordinated package in which policies in different blocs are adjusted in support of a common objective.

In the case of rules defining the movement of non-policy behavioural variables such as savings and investment, links may be used to represent "contagious" swings in confidence or expectations that result in movements that are synchronised across blocs or related variables.

Constraints

It will usually be considered implausible that the value of an instrument should depart too far from values implied by historical behaviour. The GPM provides an option to restrict adjustment of a policy instrument or non-policy behavioural variable to values within a given range of probability, e.g. 50% or 99%, relative to the historical distribution of residuals for that variable in the relevant country or bloc. Such constraints override the operation of all types of scenario rule except explicit exogenous shocks.

The imposition of constraints in the form of probability ranges makes scenarios safer in the sense that outcomes will be closer to historical experience but also implies that objectives specified for the scenario may not be fully achieved even if the specified instruments are effective and targets are computationally feasible. From an economic point of view, the chosen constraints determine how 'normal' or 'extraordinary' (even if historically feasible) the proposed changes can turn out to be.

Policy evaluation

Given that policy-makers have to deal with multiple targets that are typically not achieved with any precision and may not be achievable at all, the GPM provides a number of comparative measures that may be used to assess performance at the bloc level and global level by a set of pre-defined standardised measures.

Performance scores on a scale of 0 to 10 are currently provided for the following:

- bloc level: GDP growth, inflation, exchange rate stability, employment
- global: growth of trade, stability of commodity and oil prices, moderation of energy use, catch-up of low income blocs

In addition to performance scores, summary measures of inequality between blocs are provided for per capita income, government expenditure, primary energy production and use, and exports of manufactures and services.³⁰ Inequality measures are on a scale of 0 to 100 with 100 representing extreme inequality and 0 representing exact equality.

Performance scores

Performance with respect to each objective in each year is measured by the deviation of the actual outcome from target. The larger the deviation, the lower the score. The score is expressed as a number in the range 0 to 10 using a formula similar to

$$\text{score} = 10 / (1 + s \cdot \text{gap})$$

where *s* is a scaling parameter that normalises the historical average score for the given objective and *gap* is the difference between the target and actual outcome.

For some variables the requirement is one-sided. For example, in the case of inflation the performance gap is the excess of actual inflation over the target value; there is no penalty for inflation below the target value. Therefore in years when inflation falls below the target level, the inflation performance score is 10. Bloc scores for GDP growth and capacity utilisation and global scores for moderation of energy use and catch-up of low-income blocs are similarly one-sided. On the other hand scores for stability of variables such as exchange rates, growth of trade and prices of primary commodities and oil are two-sided in the sense that deviations from the target are counted as gaps whether the target is exceeded or the outcome falls short. To get a score of 10 the target must be achieved exactly.

Target values

A potentially troublesome aspect of any evaluation scheme is the determination of targets for each bloc and for the world as a whole. The approach followed in GPM2 is to base targets on historical performance. Thus the target value for each objective is equal to a 10-year³¹ weighted average of past values of the objective, implying that a deterioration in outcomes relative to the preceding decade will be considered as a failure or policy gap. Improving performance relative to the preceding decade results in a good score but raises the standard by which outcomes are judged in the future.

³⁰ A Theil inequality measure is provided for each variable. In addition a Gini coefficient is provided for per capita income only.

³¹ The no of years on which targets are calculated may be changed by modifying a parameter in the GPM settings program before recalculating historical data as well as the baseline projection and scenarios.

Composite scores

Composite scores are conventionally calculated using a root-mean-square formula. When individual scores are defined as above, the composite figure is calculated by an inverse root-mean-square formula:

$$\text{composite score} = 1/\text{sqrt}(\text{sum}(w(i) / \text{score}(i)^2))$$

where $w(i)$ is the weight attached to objective i . This formula ensures that low scores attract more substantial penalties. Composite scores defined this way also take values in the range 0 to 10. The choice of weights should ideally be a consensus one in order to maximize the possibility of agreement in the evaluation of alternative policy schemes.³²

³² Weights for different objectives in composite policy scores may again be changed by modifying values specified in the GPM settings program and recalculating historical data as well as the baseline and scenarios.

MULTIPLIER ANALYSIS

Properties of the model as a dynamic, interactive system can be assessed by imposing a shock on the value of one variable at a time and tracing the impact on other variables in the same bloc and the rest of the world, in the current year and subsequent years as the effects of the shock feed through.

The model provides a program to carry out such a multiplier analysis and tabulate results for a specified selection of blocs, input variables and output variables. There is also a free-style program that allows the user to quickly compute and tabulate the impact of a shock to any one variable on a list of other variables. It is essential to understand, though, that multiplier analysis in the GPM provides information on ex post consequences of an ex ante shock. The ex ante shock applied to a behavioural variable does not override or suspend normal dynamics of the variable in question implying that the ex post change in the variable includes feedback effects even in the initial year when the shock is applied.³³ Moreover, as the model is dynamic and global, the effects of a shock in one economy include spillovers in other economies and that over time will feed back into the economy where the initial shock occurred. Thus not only are values of global multipliers frequently higher than local multipliers but also, in the case of large economies, values of local multipliers are influenced by the global feedbacks.

To illustrate these points, the GDP effect of a change in government spending in the US is estimated to be 1.7 times the size of the injection in the first year, fading away quite slowly in future years because of the path dependency of government spending itself (see Appendix F).³⁴ The global GDP effect is 2.5 times the size of the injection in the first year and, perhaps unsurprisingly, the largest spillover recipient is China where the real GDP impact is 200 million dollars for each billion dollars injection in the US. On the other hand if US government spending is exogenized with an injection in one year only, then reverting to baseline values, the GDP multiplier is 1.6 in the first year and a small

³³ The multiplier analysis in the GPM does not currently have a facility for modifying the value of a variable by a given amount in one year only and keeping the variable fixed (e.g. at actual or baseline values) thereafter. Tests of this kind can in principle be set up using scenario rules to override feedbacks affecting the shocked variable.

³⁴ This result is not out of range with other models. L. Klein's *Comparative Performance of U.S. Econometric Models* (1991) summarizes the results of most popular models of the US economy in the following way: 'on average, the 'high' of expenditure simulations without monetary accommodation is 1.5 after a period of four to five quarters; [...] with monetary accommodation to keep interest rates at the baseline level, the multiplier reaches a 'high' of 2.2; [...] and] the solutions with a monetary policy reaction function fall somewhere in between'. More recently, the Council of Economic Advisors (CEA, 2009, *Estimates of Job Creation from the American Recovery and Investment Act*, pp. 11) posits a multiplier of 1.45 to 1.5 between the fourth and the fifth quarter. Note that models considered in this report are not global and therefore not designed to capture global feedbacks.

negative (0.15) in the second year with a very small positive effect in the following years, fading away slowly.

Appendix F tabulates results of a range of multiplier experiments for shocks originating in selected blocs. Examples include shocks to government spending and government revenue measured in constant ppp dollars and on the real exchange rate, the rate of cost inflation, the policy interest rate and energy demand.³⁵

Responses shown in appendix tables represent values of multipliers and elasticities for upward shocks to the above-mentioned variables calculated relative to first six years of the baseline projection with 'business as usual' policies. Given that the model is non-linear, values of multipliers and elasticities may change if shocks are generated in a downward direction or relative to a different baseline. Multipliers and elasticities can be expected to change significantly for scenarios that embody new policy rules.

Dependence on the baseline is particularly significant for interest rates and inflation since the current GPM baseline starts with unusually low inflation rates and capacity utilisation. Interest rates in many blocs are near to levels at which the liquidity trap is effective and capacity utilisation is low enough to make inflation relatively insensitive to changes in aggregate demand.

³⁵ In the GPM the oil price is calculated to clear the market and cannot be shocked directly.