CHAPTER 4

MAMS – A Computable General Equilibrium Model for Developing Country Strategy Analysis

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Abstract

This chapter presents MAMS (Maquette for MDG Simulations), a recursive-dynamic CGE model developed at the World Bank for analysis of medium- to long-run country strategies for low- and middle-income countries, including strategies aimed at improving MDG (Millennium Development Goals) outcomes. Compared to other CGE models, MAMS offers a unique combination of new and policy-relevant features, most importantly disaggregation of the government services by function, broad and integrated coverage of MDGs and endogenous links between education and the labor market. The chapter provides a detailed description of MAMS, the policy insights that it has generated, exemplified by a case study of Yemen and the lessons learned from developing and applying MAMS to a large number of countries.

Keywords

Computable general equilibrium model, millennium development goals, human development, fiscal policy

JEL classification codes

C68, E62, O15, O21, H50

4.1 INTRODUCTION

At the United Nations (UN) Millennium Summit in 2000, the leaders of the world committed themselves to the achievement by 2015 of a set of ambitious global goals, termed the Millennium Development Goals (MDGs) and related to poverty, education, health, gender equality, the environment and the creation of a global partnership for development.[1] Since then, the pursuit of policies aimed at achieving these goals have figured prominently on the agendas of developing country governments and the

[1] For the eight goals and related data, see www.worldbank.org/mdgs, http://unstats.un.org/unsd/mdg and www.undp.org/mdg. The World Bank and the International Monetary Fund produce an annual Global Monitoring Report devoted to MDGs (go.worldbank.org/UVQMEYED00), while different UN organizations produce and sponsor a wide range of global, regional and national reports (see www.undp.org/mdg).

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international community. Such policies may often have significant economy-wide repercussions due to their consequences for government budgets, the balance of payments and domestic markets for factors, goods and services. Such repercussions may be particularly pronounced in low-income countries where the most rapid progress is sought. Against this background and given its economy-wide perspective, computable general equilibrium (CGE) modeling presented itself quite naturally as an appropriate tool for analysis of MDG-related issues (along with more sector-specific approaches).

In 2004, the World Bank, at the initiative of its then Chief Economist Francois Bourguignon, embarked on the development of a country-level CGE-based modeling framework baptized MAMS (Maquette for MDG Simulations), developed with GAMS[2] as the core software and designed for the analysis of strategies aimed at achieving the MDGs, with Ethiopia as the pilot study.[3] In its framework, MAMS has focused on the MDGs that appeared as the best candidates for consideration in a country-level economy-wide model – MDG 1 (represented by the target of halving poverty rates), 2 (achieving universal primary schooling), 4 (reducing under-5 mortality rates by two thirds), 5 (reducing maternal mortality rates by three quarters) and 7 (halving the population shares without access to improved sources of water and sanitation), in all cases (except for MDG 2) relative to 1990 figures.[4]

Since the start of this work in 2004, MAMS has been applied to more than 40 countries. Together with the World Bank, the UN Department of Economic and Social Affairs (UN-DESA) it has played a leading role in many country applications, typically with a strong involvement from national researchers. After an initially exclusive focus on strategies and the requirements for achieving the MDGs by 2015, later applications have been more diverse, responding to the analytical demands from developing-country governments, World Bank country teams and different UN agencies. As examples, in addition to MDG analyses, client interest has frequently led to a focus on tradeoffs between alternative targets given limited (domestic or foreign) financing, consideration

2 The GAMS software, developed at the World Bank in the 1980s, is documented in Brooke *et al.* (2010).

3 The authors would like to thank many other colleagues for valuable inputs into the development of MAMS, including François Bourguignon, Maurizio Bussolo, Denis Medvedev, Dominique van der Mensbrugghe, Marco V. Sánchez Cantillo, Hans Timmer and Rob Vos. Institutionally, Enrique Ganuza of the UN Development Programme (UNDP) played a key role by paving the way for collaboration between the World Bank and the UN system, leading to a large number of MAMS country applications, especially in Latin America.

4 Among the goals that have not been prioritized in MAMS, MDG 8 (to develop a global partnership for development) is not relevant for an individual developing country, while MDG 3 (focused on the achievement of gender equality in primary and secondary education) is highly demanding in terms of data and modeling yet the required policies are likely to be relatively low in cost (primarily requiring changes in attitudes and institutional rules), as a consequence having relatively limited economy-wide effects. In response to demands, future analyses may attach priority to MDG 6 (to combat HIV/AIDS, malaria and other diseases) even though this may, like MDG 3, also be highly demanding analytically and in terms of data. A study of Ethiopia considered gender issues related to education, labor markets and time use (Ruggeri Laderchi *et al.*, 2010).

of additional issues (like demography and effects of the global financial crisis) and simulation periods that are dictated by national strategies and thinking, often extending beyond 2015.

This chapter provides a detailed description of MAMS, the policy insights that it has generated and the broader lessons learned, in a relatively non-academic, operational context, from developing and applying a CGE model to a large number of countries. Like other chapters in this Handbook, its primary audience is researchers and analysts who are developing, using or interacting with CGE models. In outline, Section 4.2 positions MAMS in the broader context of the evolution of CGE modeling, while Section 4.3 discusses key aspects of the model's design and evolution since 2004. A detailed presentation of MAMS' mathematical structure is covered in Section 4.4 and the content of a country-level database is described in Section 4.5. Section 4.6 presents a user-friendly Excel-based interface that has been developed with the aim of facilitating productive use of MAMS by a larger group of analysts while Section 4.7 provides an overview of the applications of MAMS and their major findings together with a detailed account of an analysis of development prospects for Yemen. Section 4.8 concludes. Among these sections, Section 4.4 is aimed at readers interested in the details of model structure, whereas the other sections also are aimed at broader audiences.

4.2 CONTEXT AND MAIN CONTRIBUTIONS OF MAMS

Since Johansen's pioneering CGE model of Norway in the late 1950s, which was used to explore issues related to long-run economic development, the evolution of CGE models has been strongly influenced by the evolution of policy concerns in the broader economics discipline and in different country contexts. Due to their versatility, CGE models have been able to respond to demands for policy insights in many different areas, including international trade, taxation, poverty and income distribution, sector policies (often with a focus on agriculture), natural resources, energy and the environment (in recent years including global warming). The issues have been analyzed with different regional treatments, ranging from single-region village models to multiregion global models, with single-region country models as the most common species.

In this broader context, MAMS is a single-region country model with a focus on policies related to the achievement of time-bound international MDG targets and, more broadly, how government spending and taxation, foreign aid and exogenous conditions (including world markets) together influence and are influenced by human development. In terms of model structure and computer implementation, MAMS is a recent example of a long tradition of CGE modeling among researchers related to the World Bank. Research in the second half of the 1970s and the early 1980s, with the volumes by Adelman and Robinson (1978) and Dervis *et al*. (1982) as the most prominent examples, played a pioneering role in CGE modeling in general and in applications to developing countries in particular. The structural features that characterize current incarnations of this tradition, some of which originated in Johansen's original model or later work in the Johansen tradition in Australia, include: the treatment of international trade with Armington and constant elasticity of transformation (CET) functions, wage differentials across producing sectors, neoclassical flexibility between primary factors but Leontief coefficients for intermediates, homogenous capital (as opposed to a vintage treatment), a preference for a recursive treatment of dynamics, variables defined in levels and model implementation using the GAMS software. For MAMS, the more recent starting points in terms of structure and computer code are the static "IFPRI Standard Model" (Lofgren *et al.*, 2002) and dynamic extensions of this model (Thurlow, 2004; Lofgren and Robinson, 2008).[5]

Nevertheless, in order to meet the analytical challenges at hand, a fair amount of innovations were required, often drawing on formulations from other economic models, especially in the CGE area, i.e. a case of "normal science" in the Kuhnian sense.[6] With the notable exception of poverty, indicators related to the MDGs and the mechanisms through which they are determined were (and are still) very rarely covered in CGE models, especially from a concrete public finance angle that links policies and their resource requirements to outcomes while also considering other factors that influence these outcomes. This gap in the literature is surprising considering the importance of these issues in development policy.

In the broader economic literature, education and health have more commonly been considered in the context of human capital in which production- (often productivity)-enhancing investments can be made, i.e. without reference to explicit labor categories differentiated by education (or other characteristics). While the human-capital perspective may be fruitful for some purposes, it is not sufficiently concrete for Ministries of Finance and Education as they consider education at different levels, student enrollment, demography and related budgetary issues. In the MDG-related areas, the closest antecedents to MAMS may be found in manpower planning models that link education and labor, but suffer from a largely exogenous treatment of the broader economic context in which education and the labor market operate (Hopkins, 2002).[7] Another model with which MAMS has some affinity is SSELMA (Social Security, Education, Labor and the Macroeconomy), built by Marouani (see, e.g. Marouani and Robalino,

5 In addition to Lofgren *et al.* (2002), Robinson *et al.* (1999) and van der Mensbrugghe (2005) present the structure and GAMS implementation of a World Bank-type CGE model.

6 Kuhn (1962, pp. 24—25) refers to "normal science" as the phase of day-to-day puzzle solving by scientists working within a central paradigm. This phase is distinct from the preceding preparadigm phase and the succeeding phase of revolutionary science.

7 Hopkins is part of an International Labour Organization-based group that in the late 1970s and early 1980s developed and applied a country-level dynamic input-output model with fixed prices to analyze basic needs; in its emphasis on human development, their model may be seen as a precursor to MAMS; for a summary, see Hopkins and van der Hoven (1982).

2008). SSELMA, which does not cover MDGs, is characterized by a highly detailed treatment of the labor market (in terms of skill levels and in terms of distinctions between permanent and temporary employment) with a link to a separate model that (without interactions) feeds SSELMA with labor-supply growth by skill, i.e. as opposed to MAMS, disaggregated labor supplies by education are not endogenous to the model. At a level of aggregation similar to that of MAMS, Jung and Thorbecke (2003) endogenize the supply of labor by education (none, primary or higher) as the outcome of optimal household decisions influenced by public education spending but with a stylized treatment of public finance aspects. In a static model, Cloutier *et al.* (2008) treat households as making income-maximizing decisions with respect to investment in higher (non-basic) education considering (exogenous) wage gaps, as well as the opportunity and direct costs of education. At the most aggregate end, the MDG Monitoring Framework may be the only CGE model other than MAMS that is explicitly developed for the purpose of MDG analysis (Agénor *et al.*, 2005). It has the advantage of demanding little data but the drawback of providing less information and can only address a relatively limited set of issues.[8]

As will be apparent from the detailed presentation in Section 4.4, MAMS draws on a wide range of models, including some of those referred to above. Nevertheless, the analytical demands put on MAMS has required the development of a tool with a unique combination of new and policy-relevant features, most importantly broad and integrated coverage of MDGs, endogenous links between education and the labor market, disaggregation of the government spending by function into current and investment and coverage of government capital stocks. More concretely, as opposed to virtually all analyses of human development, MAMS accounts for interactions between different outcomes (e.g. the fact that increased access to safe water and sanitation contributes to better health outcomes), permits services to be supplied by both government and private producers, using for each technologies that may evolve over time and change as the costs of different inputs change. The fact that MAMS links education to the labor market, and positions both in a broader economic context, permits it to consider how growth and its sectoral features influence the payoffs from educational policies — a significant improvement relative to the standard practice of evaluating today's investments in education on the basis of historical micro level benefits and costs from such investments. More broadly, MAMS addresses the striking inability of most CGE models to address not only the costs but also the benefits from government spending and how these benefits differ across different functions (*cf.* spending on infrastructure and education). A key

8 The MDG Monitoring Framework is fundamentally a single-sector macro model. The only labor input is educated labor, the quantity of which is a function of raw labor (with exogenous growth) and the stock of education capital, financed via the government budget. Most of the MDGs are treated in a top-down fashion, post-calculated in equations based on cross-country econometric estimates.

aspect of the model design is rigorous separation of model code and country database, permitting the same model code to be applied to multiple country databases without any changes, including databases with widely differing degrees of disaggregation and length of simulation periods. Partly automated procedures for aggregation of existing databases have also enhanced modeling productivity.

MAMS has numerous limitations, many of which are shared with other CGE models and broader classes of economic models and which also are hard to overcome, including the difficulty of objectively assessing the validity of a given model structure for a specific analytical task. The areas in which MAMS has made its major contributions (discussed above) are probably also the areas in which there is most room for improvements with great payoffs. Among other issues, MDG and education outcomes are modeled on the basis of what may be termed a production function approach with a limited representation of micro structure. While this is convenient, especially in terms of data requirements, it may be preferable to consider alternative approaches that more explicitly account for the role of households as demanders of human development services.[9]

4.3 MODEL DESIGN

As noted in the preceding section, the core development of MAMS has taken place in an operational, time-constrained and demand-driven context at the World Bank, initially focusing on strategies for achieving time-bound MDG targets in a given country context (that of Ethiopia), but over time evolving into applications to a wider range of issues and time frames in other countries. Nevertheless, while the settings have varied, most applications have addressed the effects of alternative scenarios for government spending (level and allocation across functions) and resource mobilization (from taxes, borrowing and foreign aid) on poverty and human development with a medium- to long-run time frame (in the range of 5–40 years). Given this, model extensions and solutions to modeling and data issues in an earlier application are almost invariably relevant to future applications. In order to work effectively in this context, it was imperative to avoid using an unchanging bare-bones model as the starting point for the different applications; this would have required repeated reinvention of the wheel. Instead, an attempt was made to ensure, in a systematic fashion, that new applications would benefit from preceding model developments and refinements, resulting in what may be termed an expanding-purpose generic model with earlier versions representing special cases. In other words, new model features are introduced without precluding replication of the simulation results of an earlier model structure and its database.

[9] For example, for health, it may be fruitful to apply the Mosley-Chen framework, which distinguishes between proximate (direct) and socioeconomic (indirect) determinants of child mortality (Mosley and Chen, 1984; Lay and Robilliard, 2009).

Technically, a critical feature of the resulting research design was strict separation between, on the one hand, generic model code (in GAMS) and, on the other hand, application-specific files (almost exclusively in Excel) that contain the database and the specification of simulations.[10] The generic GAMS model code covers everything that is common across applications, including declarations of sets, variables and parameters; declarations and definitions of equations and models; solve statements; and definitions of parameters for reports and diagnostic tests (capturing errors in the database, model solutions, or reports). A database includes all application-specific definitions of parameters and sets (which, *inter alia*, provide the domains of most parameters), including the items that are used to select among alternative, preprogrammed assumptions and define alternative simulations. In practice, this means that each database controls the disaggregation of the building blocks of the model (sectors, factors and institutions), the choice between core and MDG versions of the model, the time frame for simulations and selected assumptions about the functioning of the economy, including factor markets, macro balances and payments (split into government and non-government payments depending on whether the government is or is not involved, either as payer or payee). The MDG version can be run only if the database includes data required to cover at least a subset of the MAMS MDGs and/or links between education and the labor market. In this setting, the analyst is able to develop a tailormade application, controlled from the application database, using a generic model code. Powerful features of the GAMS software made this design feasible and attractive, including the fact that it is set-driven and able to exchange data with other software, including Excel.

As part of the modeling routine, new applications use the current version of the generic model code and database structure as its starting point. Apart from developing a database, new applications may also require changes in the model structure and/or provide lessons for diagnostic tests. Whenever such new developments have been deemed to be of interest to a non-negligible subset of future applications, they have been introduced into the generic model code in a manner that does not impose the new feature but rather offers the analyst the option of selecting it (via the application-specific database). To provide some concrete examples, the changes that have been introduced as part of this process have led to more flexibility in terms of closures and rules for macro balances and factor markets, specifications for targeting of MDG and education outcomes (selection of indicators, numerical targets and timing, with a specification echoing the international targets as one option) and policy (including easier coverage of demographic issues).

In order to ensure robustness, any modifications of the code are tested on multiple databases (currently around a dozen, typically permitting applications of the core and MDG versions of the model) — a process that often has required minor changes in the

10 For a detailed description of the MAMS file structure, see Lofgren (2011).

structure of earlier databases. In this manner, the capabilities of a generic and increasingly robust framework have gradually been growing without sacrificing backward compatibility to earlier databases. While these are important advantages, the main disadvantage of this approach is increased complexity of the model code, significantly increasing the entry cost for users who would like to be able to modify the model structure. Given this, the two primary target groups for analytical work with the model are a small group of core users (who have the knowledge and experience required to adjust or further develop the model) and a larger group who work within the existing capabilities of the framework. Up until recently, analysts using MAMS have been required to specify information in Excel files and call up GAMS separately to run the model. To reduce skill requirements (including knowledge of GAMS) and facilitate use of MAMS by a potentially much larger group of analysts, a transition is under way toward primary reliance on a user-friendly interface called ISIM-MAMS, which permits the analyst to run MAMS from Excel (see Section 4.6).

4.4 MATHEMATICAL STRUCTURE OF MAMS

In this section we present the mathematical structure of MAMS. Mathematically, MAMS may be divided into two modules – a core CGE module and an MDG module – both of which are integrated in a simultaneous system of linear and non-linear equations, including some mixed-complementary relationships. We start our discussion with the core module, after that turning to the MDG module. As with other CGE models, poverty and inequality analysis can be performed in several ways; in the last part of this section, we briefly discuss the optional poverty module (which offers alternative representative household approaches), as well as microsimulation approaches that may be used with MAMS.

For each time period, the core CGE module gives a comprehensive and consistent account of decisions and related payments involving production (activities producing outputs using factors and intermediate inputs), consumption (by households and the government), investment (private and government), trade (both domestic and foreign), taxation, transfers between institutions (households, government and the rest of the world) and the distribution of factor incomes to institutions (reflecting endowments). This module also considers the constraints under which the economy operates (the budget constraints of institutions and producers; macro balances; and market constraints for factors and commodities). In addition to these standard features of a static CGE model, the core CGE module in MAMS also updates selected parameters (including factor supplies, population and factor productivity) on the basis of exogenous trends and past endogenous variables.

The MDG module captures the processes that determine MDG achievement in the human development area, most importantly the provision of services in the areas of education, health and water and sanitation. Specifically, the MDG module typically covers MDG 2 (primary education completion), 4 (under-5 mortality rate), 5 (maternal mortality rate) and 7 (rates for access to safe water and improved sanitation). The size and skill composition of the labor force is endogenized, in large measure depending on the evolution of the education system. The MDG module has feedback effects into the rest of the economy, primarily via the labor market.

The poverty module provides relatively basic, yet quick, welfare estimations. As with other CGE models, poverty and inequality analysis can be performed in several ways. The simplest but least desirable method uses an elasticity calculation for poverty given changes in *per capita* household consumption. Representative-household or survey-based microsimulation approaches are preferable. The former assumes fixed distributions of income or consumption within each household group, providing welfare estimations directly from the CGE model results. The latter type of approach can be either top-down, feeding CGE simulation results to a separate household model, or integrated, with the household model built directly into MAMS. In addition, the top-down approach may either use microsimulations based on randomized allocation (simpler) or based on econometric analysis to determine wages and/or sector of work.

In the model, growth depends on the accumulation of production factors (labor at different educational levels, private capital and other factors such as land, if singled out in the database) and changes in factor productivity, which may be influenced by the accumulation of government capital stocks and openness to foreign trade. The structure is recursive: the decisions of economic agents depend on the past and the present, not the future; in other words, the model does not consider forward-looking behavior.

The disaggregation of MAMS is data-driven and flexible in most areas: subject to computer memory constraints, there is no upper limit on the number of primary factors, households, production activities and commodities. Some minimum disaggregation of government human development functions is needed to permit the model to address MDGs in a meaningful manner; in most applications, the government has been split into education (disaggregated by cycle or level), health, water and sanitation and other public infrastructure, in addition to a residual sector for other government. To ensure that MDG achievement in education has explicit dynamic feedback effects on labor supply, the labor force is disaggregated by educational achievement, typically into three types: those who have completed tertiary, completed secondary but not completed tertiary and less than completed secondary. Further disaggregation of labor categories is straightforward and has been implemented in some applications.

MAMS may be solved with both the core and the MDG modules (in full or only selected parts) or with only the core module; in either case, the poverty module may be included or excluded. If the MDG module is excluded, MAMS is similar to other recursive-dynamic CGE models, applicable to a more limited set of policy issues but with very limited minimum data requirements. MAMS may be solved in "multipass" mode (year by year) or in "single-pass" mode (simultaneously for all periods; often faster but less robust).[11]

The applicability of the model to specific policy issues depends in large part on the degree of disaggregation. For example, the analysis of issues related to poverty requires a relatively detailed breakdown of household income sources (from factor endowments and the production activities in which they are employed). Similarly, it is likely preferable to disaggregate non-government production into multiple sectors and commodities, as it will provide more specific results of the sectoral employment and income effects of an MDG strategy, pursued on its own or in conjunction with other policies.

The mathematical statement of MAMS is presented in Tables 4.1–4.10 (notation and equations for the core CGE module) and Tables 4.11–4.14 (notation and equations for the MDG Module).[12] The following notational conventions apply in Tables 4.1–4.14 and various parts of the main text: uppercase Latin letters are used for variables; exogenous variables have a bar on top, endogenous variables do not. Parameters have Greek or lowercase Latin letters. Subscripts refer to set indices. A "0" superscript is used to refer to base-year variable values. Otherwise, superscripts are exponents (i.e. not part of the name of the variable or parameter). In the presence of the "0" superscript, the time subscript (t) has been suppressed. The fact that an item is a variable and not a parameter signals that, at least under certain model assumptions, its value is endogenous. In Tables 4.5–4.10 and 4.14, the domain column, which follows the column with the equations, is an important part of the mathematical statement – it indicates the set elements to which each equation applies.[13]

4.4.1 Core module

The notation used for the core CGE module – its sets, parameters and variables – is presented in Tables 4.1–4.4. The equations of the module are divided into blocks covering prices, production and trade, domestic institutions, investments, system constraints and macro variables and stock updating and productivity;[14] each block is presented in Tables 4.5–4.10. The presentation will briefly explain in more technical terms the equations in each of these blocks, with a focus on non-standard characteristics, including links between government services and government capital stocks, a relatively

[11] A potential advantage of the single-pass mode is that, if some adjustments are introduced in the formulations determining agent (government or non-government) decisions, MAMS may incorporate forward-looking behavior.

[12] In tables with equations, verbal explanations in brackets are included under the mathematical expressions; this style of notation, designed to facilitate understanding, was originated by Alan Manne (Kendrick, 1996, p. 306).

[13] For example, in Table 4.5, the domain column of Equation (4.1) shows that this equation does not apply to all commodities; it is limited to commodities with imports.

[14] Apart from the fact that variables are time indexed, most of the core CGE module is similar to the IFPRI standard, static CGE model described in Lofgren et al. (2002). That document provides more detail and references to the CGE modeling literature.

Table 4.1 Sets for core MAMS module

Symbol	Explanation	Symbol	Explanation
$a \in A$	activities	$f \in FCAP(\subset F)$	capital factors
$a \in ALEO(\subset A)$	activities with Leontief function between value added and intermediate inputs	$f \in FCAPGOV(\subset FCAP)$	government capital factors
$c \in C$	commodities	$f \in FEXOG(\subset F)$	factors with exogenous growth rates
$c \in CD(\subset C)$	commodities with domestic sales of domestic output	$f \in FLABN(\subset F)$	non-labor factors
$c \in CDN(\subset C)$	commodities not in *CD*	$f \in FUEND(\subset F)$	factors with endogenous unemployment
$c \in CE(\subset C)$	exported commodities	$h \in H(\subset INSDNG)$	households (including NGOs)
$c \in CEN(\subset C)$	commodities not in *CE*	$i \in INS$	institutions (domestic and rest of world)
$c \in CECETN(\subset C)$	exported commodities without CET function	$i \in INSD(\subset INS)$	domestic institutions
$c \in CINF(\subset C)$	infrastructure commodity	$i \in INSDNG(\subset INSD)$	domestic non-government institutions
$c \in CM(\subset C)$	imported commodities	$i \in INSNG(\subset INS)$	non-government institutions
$c \in CMN(\subset C)$	commodities not in *CM*	$(f, a) \in MFA$	mapping showing that disaggregated factor f is used in activity a
$c \in CT(\subset C)$	transaction service commodities	$t \in T$	time periods
$f, f' \in F$	factors		

comprehensive treatment of government financing, links between total factor productivity (TFP) by activity and accumulation of selected capital stocks, as well as the option of deviating from neoclassical assumptions for selected sectors (sometimes useful for regulated utilities and export-oriented production based on natural resources).

4.4.1.1 *Price block*

Most of the equations in the price block, Table 4.5; Equations (4.1)−(4.11) define prices that can be expressed as functions of other endogenous variables (as opposed to being free variables

Table 4.2 Parameters (Latin letters) for core MAMS module

$capcomp_{c,f,t}$	quantity of commodity c per unit of new capital f	$pwse_{c,t}$	world price for export substitutes (FCU)
$cwts_c$	weight of commodity c in the CPI	$qdst_{c,i,t}$	quantity of stock (inventory) change
$depr_f$	depreciation rate for factor f	$\overline{qe}_{c,t}$	export demand for c if $PWE = pwse$ (world price for subs)
$dwts_c$	domestic sales price weights	$qfhhtot_{f,t}$	total household stock of exogenous, non-labor factors
$fdebtrelief_{i,t}$	foreign debt relief for domestic institution i	$qfinsadj_{i,f,t}$	exogenous factor stock adjustment
$fdi_{i,t}$	FDI by institution i (rest of world) (FCU)	$qfpc_{i,f,t}$	*per capita* quantity of exogenous-supply factor f by institution i and year t
$fintrat_{i,t}$	interest rate on foreign debt for domestic institution i (paid)	$qg01_{c,c',t}$	parameter linking government consumption growth across commodities
$fintratdue_{i,t}$	interest rate on foreign debt for domestic institution i (due)	$qggrwbar_{ac,t}$	growth in government consumption or capital stock ac in t
$fprd_{f,a,t}$	productivity of factor f in activity a	$shii_{i,i'}$	share of net income of i' to i ($i' \in INSDNG$)
$gfcfshr_{f,i,t}$	share of gross fixed capital formation for institution i in capital factor f	$ta_{a,t}$	tax rate for activity a
$gintrat_{i,t}$	interest rate on government bonds for domestic institution i	$te_{c,t}$	export tax rate
$ica_{c,a}$	quantity of c as intermediate input per unit of aggregate intermediate in activity a	$tf_{f,t}$	direct tax rate for factor f
$icd_{c,c',t}$	trade input of c per unit of commodity c' produced and sold domestically	$tfp01_{a,t}$	0−1 parameter for activities with endogenous TFP growth
$ice_{c,c',t}$	trade input of c per unit of commodity c' exported	$tfpelasqg_{a,f,t}$	elasticity of TFP for a w.r.t. to government capital stock f
$icm_{c,c',t}$	trade input of c per unit of commodity c' imported	$tfpelastrd_a$	elasticity of TFP for a w.r.t. to GDP trade share
$ifa_{f,a}$	quantity of capital f per unit of government activity a	$tfptrdwt_{t,t'}$	weight of period t' in tfp-trade link in t
$igf_{c,f,t}$	quantity of government consumption per unit of infrastructure capital stock f	$tgap_{t,t'}$	gap between t and t' (years used for calculation of expected growth rate for QA)

(*Continued*)

Table 4.2 Parameters (Latin letters) for core MAMS module—cont'd

$inta_a$	quantity of aggregate intermediate input per unit of activity *a*	$tins01_i$	0—1 parameter with 1 for institutions with potentially flexed direct tax rates
iva_a	quantity of value-added per unit of activity *a*	$tinsbar_{i,t}$	exogenous component in direct tax rate for domestic institution *i*
$mps01_i$	0—1 parameter with 1 for institutions with potentially flexed direct tax rates	$tm_{c,\,t}$	import tariff rate
$mpsbar_{i,t}$	exogenous component in savings rate for domestic institution *i*	$tq_{c,t}$	rate of sales tax
$poptot_{\,t}$	total population by year	$tva_{a,t}$	rate of tax on value added for activity *a*
$pwm_{c,t}$	import world price of *c* (FCU)		

Table 4.3 Parameters (Greek letters) for core MAMS module

α_c^{ac}	shift parameter for domestic commodity aggregation function	$\gamma_{a,c,h}^{h}$	*per capita* household subsistence consumption of home commodity *c* from activity *a*
$\alpha_{a,t}^{vag}$	exogenous component of efficiency (TFP) for activity *a*	$\gamma_{c,h}^{m}$	*per capita* household subsistence cons of marketed commodity *c*
α_c^{q}	Armington function shift parameter	$\varphi_{*,f}$	elasticity of reservation wage for *f* w.r.t. $*$, where $* = qhpc$ (household *per capita* consumption), *uerat* unemployment rate) or *cpi* (CPI)
α_c^{t}	CET function shift parameter	ρ_c^{ac}	domestic commodity aggregation function exponent
$\beta_{a,c,h}^{h}$	marginal share of household consumption on home commodity *c* from activity *a*	ρ_c^{q}	Armington function exponent
$\beta_{c,h}^{m}$	marginal share of household consumption spending on marketed commodity *c*	ρ_i^{sav}	elasticity of savings rate with respect to *per capita* income for institution (household) *h*
δ_a^{ac}	share parameter for domestic commodity aggregation function	ρ_c^{t}	CET function exponent
δ_c^{q}	Armington function share parameter	ρ_a^{va}	CES value-added function exponent
δ_c^{t}	CET function share parameter	$\theta_{a,c}$	yield of output *c* per unit of activity *a*
$\delta_{f,a}^{va}$	CES value-added function share parameter for factor *f* in activity *a*	α_i^{sav}	intercept of savings fn for domestic institution *i*

Table 4.4 Variables for Core MAMS module

$ALPHAVA_{a,t}$	efficiency parameter in the CES value-added function	$PWE_{c,t}$	export world price of c (FCU)
$ALPHAVA2_{a,t}$	endogenous TFP trend term by a	$PX_{c,t}$	aggregate producer price for commodity
$CALTFPG_{t}$	calibration factor for TFP growth	$PXAC_{a,c,t}$	price of commodity c from activity a
CPI_{t}	CPI	$QA_{a,t}$	quantity (level) of activity
$DKGOV_{f,t}$	gross government investment in f	$QD_{c,t}$	quantity sold domestically of domestically produced c
$DKINS_{i,f,t}$	gross change in capital stock (investment in) f for institution i	$QE_{c,t}$	quantity of exports of commodity c
$DMPS_{t}$	uniform point change in savings rate of selected domestic institutions	$QF_{f,a,t}$	quantity demanded of factor f by activity a
DPI_{t}	producer price index for non-traded output	$QFINS_{i,f,t}$	real endowment of factor f for institution i
$DTINS_{t}$	uniform point change in direct tax rate of selected domestic institutions	$QG_{c,t}$	quantity of government consumption of commodity c
EG_{t}	government expenditures	$QGGRW_{c,t}$	real government consumption growth of c in t relative to $t-1$
$EH_{h,t}$	consumption spending for household	$QH_{c,h,t}$	quantity consumed by household h of marketed commodity c
EXR_{t}	exchange rate (LCU per unit of FCU)	$QHA_{a,c,h,t}$	quantity consumed of home commodity c from act a by household h
$FBOR_{i,t}$	foreign borrowing for domestic institution i	$QINTA_{a,t}$	quantity of aggregate intermediate input used by activity a
$FDEBT_{i,t}$	foreign debt for domestic inst i	$QINT_{c,a,t}$	quantity of commodity c as intermediate input to activity a
$FGRANT_{i,t}$	foreign grants to domestic institution i (FCU)	$QINV_{c,t}$	quantity of investment demand for commodity c
$GBOR_{i,t}$	change in holding of government bonds for domestic institution i	$QM_{c,t}$	quantity of imports of commodity c
$GBORTOT_{t}$	total change in holding of government bonds	$QQ_{c,t}$	quantity of commodity c supplied to domestic market (composite supply)
$GBORMS_{i,t}$	government monetary system borrowing (deficit monetization) burden for institution i	$QT_{c,t}$	quantity of trade and transport demand for commodity c
$GBORMSTOT_{t}$	total government monetary system borrowing (deficit monetization)	$QVA_{a,t}$	quantity of (aggregate) value-added

$GDEBT_{i,t}$	endowment of government bonds for i
$GDPREAL_t$	real GDP at market prices
$GDPREALFC_t$	real GDP at factor cost
$GSAV_t$	government savings
$INSSAV_{i,t}$	savings of domestic non-government institution i
$INVVAL_{i,t}$	investment value for institution i
$MPS_{i,t}$	marginal propensity to save for domestic non-government institution i
$MPSADJ_t$	savings rate scaling factor
$PA_{a,t}$	activity price (unit gross revenue)
$PDD_{c,t}$	demand price for commodity c produced and sold domestically
$PDS_{c,t}$	supply price for commodity c produced and sold domestically
$PE_{c,t}$	export price (domestic currency)
$PINTA_{a,t}$	aggregate intermediate input price for activity a
$PK_{f,t}$	price of new capital stock a
$PM_{c,t}$	import price (domestic currency)
$POP_{i,t}$	population by household
$PQ_{c,t}$	composite commodity price
$PVA_{a,t}$	value-added price (factor income per unit of activity)
$QX_{c,t}$	aggregated quantity of domestic output of commodity
$QXAC_{a,c,t}$	quantity of output of commodity c from activity a
$SHIF_{i,f,t}$	share of institution i in income of factor f
$TINS_{i,t}$	direct tax rate for domestic non-government institution i
$TINSADJ_t$	direct tax scaling factor
$TRDGDP_t$	foreign trade as share of GDP
$TRII_{i,i',t}$	transfers from institution i' to i (both in the set *INSDNG*)
$TRNSFR_{ac,i,t}$	transfers from non-household institution i to i non-household institution or factor ac
$TRNSFRPC_{i,i',t}$	*per capita* transfers from institution i' to household institution i
$WF_{f,t}$	economy-wide wage of factor f
$WFDIST_{f,a,t}$	wage distortion factor for factor f in activity a
$WFRES_{f,t}$	reservation wage for factor f
$YF_{f,t}$	income of factor f
YG_t	government revenue
$YI_{i,t}$	income of domestic non-government institution
$YIF_{i,f,t}$	income to domestic institution i from factor f
$YIINT_{i,t}$	net interest income of institution i

Table 4.5 Price block equations

(4.1)	$$PM_{c,t} = pwm_{c,t} \cdot (1 + tm_{c,t}) \cdot EXR_t + \sum_{c' \in C} \left(PQ_{c',t} \cdot icm_{c',c,t} \right)$$ $$\begin{bmatrix} \textit{import price} \\ (LCU) \end{bmatrix} = \begin{bmatrix} \textit{import price} \\ (FCU) \end{bmatrix} \cdot \begin{bmatrix} \textit{tariff} \\ \textit{adjustment} \end{bmatrix} \cdot \begin{bmatrix} \textit{exchange rate} \\ (LCU \textit{per } FCU) \end{bmatrix} + \begin{bmatrix} \textit{transaction} \\ \textit{costs} \end{bmatrix}$$	$c \in CM$ $t \in T$	Import price
(4.2)	$$PE_{c,t} = \overline{PWE}_{c,t} \cdot (1 - te_{c,t}) \cdot EXR_t - \sum_{c' \in C} \left(PQ_{c',t} \cdot ice_{c',c,t} \right)$$ $$\begin{bmatrix} \textit{export price} \\ (LCU) \end{bmatrix} = \begin{bmatrix} \textit{export price} \\ (FCU) \end{bmatrix} \cdot \begin{bmatrix} \textit{tariff} \\ \textit{adjustment} \end{bmatrix} \cdot \begin{bmatrix} \textit{exchange rate} \\ (LCU \textit{ per } FCU) \end{bmatrix} - \begin{bmatrix} \textit{transaction} \\ \textit{costs} \end{bmatrix}$$	$c \in CE$ $t \in T$	Export price
(4.3)[15] (a)	$$PDS_{c,t} \geq PE_{c,t}$$ $$\begin{bmatrix} \textit{domestic supply} \\ \textit{price} \end{bmatrix} \geq \begin{bmatrix} \textit{export price} \\ (LCU) \end{bmatrix}$$	$c \in (CD \cap CECETN)$ $t \in T$	For non-CET exportables with domestic sales: (a) domestic floor price, (b) non-negative export quantity constraints and (c) related complementary-slackness relationship
(b)	$$QE_{c,t} \geq 0$$ $$\begin{bmatrix} \textit{export} \\ \textit{quantity} \end{bmatrix} \geq [0]$$		

(c)

$$\left(PDS_{c,t} - PE_{c,t}\right)\left(QE_{c,t} - 0\right) = 0$$

$$\begin{bmatrix} \textit{Complementary slackness relationship:} \\ \textit{1. If domestic price exceeds export price then export quantity is zero.} \\ \textit{2. If export quantity excceds zero, then domestic price equals export price.} \end{bmatrix}$$

(4.4)

$$PDD_{c,t} = PDS_{c,t} + \sum_{c' \in C} \left(PQ_{c',t} \cdot icd_{c',c,t}\right)$$

$$\begin{bmatrix} \textit{domestic demander} \\ \textit{price} \end{bmatrix} = \begin{bmatrix} \textit{domestic supplier} \\ \textit{price} \end{bmatrix} + \begin{bmatrix} \textit{transaction} \\ \textit{costs} \end{bmatrix}$$

$c \in CD$
$t \in T$

Domestic demander price for domestic commodity

(4.5)

$$PQ_{c,t} \cdot \left(1 - tq_{c,t}\right) \cdot QQ_{c,t} = PDD_{c,t} \cdot QD_{c,t} + PM_{c,t} \cdot QM_{c,t}$$

$$\begin{bmatrix} \textit{absorption} \\ \textit{(at demand prices} \\ \textit{net of sales tax)} \end{bmatrix} = \begin{bmatrix} \textit{domestic demander} \\ \textit{price times} \\ \textit{domestic sales quantity} \end{bmatrix} + \begin{bmatrix} \textit{import price} \\ \textit{times} \\ \textit{import quantity} \end{bmatrix}$$

$c \in (CD \cup CM)$
$t \in T$

Domestic demand value

(*Continued*)

Table 4.5 Price block equations—cont'd

(4.6)	$PX_{c,t} \cdot QX_{c,t} = PDS_{c,t} \cdot QD_{c,t} + PE_{c,t} \cdot QE_{c,t}$ $\begin{bmatrix} \textit{producer price} \\ \textit{times marketed} \\ \textit{output quantity} \end{bmatrix} = \begin{bmatrix} \textit{domestic supplier} \\ \textit{price times} \\ \textit{domestic sales quantity} \end{bmatrix} + \begin{bmatrix} \textit{export price} \\ \textit{times} \\ \textit{export quantity} \end{bmatrix}$	$c \in (CD \cup CE)$ $t \in T$	Marketed output value
(4.7)	$PA_{a,t} = \sum_{c \in C} PXAC_{a,c,t} \cdot \theta_{a,c}$ $\begin{bmatrix} \textit{activity} \\ \textit{price} \end{bmatrix} = \begin{bmatrix} \textit{producer prices} \\ \textit{times yields} \end{bmatrix}$	$a \in A$ $t \in T$	Activity price
(4.8)	$PINTA_{a,t} = \sum_{c \in C} PQ_{c,t} \cdot ica_{c,a}$ $\begin{bmatrix} \textit{aggregate} \\ \textit{intermediate} \\ \textit{input price} \end{bmatrix} = \begin{bmatrix} \textit{intermediate input cost} \\ \textit{per unit of aggregate} \\ \textit{intermediate input} \end{bmatrix}$	$a \in A$ $t \in T$	Aggregate intermediate input price

(4.9)
$$PA_{a,t} \cdot \left(1 - ta_{a,t}\right) \cdot QA_{a,t} = PVA_{a,t} \cdot QVA_{a,t} + PINTA_{a,t} \cdot QINTA_{a,t}$$
$a \in A$
$t \in T$
Activity revenue and costs
$$\begin{bmatrix} \textit{activity price} \\ (\textit{net of taxes}) \\ \textit{times activity level} \end{bmatrix} = \begin{bmatrix} \textit{value} - \textit{added} \\ \textit{price times} \\ \textit{quantity} \end{bmatrix} + \begin{bmatrix} \textit{aggregate intermediate} \\ \textit{input price times quantity} \end{bmatrix}$$

(4.10)
$$\overline{CPI_t} = \sum_{c \in C} PQ_{c,t} \cdot cwts_c$$
$t \in T$
CPI
$$[CPI] = \begin{bmatrix} \textit{prices times} \\ \textit{weights} \end{bmatrix}$$

(4.11)
$$DPI_t = \sum_{c \in CD} PDS_{c,t} \cdot dwts_c$$
$t \in T$
Price index for non-tradables
$$\begin{bmatrix} \textit{price index for} \\ \textit{non-tradables} \end{bmatrix} = \begin{bmatrix} \textit{supplier price for output} \\ \textit{marketed domestically} \\ \textit{times weights} \end{bmatrix}$$

[15]Among Equations (4.3a–c), only part (a) is an explicit equation in the GAMS code. The non-negativity constraint (b) on $QE_{c,t}$ is handled via a lower limit of zero on this variable. The complementary-slackness condition (c) is imposed via the GAMS model definition in which Equation (a) is associated with $QE_{c,t}$. MAMS also includes complementary-slackness conditions for government investment, the labor market constraint and MDG targeting (in the core module blocks for investment and other system constraints and the MDG module, respectively). In terms of the GAMS code, the treatment is similar to the case of exports with perfect transformability.

that perform market-clearing functions). Among these prices, it is worth noting that transactions costs (the cost of moving the commodity between the border and demanders or suppliers, or between domestic demanders and suppliers) are accounted for in the definitions of demander (domestic-currency) import prices, supplier (domestic-currency) export prices and demander prices for domestic output sold domestically, Equations (4.1), (4.2) and (4.4).

Whereas most outputs with exports have imperfect transformability between exports and domestic sales, the model also allows for the case of perfect transformability, using a complementary-slackness formulation, Equation (4.3). Perfect transformability is useful for commodities that are relatively homogeneous, with only small differences depending on whether the demander is domestic or foreign (like grains). Equation (4.3) has three components: (i) The constraint that domestic supplier prices are larger than or equal to export prices in local currency units (LCU); (ii) the constraint that exports are larger than or equal to zero (i.e. zero is a possible outcome); and (iii) a complementary-slackness relationship according to which at least one of (i) and (iii) has to hold as a strict equality — domestic supplier prices only exceed export prices if exports are zero or, if exports are above zero, then the two prices are equal. In terms of economics, this means that the export price is a floor price and that producers prefer to sell at the highest price that is offered. If the domestic price is above the export price, then nothing is exported. If, in the absence of exports, the price would have fallen below the export price, then exports will be positive, preventing a decline below the export price.[16]

Various aggregative prices — for composite supplies, for produced commodities and value-added — are derived from relationships that define total revenue or costs as the sum of disaggregated receipts or payments, Equations (4.5—4.7) and (4.9). The price of the aggregative intermediate commodity for any activity depends on its commodity composition and the prices of the commodities involved, Equation (4.8). The model is homogeneous of degree zero in prices, with the consumer price index (CPI) serving as the model numéraire, Equation (4.10). Alternatively, the price index for non-tradables may serve as numéraire, Equation (4.11).[17]

4.4.1.2 Production and trade block

This block (Table 4.6; Equations (4.12—4.27)) includes the first-order conditions for profit-maximizing production and transformation decisions as well as cost-minimizing domestic demand decisions. Given available technology and market prices (taken as given

16 In GAMS, a model formulated as an MCP (mixed-complementarity problem) can handle a combination of equations that are: (i) Strict equalities and (ii) non-strict inequalities linked to variables with lower limits in a mixed-complementarity relationship.

17 The GAMS code permits the user to choose either the CPI or the price index for non-tradables as numéraire. As long as the model is homogeneous of degree zero in prices, this choice has no impact on the equilibrium values of real variables. This homogeneity condition is not met under macro closures with fixed savings or domestic borrowing for the government. In these cases, it is implicitly assumed that the fixed variables are indexed to the numéraire.

in a perfectly competitive setting), producers maximize profits.[18] The technology is defined by a nested, two-level structure. At the top, output is a Leontief aggregation of real value-added and a real aggregate intermediate, Equations (4.12 and 4.13).[19] At the bottom, these are linked to a constant elasticity of substitution (CES) aggregation of primary factors (a value-added function) and a Leontief aggregation of intermediate inputs, Equations (4.14–4.16). Given that the national accounts rarely attribute value-added to government capital, the CES value-added functions for government production do not include capital factors. Typically, government value-added is limited to labor.[20]

Note that, at the activity level, the wage paid is the product of $WF_{f,t}$ and $WFDIST_{f,a,t}$, *cf.* Equation (4.15). $WFDIST_{f,a,t}$, a distortion (or differential) term that typically is exogenous, reflects relative wage differences across activities. In some cases it may be desirable to impose an exogenous time path for the employment of specific factors in selected activities (drawing on other pieces of information, e.g. data on the expected evolution of sectors based on the exploitation of natural resources). For the factor—activity—time combination in question, the analyst only has to flex the wage distortion variable ($WFDIST_{f,a,t}$) and fix the employment variable ($QF_{f,a,t}$). Such an assumption can coexist with factor markets with or without endogenous unemployment.

Each activity produces one or more outputs with fixed yield coefficients, Equation (4.17). Any commodity may be produced and marketed by more than one activity. A CES approach, assuming profit-maximizing producer behavior, is used to aggregate market sales of any commodity from different activities, Equations (4.18 and 4.19). Production is transformed into exports and domestic sales on the basis of a CET function. The profit-maximizing, optimal ratio between the quantities of exports and domestic sales is positively related to the ratio between the corresponding supply prices, Equations (4.20 and 4.21). A less complex relationship applies to production without exports or without domestic sales, Equation (4.22). Government and private social services are typically non-traded, i.e. they have no exports and all of the supply is from domestic producers. For any exported commodity, two alternatives are possible for export demand: (i) Exogenous prices in

[18] In some applications MAMS has included a private regulated sector (typically a utility) for which behavior deviates from the assumption of profit-maximizing output and input demand (including capital use) given market prices and rents. Each regulated activity has its own capital stock. (Otherwise, there is only one private capital stock, which is mobile across private activities.) For regulated activities, output prices, investment and capital use are exogenous; production is demand-driven at fixed output prices. Their capital stocks earn an endogenous, residual share of value-added which most likely deviates from the market rent; other factors earn market wages.

[19] MAMS also permits the alternative of a CES aggregation of the real aggregates of value-added and intermediates. The choice does not tend to have a major impact on results. Most applications have used the Leontief alternative.

[20] Nevertheless, the model accounts for the fact that government capital stocks indeed are needed in government activities by imposing investments derived from a Leontief-relationship between government activity levels and related capital stocks, with the stocks being defined on the basis of initial stocks, investment and depreciation (see Equation (4.45). In the exceptional cases when the SAM indicates that government capital earns value-added, this value-added is a fixed share of the total value-added of the activity (in effect equivalent to a tax on value-added), not related to any market rent.

Table 4.6 Production and trade block equations

(4.12)	$QVA_{a,t} = iva_a \cdot QA_{a,t}$ $\begin{bmatrix} \textit{demand for} \\ \textit{value-added} \end{bmatrix} = f\begin{bmatrix} \textit{activity} \\ \textit{level} \end{bmatrix}$	$a \in ALEO$ $t \in T$	Demand for aggregate value-added
(4.13)	$QINTA_{a,t} = inta_a \cdot QA_{a,t}$ $\begin{bmatrix} \textit{demand for aggregate} \\ \textit{intermediate input} \end{bmatrix} = f\begin{bmatrix} \textit{activity} \\ \textit{level} \end{bmatrix}$	$a \in ALEO$ $t \in T$	Demand for aggregate intermediate input
(4.14)	$QVA_{a,t} = ALPHAVA_{a,t} \cdot \left(\sum_{f \in F} \delta^{\mathrm{va}}_{f,a} \cdot \left(fprd_{f,a,t} \cdot QF_{f,a,t} \right)^{-\rho^{\mathrm{va}}_a} \right)^{-\frac{1}{\rho^{\mathrm{va}}_a}}$ $\begin{bmatrix} \textit{quantity of aggregate} \\ \textit{value-added} \end{bmatrix} = CES\begin{bmatrix} \textit{factor} \\ \textit{inputs} \end{bmatrix}$	$a \in A$ $t \in T$	Value-added

(4.15)

$$WF_{f,t} \cdot \overline{WFDIST}_{f,a,t} = PVA_{a,t} \cdot \left(1 - tva_{a,t}\right) \cdot QVA_{a,t}$$

$$\cdot \left(\sum_{f' \in F} \delta^{va}_{f',a} \cdot \left(fprd_{f',a,t} \cdot QF_{f',a,t} \right)^{-\rho^{va}_{a}} \right)^{-1} \cdot \delta^{va}_{f,a} \cdot fprd_{f,a,t}{}^{-\rho^{va}_{a}} \cdot QF_{f,a,t}{}^{-\rho^{va}_{a}-1}$$

$$\left[\begin{matrix} \textit{marginal cost of} \\ \textit{factor } f \textit{ in activity } a \end{matrix} \right] = \left[\begin{matrix} \textit{marginal revenue product} \\ \textit{of factor } f \textit{ in activity } a \end{matrix} \right]$$

$a \in A$, $f \in F$, $t \in T$

Factor demand

(4.16)

$$QINT_{c,a,t} = ica_{c,a} \cdot QINTA_{a,t}$$

$$\left[\begin{matrix} \textit{intermediate demand} \\ \textit{for commodity } c \\ \textit{from activity } a \end{matrix} \right] = f \left[\begin{matrix} \textit{aggregate intermediate} \\ \textit{input quantity} \\ \textit{for activity } a \end{matrix} \right]$$

$c \in C$, $a \in A$, $t \in T$

Disaggregated intermediate input demand

(4.17)

$$QXAC_{a,c,t} + \sum_{h \in H} QHA_{a,c,h,t} = \theta_{a,c} \cdot QA_{a,t}$$

$$\left[\begin{matrix} \textit{quantity of output} \\ \textit{of commodity } c \\ \textit{from activity } a \end{matrix} \right] + \left[\begin{matrix} \textit{quantity consumed of} \\ \textit{home commodity } c \\ \textit{from activity } a \textit{ in} \\ \textit{all households} \end{matrix} \right] = \left[\begin{matrix} \textit{activity-specific} \\ \textit{marketed} \\ \textit{production of} \\ \textit{commodity } c \end{matrix} \right]$$

$a \in A$, $c \in C$, $t \in T$

Commodity production and allocation between market and home

(*Continued*)

Table 4.6 Production and trade block equations—cont'd

(4.18)	$QX_{c,t} = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{a,c}^{ac} \cdot QXAC_{a,c,t}{}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}}}$ $\begin{bmatrix} \textit{aggregate marketed} \\ \textit{production of} \\ \textit{commodity } c \end{bmatrix} = CES \begin{bmatrix} \textit{output of commodity } c \\ \textit{from activity } a \end{bmatrix}$	$c \in$ $(CE \cup CD)$ $t \in T$	Output aggregation function
(4.19)	$\frac{PXAC_{a,c,t}}{PX_{c,t}} = QX_{c,t} \cdot \sum_{a' \in A} \left(\delta_{a',c}^{ac} \cdot QXAC_{a',c,t}{}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{a,c}^{ac} \cdot QXAC_{a,c,t}{}^{-\rho_c^{ac}-1}$ $\begin{bmatrix} \textit{ratio of price of commodity } c \\ \textit{from activity } a \textit{ to} \\ \textit{average output price} \end{bmatrix} = f \begin{bmatrix} \textit{aggregate marketed commodity} \\ \textit{output and output of commodity } c \\ \textit{from activity } a \end{bmatrix}$	$a \in A$ $c \in C$ $t \in T$	Ratio of prices for output aggregation function
(4.20)	$QX_{c,t} = \alpha_c^{t} \cdot \left(\delta_c^{t} \cdot QE_{c,t}{}^{\rho_c^{t}} + \left(1 - \delta_c^{t}\right) \cdot QD_{c,t}{}^{\rho_c^{t}} \right)^{\frac{1}{\rho_c^{t}}}$ $\begin{bmatrix} \textit{aggregate marketed} \\ \textit{domestic output} \end{bmatrix} = CET \begin{bmatrix} \textit{export quantity, domestic} \\ \textit{sales of domestic output} \end{bmatrix}$	$c \in (CD \cap$ $CECET)$ $t \in T$	Output transformation (CET) function

(4.21)	$$\frac{QE_{c,t}}{QD_{c,t}} = \left(\frac{PE_{c,t}}{PDS_{c,t}} \cdot \frac{1-\delta^{t}_{c}}{\delta^{t}_{c}}\right)^{\frac{1}{\rho^{t}_{c}-1}}$$ $$\begin{bmatrix} export\text{–}domestic \\ supply\ ratio \end{bmatrix} = f \begin{bmatrix} export\text{–}domestic \\ price\ ratio \end{bmatrix}$$	$c \in (CD \cap CECET)$ $t \in T$	Export-domestic supply ratio
(4.22)	$$QX_{c,t} = QD_{c,t} + QE_{c,t}$$ $$\begin{bmatrix} aggregate \\ marketed \\ domestic\ output \end{bmatrix} = \begin{bmatrix} domestic\ market \\ sales\ of\ domestic \\ output[unless \\ c \in (CE \cap CDN)] \end{bmatrix} + \begin{bmatrix} exports\ [unless \\ c \in (CD \cap CEN)] \end{bmatrix}$$	$c \in (CD \cap CEN) \cup (CE \cap CDN) \cup (CD \cap CECETN)$, $t \in T$	Output transformation for outputs without exports, exports without domestic sales and non-CET exports with domestic sales
(4.23)	$$QE_{c,t} = \overline{qe}_{c,t} \cdot \left(\frac{PWE_{c,t}}{pwse_{c,t}}\right)^{\rho^{e}_{c}}$$ $$\begin{bmatrix} export \\ demand \end{bmatrix} = f \begin{bmatrix} trend\ export\ quantity,\ world\ price \\ for\ exports\ relative\ to\ world \\ price\ for\ export\ substitutes \end{bmatrix}$$	$c \in CED$ $t \in T$	Export demand with CE demand function

(*Continued*)

Table 4.6 Production and trade block equations—cont'd

(4.24)	$QQ_{c,t} = \alpha_c^{q} \cdot \left(\delta_c^{q} \cdot QM_{c,t}^{\;-\rho_c^{q}} + \left(1-\delta_c^{q}\right) \cdot QD_{c,t}^{\;-\rho_c^{q}}\right)^{-\frac{1}{\rho_c^{q}}}$ $\begin{bmatrix} composite \\ supply \end{bmatrix} = CES \begin{bmatrix} import\ quantity,\ domestic \\ use\ of\ domestic\ output \end{bmatrix}$	$c \in (CM \cap CD)$ $t \in T$	Composite supply (Armington) function
(4.25)	$\dfrac{QM_{c,t}}{QD_{c,t}} = \left(\dfrac{PDD_{c,t}}{PM_{c,t}} \cdot \dfrac{\delta_c^{q}}{1-\delta_c^{q}}\right)^{\frac{1}{1+\rho_c^{q}}}$ $\begin{bmatrix} import\text{–}domestic \\ demand\ \ ratio \end{bmatrix} = f \begin{bmatrix} domestic\text{–}import \\ price\ \ ratio \end{bmatrix}$	$c \in (CM \cap CD)$ $t \in T$	Import-domestic demand ratio

(4.26)

$$QQ_{c,t} = QD_{c,t} + QM_{c,t}$$

$$\begin{bmatrix} composite \\ supply \end{bmatrix} = \begin{bmatrix} domestic\ use\ of \\ marketed\ domestic \\ output\ [for \\ c \in (CD \cap CMN)] \end{bmatrix} + \begin{bmatrix} imports\ [for \\ c \in (CM \cap CDN)] \end{bmatrix}$$

$c \in (CD \cap CMN) \cup (CM \cap CDN)$, $t \in T$

Composite supply for non-imported outputs and non-produced imports

(4.27)

$$QT_{c,t} = \sum_{c' \in C'} \left(icm_{c,c',t} \cdot QM_{c',t} + ice_{c,c',t} \cdot QE_{c',t} + icd_{c,c',t} \cdot QD_{c',t} \right)$$

$$\begin{bmatrix} trade\ and\ transport \\ demand\ for\ commodity\ c \end{bmatrix} = [from\ imports] + [from\ exports] + \begin{bmatrix} from\ marketed \\ domestic\ output \end{bmatrix}$$

$c \in CT$, $t \in T$

Demand for transaction services

foreign currency units (FCU) combined with an infinitely elastic demand or (ii) price-sensitive export demands (defined by constant-elasticity functions) with the FCU prices linked to domestic conditions and the exchange rate, Equation (4.23) applies to the constant-elasticity case). Given that, in equations other than Equation (4.23), $PWE_{c,t}$ (the export world price) has a bar on top, we assume that the set *CED* is empty and that Equation (4.23) is not used.

Domestic demanders are assumed to minimize the cost of imperfectly substitutable imports and commodities from domestic production according to an Armington (CES aggregation) function, Equations (4.24 and 4.25). For commodities with only one of the two supply sources (domestic or import), the supply from this source equals the composite supply, Equation (4.26). The transaction (trade and transport) demand for any service commodity is the sum of demands arising from domestic sales, exports and imports, each of which is the product of the quantity traded and a fixed input coefficient (showing the quantity of the service commodity per unit of trade, Equation (4.27).

Government service sectors typically produce single outputs, and have fixed coefficients for intermediate inputs and capital (typically without any value-added payment; also see discussion in Section 4.4.14), but labor demands that respond to relative wage changes. The demanders (often only the government) pay a price that covers the cost of labor and intermediates, i.e. excluding capital.

4.4.1.3 Domestic institution block

This block, Table 4.7; Equations (4.28–4.44) account for the receipts and expenditures of all domestic institutions, both government and non-government (households) as well as current, non-trade payment flows to and from the rest of the world (i.e. factor incomes and transfers). When they represent inflows of foreign currency, these payments tend to be fixed (in FCU). The equations are structured to accommodate databases with any number of households, one government and one entity representing the rest of the world. The payments in this block are highly inter-related since institutions often are both at the receiving and paying ends. Transfers between any two institutions may flow in both directions; however, if so, the analyst may often find it more convenient to net these in the initial model social accounting matrix (SAM).

Turning to the equations, factor incomes are defined as a function of domestic wages (which may vary across activities) and employment levels, augmented by factor incomes from the rest of the world, Equation (4.28) and allocated across different institutions (domestic and foreign), net of direct factor taxes, in value shares that depend on endogenous factor endowment shares, Equations (4.29 and 4.30). Domestic non-government institutions: (i) Earn net interest incomes, defined as the difference between net interest earnings from loans to the government and net interest payments to the rest of the world on foreign debt, Equation (4.31), with all interest rates assumed to be exogenous; (ii) transfer fixed shares of their incomes (net of direct taxes and savings) to

Table 4.7 Domestic institution block equations

(4.28)

$$YF_{f,t} = \sum_{a \in A} WF_{f,t} \cdot \overline{WFDIST}_{f,a,t} \cdot QF_{f,a,t} + \overline{TRNSFR}_{f,\mathrm{row},t} \cdot EXR_t$$

$$\begin{bmatrix} \textit{income of} \\ \textit{factor } f \end{bmatrix} = \begin{bmatrix} \textit{sum of activity payments} \\ (\textit{activity} - \textit{specific wages} \\ \textit{times employment levels}) \end{bmatrix} + \begin{bmatrix} \textit{income to factor } f \\ \textit{from rest of world} \end{bmatrix}$$

$f \in F$
$t \in T$

Factor income

(4.29)

$$SHIF_{i,f,t} = \frac{QFINS_{i,f,t}}{\sum_{i' \in INS} QFINS_{i',f,t}}$$

$$\begin{bmatrix} \textit{share of institution } i \textit{ in} \\ \textit{the income of factor } f \end{bmatrix} = \begin{bmatrix} \textit{endowment of institution } i \textit{ of factor } f \\ \textit{divided by total endowment of factor } f \end{bmatrix}$$

$i \in INS$
$f \in F$
$t \in T$

Institutional shares in factor incomes

(4.30)

$$YIF_{i,f,t} = SHIF_{i,f,t} \cdot \left[\left(1 - tf_{f,t} \right) \cdot YF_{f,t} \right]$$

$$\begin{bmatrix} \textit{income of} \\ \textit{institution } i \\ \textit{from factor } f \end{bmatrix} = \begin{bmatrix} \textit{share of income} \\ \textit{of factor } f \textit{ to} \\ \textit{institution } i \end{bmatrix} \cdot \begin{bmatrix} \textit{income of factor } f \\ (\textit{net of tax}) \end{bmatrix}$$

$i \in INS$
$f \in F$
$t \in T$

Institutional factor incomes

(*Continued*)

Table 4.7 Domestic institution block equations—cont'd

(4.31)

$$YIINT_{i,t} = gintrat_{i,t} \cdot GDEBT_{i,t} - fintrat_{i,t} \cdot FDEBT_{i,t} \cdot EXR_t$$

$$\begin{bmatrix} net\ interest \\ income\ of \\ institution\ i \end{bmatrix} = \begin{bmatrix} interest\ earnings \\ on\ government \\ bonds \end{bmatrix} - \begin{bmatrix} interest \\ payments \\ on\ foreign\ debt \end{bmatrix}$$

$i \in INSDNG$, $t \in Tv$ — Institutional net interest income

(4.32)

$$TRII_{i,i',t} = shii_{i,i'} \cdot \left(1 - MPS_{i',t}\right) \cdot \left(1 - TINS_{i',t}\right) \cdot YI_{i',t}$$

$$\begin{bmatrix} transfer\ from \\ institution\ i'\ to\ i \end{bmatrix} = \begin{bmatrix} share\ of\ net\ income \\ of\ institution\ i' \\ transfered\ to\ i \end{bmatrix} \cdot \begin{bmatrix} income\ of\ institution \\ i',\ net\ of\ savings\ and \\ direct\ taxes \end{bmatrix}$$

$i \in INS$, $i' \in INSDNG$, $t \in T$ — Intra-institutional transfers

(4.33)

$$YI_{i,t} = \sum_{f \in F} YIF_{i,f,t} + \sum_{i' \in INSDNG'} TRII_{i,i',t} + YIINT_{i,t}$$

$$\begin{bmatrix} income\ of \\ institution\ i \end{bmatrix} = \begin{bmatrix} factor \\ income \end{bmatrix} + \begin{bmatrix} transfers\ from\ other \\ domestic\ non\text{-}government \\ institutions \end{bmatrix} + \begin{bmatrix} net \\ interest \\ income \end{bmatrix}$$

$$+\overline{TRNSFR}_{i,\mathrm{gov},t} \cdot \overline{CPI}_t + trnsfrpc_{i,\mathrm{gov},t} \cdot POP_{i,t} \cdot \overline{CPI}_t$$

$$+\begin{bmatrix} transfers\ from\ government \\ to\ non-household\ institutions \end{bmatrix} + \begin{bmatrix} transfers\ from \\ government\ to\ households \end{bmatrix}$$

$$+\overline{TRNSFR}_{i,\mathrm{row},t} \cdot EXR_t + trnsfrpc_{i,\mathrm{row},t} \cdot POP_{i,t} \cdot EXR_t$$

$$+\begin{bmatrix} transfers\ from\ Rest\ of\ World \\ to\ non-household\ institutions \end{bmatrix} + \begin{bmatrix} transfers\ from \\ Rest\ of\ World\ to\ households \end{bmatrix}$$

$i \in INSDNG$, $t \in T$ — Income of domestic, non-government institutions

(4.34)

$$TINS_{i,t} = tinsbar_{i,t} \cdot \left(1 + \overline{TINSADJ}_t \cdot tins01_i\right) + DTINS_t \cdot tins01_i$$

$$\begin{bmatrix} \textit{direct tax} \\ \textit{rate for} \\ \textit{institution } i \end{bmatrix} = \begin{bmatrix} \textit{exogenous rate adjusted} \\ \textit{for scaling for} \\ \textit{selected institutions} \end{bmatrix} + \begin{bmatrix} \textit{point change} \\ \textit{for selected} \\ \textit{institutions} \end{bmatrix}$$

$i \in INSDNG$, $t \in T$

Direct tax rates for domestic non-government institutions

(4.35)

$$MPS_{i,t} = mpsbar \cdot \left(\frac{\left(1 - TINS_{i,t}\right) \cdot YI_{i,t}}{\overline{POP}_{i,t}}\right)^{\rho_i^{sav}} \cdot \left(1 + \overline{MPSADJ}_t \cdot mps01_i\right) + \overline{DMPS}_t \cdot mps01_i$$

$$\begin{bmatrix} \textit{marginal} \\ \textit{propensity} \\ \textit{to save} \end{bmatrix} = \begin{bmatrix} \textit{exogenous} \\ \textit{term} \end{bmatrix} \cdot \begin{bmatrix} \textit{adjustment for} \\ \textit{per capita} \\ \textit{post-tax income} \end{bmatrix} \cdot \begin{bmatrix} \textit{scaling adjustment} \\ \textit{for selected} \\ \textit{institutions} \end{bmatrix} + \begin{bmatrix} \textit{point-change} \\ \textit{adjustment for} \\ \textit{selected institutions} \end{bmatrix}$$

$i \in INSDNG$, $t \in T$

Savings rates for domestic non-government institutions

(4.36)

$$INSSAV_{i,t} = \alpha_i^{sav} \cdot \overline{POP}_{i,t} + MPS_{i,t} \cdot \left(1 - TINS_{i,t}\right) \cdot YI_{i,t}$$

$$\begin{bmatrix} \textit{savings for} \\ \textit{institution } i \end{bmatrix} = \begin{bmatrix} \textit{intercept of} \\ \textit{savings function} \end{bmatrix} + \begin{bmatrix} \textit{marginal} \\ \textit{propensity} \\ \textit{to save} \end{bmatrix} \cdot \begin{bmatrix} \textit{income of} \\ \textit{institution } i \\ (\textit{net of direct taxes}) \end{bmatrix}$$

$i \in INSDNG$

Savings for domestic non-government institutions

(*Continued*)

Table 4.7 Domestic institution block equations—cont'd

(4.37)	$EH_{h,t} = \left(1 - \sum_{i\in INSDNG} shii_{i,h}\right)\cdot\left(1 - MPS_{h,t}\right)\cdot\left(1 - TINS_{h,t}\right)\cdot YI_{h,t}$ $\begin{bmatrix} household\ income \\ disposable\ for \\ consumption \end{bmatrix} = \begin{bmatrix} household\ income,\ net\ of\ direct \\ taxes,\ savings\ and\ transfers\ to \\ other\ non-government\ institutions \end{bmatrix}$	$h \in H$ $t \in T$	Household consumption expenditure
(4.38)	$QH_{c,h,t} = \overline{POP}_{h,t}\cdot \left(\gamma^{m}_{c,h} + \frac{\beta^{m}_{c,h}\cdot\left(\left[\frac{EH_{h,t}}{\overline{POP}_{h,t}}\right] - \sum_{c'\in C} PQ_{c',t}\cdot\gamma^{m}_{c',h} - \sum_{a\in A}\sum_{c'\in C} PXAC_{a,c',t}\cdot\gamma^{h}_{a,c',h}\right)}{PQ_{c,t}}\right)$ $\begin{bmatrix} quantity\ of \\ household\ demand \\ for\ commodity\ c \end{bmatrix} = f\begin{bmatrix} household \\ consumption \\ spending,\ prices \end{bmatrix}$	$c \in C$ $h \in H$ $t \in T$	Household consumption demand for commodities from market
(4.39)	$QHA_{a,c,h,t} = \overline{POP}_{h,t}\cdot \left(\gamma^{h}_{a,c,h} + \frac{\beta^{h}_{a,c,h}\cdot\left(\left[\frac{EH_{h,t}}{\overline{POP}_{h,t}}\right] - \sum_{c'\in C} PQ_{c',t}\cdot\gamma^{m}_{c',h} - \sum_{a'\in A}\sum_{c'\in C} PXAC_{a',c',t}\cdot\gamma^{h}_{a',c',h}\right)}{PXAC_{a,c,t}}\right)$ $\begin{bmatrix} quantity\ of\ household\ demand \\ for\ commodity\ c\ from\ activity\ a \end{bmatrix} = f\begin{bmatrix} household\ consumption \\ spending,\ prices \end{bmatrix}$	$a \in A$ $c \in C$ $h \in H$ $t \in T$	Household consumption demand for own production

(4.40)	$$YG_t = \sum_{i \in INSDNG} TINS_{i,t} \cdot YI_{i,t} + \sum_{f \in F} tf_{f,t} \cdot YF_{f,t} + \sum_{a \in A} ta_{a,t} \cdot PA_{a,t} \cdot QA_{a,t}$$	$t \in T$	Government current revenue

$$\begin{bmatrix} government \\ revenue \end{bmatrix} = \begin{bmatrix} direct\ taxes \\ from\ institutions \end{bmatrix} + \begin{bmatrix} direct\ taxes \\ from\ factors \end{bmatrix} + [activity\ tax]$$

$$+ \sum_{a \in A} tva_{a,t} \cdot PVA_{a,t} \cdot QVA_{a,t} + \sum_{c \in CM} tm_{c,t} \cdot pwm_{c,t} \cdot QM_{c,t}$$

$$+[value - added\ tax] + [import\ tariffs]$$

$$+ \sum_{c \in CE} te_{c,t} \cdot \overline{PWE}_{c,t} \cdot QE_{c,t} \cdot EXR_t + \sum_{c \in C} tq_{c,t} \cdot PQ_{c,t} \cdot QQ_{c,t}$$

$$+[export\ taxes] + [sales\ tax]$$

$$+ \sum_{f \in F} YIF_{\mathrm{gov},f,t} + \sum_{i \in INSDNG} TRII_{\mathrm{gov},i,t} + \overline{TRNSFR}_{\mathrm{gov,row},t} \cdot EXR_t$$

$$+[factor\ income] + \begin{bmatrix} transfers\ \ from \\ domestic\ institutions \end{bmatrix} + [transfers\ from\ rest\ of\ world]$$

(*Continued*)

Table 4.7 Domestic institution block equations—cont'd

(4.41)

$$
\begin{aligned}
EG_t &= \sum_{c \in C} PQ_{c,t} \cdot QG_{c,t} + \sum_{i \in INSDNH} \overline{TRNSFR}_{i,\mathrm{gov},t} \cdot \overline{CPI}_t \\
\begin{bmatrix} \textit{government} \\ \textit{spending} \end{bmatrix} &= \begin{bmatrix} \textit{government} \\ \textit{consumption} \end{bmatrix} + \begin{bmatrix} \textit{transfers to domestic} \\ \textit{non-household institutions} \end{bmatrix} \\
&+ \sum_{h \in H} trnsfrpc_{h,\mathrm{gov},t} \cdot \overline{POP}_{h,t} \cdot \overline{CPI}_t + \overline{TRNSFR}_{\mathrm{row},\mathrm{gov},t} \cdot EXR_t \\
&+ \begin{bmatrix} \textit{transfers to domestic} \\ \textit{households} \end{bmatrix} + \begin{bmatrix} \textit{transfers to} \\ \textit{rest of world} \end{bmatrix} \\
&+ \sum_{i \in INS} gintrat_{i,t} \cdot GDEBT_{i,t} + fintrat_{\mathrm{gov},t} \cdot FDEBT_{\mathrm{gov},t} \cdot EXR_t \\
&+ \begin{bmatrix} \textit{interest payment} \\ \textit{on domestic debt} \end{bmatrix} + \begin{bmatrix} \textit{interest payment} \\ \textit{on foreign debt} \end{bmatrix}
\end{aligned}
$$

$t \in T$

Government recurrent expenditures

(4.42)

$$
\begin{aligned}
QG_{c,t} &= QG_{c,t-1} \\
&\cdot \left(1 + qggrwbar_{c,t} + \sum_{c' \in C} qg01_{c,c',t} \cdot \overline{QGGRW}_{c',t} \right)
\end{aligned}
$$

$$
\begin{bmatrix} \textit{real} \\ \textit{government} \\ \textit{consumption} \\ \textit{of } c \textit{ in } t \end{bmatrix} = \begin{bmatrix} \textit{real} \\ \textit{government} \\ \textit{consumption} \\ \textit{of } c \textit{ in } t-1 \end{bmatrix} \cdot \left[1 + \begin{bmatrix} \textit{growth rate} \\ \textit{of } c \textit{ in } t \\ \textit{(exogenous} \\ \textit{part)} \end{bmatrix} + \begin{bmatrix} \textit{growth adjustment} \\ \textit{for } c \textit{ (if } c \textit{ is linked to} \\ c' \textit{ via } qg01 \textit{ and if} \\ QGGRW_{c'} \textit{ is endogenous)} \end{bmatrix} \right]
$$

$c \in C$
$c \notin CINF$
$t \in T$
$t > 1$

Real government consumption (excluding infrastructure services)

(4.43)

$$QG_{c,t} = \sum_{\substack{i \in INS \\ f \in F}} igf_{c,f,t} \cdot QFINS_{i,f,t}$$

$c \in CINF$, $t \in T$, $t > 1$ — Real government consumption of infrastructure services

$$\begin{bmatrix} \textit{real government} \\ \textit{consumption} \\ \textit{of } c \textit{ in } t \end{bmatrix} = \begin{bmatrix} \textit{quantity of gov consumption} \\ \textit{per unit of gov infrastructure} \\ \textit{capital stock } f \end{bmatrix} \cdot \begin{bmatrix} \textit{real endowment of} \\ \textit{factor } f \textit{ for} \\ \textit{institution } i \end{bmatrix}$$

(4.44)

$$GSAV_t = YG_t - EG_t$$

$t \in T$ — Government savings

$$\begin{bmatrix} \textit{government} \\ \textit{savings} \end{bmatrix} = \begin{bmatrix} \textit{government} \\ \textit{recurrent revenue} \end{bmatrix} - \begin{bmatrix} \textit{government} \\ \textit{recurrent expenditures} \end{bmatrix}$$

other institutions (domestic or foreign), Equation (4.32); (iii) earn total gross incomes defined as the sum of factor incomes, net interest incomes and transfers from other institutions, where the treatment of the latter differs depending on the nature of the sending institution (government, the rest of the world, or another domestic non-government institution) and the receiving institution (household or non-household), Equation (4.33); (iv) pay direct taxes according to rates that are fixed unless adjusted as part of the government closure rule, Equation (4.34); note that all right-hand-side terms are exogenous; and (v) save out of incomes net of direct taxes according to marginal (and average) rates that are endogenous, depending on changes in *per capita* incomes if the elasticity of savings with respect to *per capita* income is different from zero, Equation (4.35 and 4.36).[21] In Equation (4.36), the savings of domestic non-government institutions are a linear function of their respective income, Equation (4.36) allows for the marginal propensity to save to be different from the average propensity to save.[22] Alternatively, for any given institution, the savings and/or direct tax rate may be adjusted as part of the savings—investment and government closure rules. If direct taxes are adjusted as part of the government closure rule, selected institutions face changes in their rates, either via uniform scaling ($TINSADJ_t$) or via a uniform point change ($DTINS_t$). As suggested by the absence of a bar above $DTINS_t$, this mathematical statement assumes that changes in direct tax payments via adjustments in $DTINS_t$ clear the government budget. The marginal propensity to save can be adjusted through similar alternative mechanisms (through $MPSADJ_t$ or $DMPS_t$) as part of the savings—investment rule.

For households, incomes net of direct taxes, savings and transfers to other institutions, defined in Equation (4.37) are allocated across different commodities according to demand functions belonging to a linear expenditure system (LES), defined in *per capita* form with separate equations for demands from the market and from own-production, see Equations (4.38 and 4.39). If the database explicitly considers transactions costs, then market demands include these whereas demands for own production do not.

For the remaining domestic institution, the government, current incomes come from taxes (which are disaggregated into a wide range of categories), factor endowments (the government may own non-labor factors) and transfers from other domestic institutions and the rest of the world, Equation (4.40); transfers from the rest of the world may be endogenous, clearing the government budget as part of the government closure rule.

[21] Drawing on empirical evidence and a formulation used in van der Mensbrugghe (2005b), the model code for Equation (4.35) has been expanded to permit an optional link between changes in youth and old-age dependency ratios and the marginal propensity to save, using a constant-elasticity formulation. This may be particularly relevant in analyses of demographic issues.

[22] If the database does not include independent information about the marginal propensity save, then the intercept vanishes and the initial average and marginal savings propensities become equal. An independent estimate of the marginal propensity is required if base-year savings are negative.

(If so, direct taxes do not perform this role.) The current expenditures of the government are divided into consumption, transfers to domestic institutions (CPI-indexed) and the rest of the world (fixed in FCU) and interest payments on domestic and foreign debt, Equation (4.41). For each period except the first, real government consumption, disaggregated by commodity (excluding consumption for infrastructure), is defined as the level in the previous year times a growth factor that consists of multiple terms, Equation (4.42). In the mathematical statement, the right-hand side terms are all exogenous or lagged; in simulations with other rules for determining government consumption (including simulations targeting MDGs), one of the exogenous terms is endogenous.[23] Real government consumption of infrastructure services, also for each period except the first, is defined as the quantity of government consumption per unit of the government infrastructure capital stock times the real endowment of that capital stock by the government, i.e. the size of the capital stock determines consumption (which may represent maintenance, administration and so on, see Equation (4.43). Finally, government savings is simply the difference between current revenues and current expenditures, Equation (4.44).

4.4.1.4 Investment block

This block, Table 4.8; Equations (4.45—4.53) covers the determination of government and private investment [including foreign direct investment (FDI)] and how these are financed.

Government investment demand by capital stock ($DKGOV_{f,t}$) is defined in Equation (4.45), which consists of three parts, including a complementary-slackness relationship (*cf.* above discussion of Equation (4.3) for outputs with perfect transformability between exports and domestic sales). Different treatments are applied to service capital (used in the production of government services) and infrastructure capital (which requires government support services), see Equation (4.45a). For service capital, growth in service production is the driving force; investment demand is determined as the difference between: (i) The anticipated capital demand next year (assuming that production growth will be the same as last year and using a fixed capital-input coefficient) and (ii) the capital stock that would remain if no investments were made.[24] For infrastructure capital, government investment demand is determined as the difference between: (i) An exogenous growth term times the infrastructure capital stock in t, similar to Equation (4.21) and (ii) the capital stock that

23 MAMS permits government demand for a commodity c to be endogenous for several reasons: the demand is an exogenous share of GDP or absorption; demand adjusts as part of outcome targeting with the provision of commodity c as the tool; demand adjusts to clear the government budget — if so, the variable $QGGRWC_{c,t}$ is flexible. For the most straightforward case, $qg01_{c,c',t}$, a parameter for mapping one c to another, is 1 when $c = c'$ and zero otherwise. If the analyst wants one or more kinds of government consumption to grow in tandem with another (e.g. as part of budget clearing), more than one c may have a value of one for any given c'. In either case, each c is linked to only one c'.

24 In GAMS, the treatment is more general, giving the user the option to assume that the rate of expected output growth is the same as the rate of simulated output growth during the last one, two or three years.

Table 4.8 Investment block

(4.45) (a)	$$DKGOV_{f,t} \geq \sum_{a \in A \,\mid_{(f,a) \in MFA}} ifa_{f,a,t} \cdot QA_{a,t} \cdot EXP\left(\ln\left(\frac{QA_{a,t}}{QA_{a,t-1}}\right)\right)\Bigg|_{f \in FCAPGOVSER}$$ $$\begin{bmatrix} \textit{government investment} \\ \textit{demand for capital } f \end{bmatrix} \geq \begin{bmatrix} \textit{demand for government service capital in } t+1: \\ \textit{capital coefficient times expected activity level in } t+1 \end{bmatrix}$$ $$+\left(\left(1 + qggrwbar_{f,t} + \sum_{c \in C} qg01_{f,c,t} \cdot \overline{QGGRW}_{c,t}\right) \cdot QFINS_{\text{gov},f,t}\right)\Bigg|_{f \in FCAPGOVINF}$$ $$+\begin{bmatrix} \textit{demand for government infrastructure capital in } t+1: \\ \textit{growth rate times infrastructure capital stock in } t \end{bmatrix}$$ $$- QFINS_{\text{gov},f,t} \cdot \left(1 - depr_{f,t}\right) - \begin{bmatrix} \textit{remaining capital stock (after dep-} \\ \textit{reciation) in } t+1 \textit{ if no investment in } t \end{bmatrix}$$	$f \in FCAPGOV$ $t \in T$ $t > 1$	Real government demand for investment in capital stock f
(b)	$$DKGOV_{f,t} \geq 0$$ $$[\textit{government investment}] \geq [\textit{zero}]$$		
(c)	$$\left(DKGOV_{f,t} - DKGOVDEM_{f,t}\right) \cdot \left(DKGOV_{f,t} - 0\right) = 0$$ where $DKGOVDEM_{f,t}$ = right-hand of part (a) of Equation 4.45 $$\begin{bmatrix} \textit{Complementary slackness relationship:} \\ \textit{1. If government investment exceeds its demand then this investment level is zero.} \\ \textit{2. If the government investment level is above zero, then it equals its demand.} \end{bmatrix}$$		

(4.46)

$$DKINS_{\text{gov},f,t} = DKGOV_{f,t}$$

$$\begin{bmatrix} \textit{gross investment in f of} \\ \textit{government} \end{bmatrix} = \begin{bmatrix} \textit{gross government investment} \\ \textit{demand for capital} \end{bmatrix}$$

$f \in FCAPGOV$
$t \in T$
$t > 1$

Real government investment in capital stock f (investment by destination)

(4.47)

$$PK_{f,t} = \sum_{c \in C} capcomp_{c,f} \cdot PQ_{c,t}$$

$$\begin{bmatrix} \textit{price of new} \\ \textit{capital stock} \end{bmatrix} = \begin{bmatrix} \textit{total value of commodities c} \\ \textit{per unit of new capital} \end{bmatrix}$$

$f \in FCAP$
$t \in T$

Price of new capital stock

(4.48)

$t \in T$

Government investment value and financing

$$\sum_{f \in FCAPGOV} PK_{f,t} \cdot DKINS_{\text{gov},f,t} = GSAV_t - \sum_{c \in C} PQ_{c,t} \cdot qdst_{c,\text{gov},t} + \overline{GBORTOT}_t$$

$$\begin{bmatrix} \textit{government fixed} \\ \textit{investment value} \end{bmatrix} = \begin{bmatrix} \textit{government} \\ \textit{savings} \end{bmatrix} - \begin{bmatrix} \textit{spending on} \\ \textit{stock changes} \end{bmatrix} + \begin{bmatrix} \textit{total change in holdings} \\ \textit{of government bonds} \end{bmatrix}$$

$$+\overline{GBORMSTOT}_t + (\overline{FBOR}_{\text{gov},t} + \overline{FGRANT}_{\text{gov},t}) \cdot EXR_t$$

$$+\begin{bmatrix} \textit{Government monetary system} \\ \textit{borrowing (deficit monetization)} \end{bmatrix} + \begin{bmatrix} \textit{foreign borrowing and foreign} \\ \textit{grants (transformed into LCU)} \end{bmatrix}$$

(*Continued*)

Table 4.8 Investment block—cont'd

(4.49)	$GBOR_{i,t} = \overline{gbor}_{i,t} + \left(\overline{GBORTOT}_t - \sum_{i' \in INSDNG'} \overline{gbor}_{i',t}\right) \frac{INSSAV_{i,t}}{\sum_{i' \in INSDNG'} INSSAV_{i',t}}$ $\begin{bmatrix} \text{change in holdings} \\ \text{of government} \\ \text{bonds by} \\ \text{institution } i \end{bmatrix} = \begin{bmatrix} \text{exogenous} \\ \text{borrowing from} \\ \text{institution } i \end{bmatrix} + \begin{bmatrix} \text{remaining} \\ \text{total} \\ \text{borrowing} \end{bmatrix} \cdot \begin{bmatrix} \text{share of} \\ \text{institution } i \text{ in} \\ \text{total savings} \end{bmatrix}$	$i \in INSDNG$ $t \in T$	Allocation of government bond borrowing across domestic non-government institutions
(4.50)	$GBORMS_{i,t} = \overline{gborms}_{i,t} + \left(\overline{GBORMSTOT}_t - \sum_{i' \in INSDNG'} \overline{gborms}_{i',t}\right) \frac{INSSAV_{i,t}}{\sum_{i' \in INSDNG'} INSSAV_{i',t}}$ $\begin{bmatrix} \text{burden of government} \\ \text{monetary} \\ \text{system borrowing} \\ \text{allocated to} \\ \text{institution } i \end{bmatrix} = \begin{bmatrix} \text{exogenous} \\ \text{burden for} \\ \text{institution } i \end{bmatrix} + \begin{bmatrix} \text{remaining} \\ \text{monetary} \\ \text{system} \\ \text{borrowing} \end{bmatrix} \cdot \begin{bmatrix} \text{share of} \\ \text{institution } i \text{ in} \\ \text{total savings} \end{bmatrix}$	$i \in INSDNG$ $t \in T$	Allocation of the burden of monetary system borrowing across domestic non-government institutions
(4.51)	$INVVAL_{i,t} = INSSAV_{i,t} - \sum_{c \in C} PQ_{c,t} \cdot qdst_{c,i,t} - GBOR_{i,t}$ $\begin{bmatrix} \text{non-government fixed} \\ \text{investment value} \end{bmatrix} = [\text{savings}] - \begin{bmatrix} \text{stock} \\ \text{changes} \end{bmatrix} - \begin{bmatrix} \text{change in holdings of} \\ \text{government bonds} \end{bmatrix}$ $-GBORMS_{i,t} + \left(\overline{FBOR}_{i,t} + fdi_{i,t}\right) \cdot EXR_t$ $-\begin{bmatrix} \text{Government Central} \\ \text{Bank borrowing} \end{bmatrix} + \begin{bmatrix} \text{foreign borrowing and} \\ \text{FDI (transformed into LCU)} \end{bmatrix}$	$i \in INSDNG$ $t \in T$	Investment financing for non-government institutions

(4.52)

$$PK_{f,t} \cdot DKINS_{i,f,t} = gfcfshr_{f,i,t} \cdot INVVAL_{i,t}$$

$$\begin{bmatrix} \textit{non-government spending} \\ \textit{on capital stock } f \end{bmatrix} = \begin{bmatrix} \textit{total fixed investment value} \\ \textit{times share for capital stock } f \end{bmatrix}$$

$i \in INSNG$
$f \in FCAP$
$t \in T$

Non-government investment by capital stock (investment by destination)

(4.53)

$$QINV_{c,t} = \sum_{f \in FCAP} \left(capcomp_{c,f,t} \cdot \sum_{i \in INS} DKINS_{i,f,t} \right)$$

$$\begin{bmatrix} \textit{real investment demand} \\ \textit{for commodity } c \end{bmatrix} = \begin{bmatrix} \textit{demand for } c \textit{ for each type of capital,} \\ \textit{summed over all institutions and capital types} \end{bmatrix}$$

$c \in C$
$t \in T$

Total real investment demand by commodity (investment by origin or source)

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would remain if no investments were made.[25] A non-negativity constraint is also imposed for government investment, Equation (4.45b). A complementary-slackness condition, Equation (4.45c) imposes that (i) if $DKGOV_{f,t}$ is positive, then Equation (4.45a) must hold as an equality, and (ii) if the right-hand side of Equation (4.45a) is negative, then $DKGOV_{f,t}$ will be zero and Equation (4.45a) will hold as a strict inequality. This treatment is used to avoid a negative investment value ($DKGOV_{f,t} < 0$) in the exceptional case of an anticipated production *decline* that is larger than the depreciation rate. Equation (4.46) transfers the value of $DKGOV_{f,t}$ to investment by institution, $DKINS_{\text{gov},f,t}$ (for the government), a variable that is used elsewhere in the model for investment across all capital stocks.[26]

The prices of new capital stocks (disaggregated by type) depend on their composition and market prices, Equation (4.47). The resulting fixed government investment value (defined on the basis of the price and quantity information generated in the preceding equations) is financed by some combination of government savings (net of spending on stock changes), sales of government bonds (i.e. new interest-bearing borrowing), borrowing via the monetary system, foreign borrowing and foreign capital grants (which is separate from current government transfers from the rest of the world), Equation (4.48). Returning to the equations, government bond sales and borrowing via the monetary system are allocated across households on the basis of their savings shares adjusted for an exogenous, household-specific term in each equation, see Equations (4.49) and (4.50).[27]

Equation (4.48) concludes the series of equations that summarize the government budget, see also Equations (4.40), (4.41) and (4.44). The choice of mechanism for clearing the budget (the government closure rule) is often an important part of the simulations. As noted above, in this mathematical statement it is assumed that changes in the variable $DTINS_t$, see Equation (4.34) and adjust direct tax payments sufficiently to clear the budget. The other terms in the expressions for government receipts and outlays are exogenous or determined via other mechanisms. Under alternative government closures, $DTINS_t$ is exogenous while some other variable is endogenous, clearing the government budget, e.g. government bond sales ($GBORTOT_t$) or government borrowing from the rest of the world ($FBOR_{\text{gov},t}$).

Each alternative closure has specific macroeconomic repercussions. Increases in government bond sales reduces the amount of financing that is available for private

25 For public infrastructure, actual $QG_{c,t}$ (government service level) is determined by the current capital stock, see Equation (4.43). In Equation (4.45), the exogenous growth variable $QGGRWC_{c,t}$ (which is defined over c, where the relevant c may be public infrastructure services) is mapped to the capital stock f associated with c and drives the expansion in the capital stock.

26 In order to permit smoothing of year-to-year changes investment quantities, the GAMS code permits the user to define $DKINS_{\text{gov},f,t}$ as a weighted average between $DKGOV_{f,t}$ and $DKINS_{\text{gov},f,t}$ in the previous year.

27 The burden of monetary system borrowing is felt by other agents since it extracts real purchasing power from them by reducing the value of the old money that they hold. In the absence of an explicit treatment of money in this model, this burden is here allocated across households on the basis of their savings shares. The terms $\overline{gbor}_{i,t}$ and $\overline{gborms}_{i,t}$ are non-zero in the initial year in so far as observed shares for government borrowing deviate from savings share.

investment, *cf.* Equation (4.51) while increases in foreign grants or foreign borrowing tend to permit more rapid growth in GDP and private final demand (consumption and investment). Reliance on foreign resources also tends to bring about real exchange rate appreciation, slower export growth and more rapid growth in imports and production of non-tradables. The strength of these effects depends on the growth impact of the expansion in government spending as well as on whether the new spending has high or low import shares. If the country later needs to reverse the switch toward production of non-tradables (e.g. because of a decline in foreign grants in the future), and its structure is rigid, it may end up suffering from "Dutch Disease." Expansion in foreign borrowing is less favorable than grants since it drives up the foreign debt (which, in the absence of debt relief, eventually has to be repaid) and related interest payments (more or less burdensome depending on loan conditions). The alternative of raising direct taxes tends to be less favorable to growth in GDP and private final demand than reliance on foreign resources. However, given that most of the cut in household disposable income is born by consumption as opposed to savings and investment, the direct tax alternative is more favorable than domestic government borrowing for long-run growth in GDP and private final demand.

Equation (4.51) defines the fixed investment values for non-government institutions — all terms do not apply to each institution — as own savings, net of spending on stock changes and lending to the government and augmented by borrowing, capital grants and FDI from the rest of the world.[28] For the latter, the fixed investment value is simply the value of FDI (fixed in FCU) times the exchange rate. (The FDI term is invariably fixed at zero for domestic institutions.) Implicitly, Equation (4.51) shows a rule for ensuring that total savings and total investment are equal: given that government and households savings, government investment and FDI all are determined by rules, the clearing variable is private household investment ($INVVAL_{h,t}$).

For each non-government institution, real investment in different capital stocks (investment by destination) is determined by its total fixed investment values, the prices of capital goods and exogenous value shares by capital stock; the value share is unity if the database only specifies a single private capital type, Equation (4.52).[29]

The final equation in this block defines total investment demand by commodity source (often referred to as investment by origin). It is defined on the basis of real gross fixed capital formation (both private and government; investment by destination) and the capital composition parameter, Equation (4.53).

[28] Note that MAMS does not cover borrowing and related debts obligations that only involve domestic non-government institutions (i.e. without involvement from the government or the rest of the world).

[29] Typically, the model will only have one private capital stock, i.e. the value of the share parameter is unity for this capital type. If the model has more than one private capital stock, the allocation between the different stocks may be endogenized, possibly deviating from the base-level allocation in response to changes in relative profit rates — a relationship that would need to be specified in one or more additional equations.

4.4.1.5 Other system constraints: foreign exchange, factors and commodities

In the preceding, we discussed alternative mechanisms for clearing two of the macro constraints of the model, the government budget and the savings—investment balance. The current block, see Table 4.9; Equations (4.54—4.58), includes the remaining system constraints: the balance of payments and the markets for factors and commodities.

The balance of payments (or foreign exchange constraint) Equation (4.54) imposes equality between foreign exchange uses (spending on imports, factor incomes and transfers to the rest of the world and interest payments on foreign debts) and sources (export revenues, transfers, factor incomes, borrowing, capital grants and FDI).[30] In practice, the only plausible assumption for medium- and long-run analysis tends to be that the (real) exchange rate (EXR_t) clears this balance. For example, other things being equal, depreciation (an increase in EXR_t) will remove a deficit by raising supplies for export relative to supplies for home sales while reducing domestic use of imports relative to domestic use of local output.[31]

The market constraint for factors, Equation (4.55), which applies to all factors except government capital, states that total demand for any factor (the left-hand side) equals the total endowment times the employment rate (1 — the unemployment rate). This is straightforward if the unemployment rate is exogenous — if so, in any time period, the economy-wide wage variable ($WF_{f,t}$) will clear the market by influencing the quantities demanded.

On the other hand, for factors with endogenous unemployment (in the set *FUEND*; typically including labor), Equations (4.56) and (4.57) are also included.[32] Using labor as an example, workers have a reservation (minimum) wage ($WFRES_{f,t}$) below which they will not work, Equation (4.56). It is defined as a function of the economy-wide wage in the base year, and the ratios between current and base-year values for the unemployment rate, household consumption *per capita* (as an indicator of real living standards) and the CPI. The ratio terms are raised to elasticities that determine their importance (an elasticity of zero implies that a term has no importance in the application in question). Equation (4.57) consists of three parts: (4.57a) the constraint that the economy-wide wage for each factor cannot fall below the endogenous reservation wage, (4.57b) the constraint that the unemployment rate cannot fall below an exogenous minimum ($ueratmin_{f,t}$)[33] and (4.57c) a complementary slackness condition, which states that either (a) or (b) but not both are slack (non-

30 Implicitly, an additional system constraint, the savings—investment balance, also holds: by channeling domestic savings and the terms that make up foreign savings to investment, the model equations ensure that total savings and total investment are equal.

31 Alternative assumptions (e.g. that foreign grants or borrowing clear the balance) typically seem farfetched and may also cause sharp imbalances for the domestic institution that is involved (in this example as recipient of foreign grants or loans).

32 This formulation draws on van der Mensbrugghe (2005, pp. 20—21). See also Agénor (2007, Chapter 1).

33 The level of the base-year unemployment rate relative to the minimum unemployment rate indicates the potential for employment growth over and above the growth rate of the labor stock.

Table 4.9 Constraints for foreign exchange, factors and commodities

(4.54)	$$\sum_{c \in CM} pwm_{c,t} \cdot QM_{c,t} + \frac{\sum_{f \in F} YIF_{\text{row},f,t}}{EXR_t} + \frac{\sum_{i \in INSDNG} TRII_{\text{row},i,t}}{EXR_t}$$ $$\left[\begin{matrix}\textit{import}\\ \textit{spending}\end{matrix}\right] + \left[\begin{matrix}\textit{factor income}\\ \textit{to RoW}\end{matrix}\right] + \left[\begin{matrix}\textit{transfers from domestic}\\ \textit{non-government institutions to RoW}\end{matrix}\right]$$ $$+\overline{TRNSFR}_{\text{row},\text{gov},t} + \sum_{i \in INSD} fintrat_{i,t} \cdot FDEBT_{i,t} =$$ $$+\left[\begin{matrix}\textit{transfers from}\\ \textit{government to RoW}\end{matrix}\right] + \left[\begin{matrix}\textit{interest payment}\\ \textit{on foreign debt}\end{matrix}\right] =$$ $$\sum_{c \in CE} \overline{PWE}_{c,t} \cdot QE_{c,t} + \sum_{i \in INSDNH} \overline{TRNSFR}_{i,\text{row},t} + \sum_{h \in H} trnsfrpc_{h,\text{row},t} \cdot \overline{POP}_{h,t}$$ $$\left[\begin{matrix}\textit{export}\\ \textit{revenue}\end{matrix}\right] + \left[\begin{matrix}\textit{transfers from RoW to domestic}\\ \textit{non-household institutions}\end{matrix}\right] + \left[\begin{matrix}\textit{transfers from RoW to}\\ \textit{domestic households}\end{matrix}\right]$$ $$+\sum_{f \in F} \overline{TRNSFR}_{f,\text{row},t} + \sum_{i \in INSD} \overline{FBOR}_{i,t} + fdi_{\text{row},t}$$ $$+\left[\begin{matrix}\textit{factor income}\\ \textit{from RoW}\end{matrix}\right] + \left[\begin{matrix}\textit{borrowing}\\ \textit{from RoW}\end{matrix}\right] + \left[\begin{matrix}\textit{grants}\\ \textit{from RoW}\end{matrix}\right] + \left[\begin{matrix}\textit{foreign direct}\\ \textit{investment}\end{matrix}\right]$$	$t \in T$	Balance of payments (in FCU)

(*Continued*)

Table 4.9 Constraints for foreign exchange, factors and commodities—cont'd

(4.55)	$\sum_{a \in A} QF_{f,a,t} = \left(1 - UERAT_{f,t}\right) \cdot \sum_{i \in INS} QFINS_{i,f,t}$ $\begin{bmatrix} demand\ for \\ market\ factor\ f \end{bmatrix} = \begin{bmatrix} 1 - unemployment\ rate \\ (i.e.\ employment\ rate) \end{bmatrix} \cdot \begin{bmatrix} sum\ of\ all\ institutional \\ endowments\ of\ factor\ f \end{bmatrix}$	$f \in F$ $t \in T$	Factor markets
(4.56)	$WFRES_{f,t} = WF_f^0 \cdot \left(\frac{QHPC_t}{QHPC^0}\right)^{\varphi_{qhpc,f}} \cdot \left(\frac{UERAT_{f,t}}{UERAT_f^0}\right)^{\varphi_{uerat,f}} \cdot \left(\frac{CPI_t}{CPI^0}\right)^{\varphi_{cpi,f}}$ $\begin{bmatrix} reservation\ wage \\ for\ factor\ f \\ in\ year\ t \end{bmatrix} = \begin{bmatrix} economy\text{-}wide\ wage \\ for\ factor\ f\ in \\ the\ base\ year \end{bmatrix} \cdot \begin{bmatrix} adjustment\ due\ to:\ percapita \\ household\ consumption, \\ unemployment\ rate\ and CPI \\ (all\ relative\ to\ base\ year\ values) \end{bmatrix}$	$f \in FUEND$ $t \in T$	Reservation wage
(4.57)(a)	$WF_{f,t} \geq WFRES_{f,t}$ $\begin{bmatrix} economy\text{-}wide \\ wage\ for\ factor \\ f\ in\ year\ t \end{bmatrix} \geq \begin{bmatrix} reservation \\ wage\ for\ factor \\ f\ in\ year\ t \end{bmatrix}$	$f \in FUEND$ $t \in T$	For factors with endogenous unemployment: (a) wage and (b) unemployment constraints; and (c) related complementary-slackness relationship
(b)	$UERAT_{f,t} \geq ueratmin_{f,t}$ $\begin{bmatrix} unemployment \\ rate\ for\ factor \\ f\ in\ year\ t \end{bmatrix} \geq \begin{bmatrix} minimum\ unemployment \\ rate\ for\ factor\ f \\ in\ year\ t \end{bmatrix}$		

(c) $$\left(WF_{f,t} - WFRES_{f,t}\right) \cdot \left(UERAT_{f,t} - ueratmin_{f,t}\right) = 0$$

$$\left[\begin{array}{l} \textit{Complementary slackness relationship:} \\ 1.\ \textit{If wage exceeds reservation wage then unemployment rate is at its minimum.} \\ 2.\ \textit{If unemployment rate excceds its minimum, then wage equals reservation wage.} \end{array}\right]$$

(4.58) $$QQ_{c\ t} = \sum_{a \in A} QINT_{c,a,t} + \sum_{h \in H} QH_{c,h,t} + QG_{c,t}$$

$$\left[\begin{array}{c} composite \\ supply \end{array}\right] = \left[\begin{array}{c} intermediate \\ use \end{array}\right] + \left[\begin{array}{c} household \\ consumption \end{array}\right] + \left[\begin{array}{c} government \\ consumption \end{array}\right]$$

$$+QINV_{c,t} + \sum_{i \in INS} qdst_{c,i,t} + QT_{c,t}$$

$$+\left[\begin{array}{c} fixed \\ investment \end{array}\right] + \left[\begin{array}{c} stock \\ change \end{array}\right] + \left[\begin{array}{c} trade\ and \\ transport \end{array}\right]$$

$c \in C$

$t \in T$

Composite commodity markets

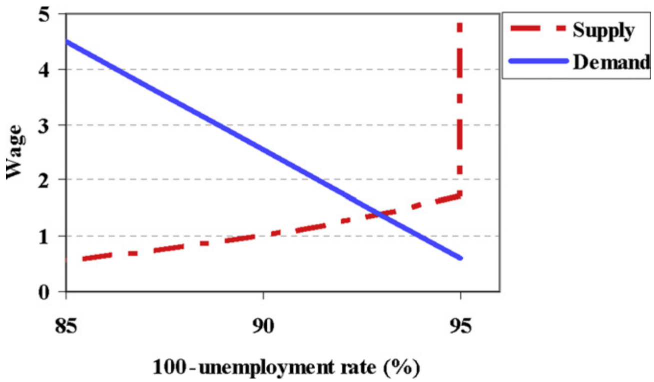

Figure 4.1 Labor market adjustment with endogenous unemployment.

binding). In other words, if the unemployment rate is above its minimum, then the wage must be at the reservation level; if the wage is above the reservation level, then the unemployment rate must be at its minimum.

Figure 4.1 illustrates the functioning of factor markets with endogenous unemployment. The supply curve is upward-sloping, reflecting that, *cet. par.*, workers request higher wages as the labor market gets tighter. When the market reaches "full employment," i.e. when the minimum unemployment rate is reached (which here is set at 5%), the supply curve turns vertical. When the factor market is below full employment, market-clearing changes in the economy-wide wage variable ($WF_{f,t}$) brings about changes, not only on the demand side but also on the supply side of the labor market; at full employment, only the demand side responds. Unemployment should be seen as broadly defined, representing the degree of underutilization of the factor (and the potential for increased utilization), due to a combination of full or partial unemployment (i.e. also considering underemployment) *cf.* above discussion of Equation (4.3) for outputs with perfect transformability between exports and domestic sales, which also includes a complementary-slackness condition.

For each composite commodity, the supply is set equal to the sum of demands, Equation (4.58). As noted earlier, composite supplies stem from two sources, imports and domestic supplies to domestic markets, *cf.* Equation (4.24); for each commodity with both sources, demand is allocated between them on the basis of relative prices. The market-clearing variables are the quantity ($QM_{c,t}$) for imports and, for domestic output, the price ($PDS_{c,t}$ for suppliers and $PDD_{c,t}$ for demanders, with a wedge between the two in the presence of transactions costs).

4.4.1.6 Asset stock updating and productivity block

The equations in this block update institutional stocks of assets and liabilities and TFP by activity, Table 4.10; Equations (4.59)−(4.66). Except for equations defining

Table 4.10 Asset stock updating and productivity block

	Equation	Domain	Description
(4.59)	$QFINS_{i,f,t} = \left(1 - depr_{f,t-1}\right) \cdot QFINS_{i,f,t-1} + DKINS_{i,f,t-1} + qfinsadj_{i,f,t-1}$ $\begin{bmatrix} \textit{stock of capital} \\ \textit{type } f \textit{ held} \\ \textit{by institution } i \end{bmatrix} = \begin{bmatrix} \textit{non-depreciated} \\ \textit{capital stock} \end{bmatrix} + \begin{bmatrix} \textit{fixed investment} \\ \textit{in } t-1 \end{bmatrix} + \begin{bmatrix} \textit{exogenous adjustment} \\ \textit{in capital stock} \end{bmatrix}$	$i \in INS$ $f \in FCAP$ $t \in T$ $t > 1$	Capital stocks by institution
(4.60)	$FDEBT_{i,t} = FDEBT_{i,t-1} + FBOR_{i,t-1} + \left(fintratdue_{i,t-1} - fintrat_{i,t-1}\right) \cdot FDEBT_{i,t-1} - fdebtrelief_{i,t-1}$ $\begin{bmatrix} \textit{foreign} \\ \textit{debt in } t \end{bmatrix} = \begin{bmatrix} \textit{foreign} \\ \textit{debt in } t-1 \end{bmatrix} + \begin{bmatrix} \textit{foreign} \\ \textit{borrowing in } t-1 \end{bmatrix} + \begin{bmatrix} \textit{unpaid interest on} \\ \textit{foreign debt in } t-1 \end{bmatrix} - \begin{bmatrix} \textit{foreign debt} \\ \textit{relief in } t-1 \end{bmatrix}$	$i \in INSD$ $t \in T$ $t > 1$	Foreign debt of domestic institutions
(4.61)	$GDEBT_{i,t} = GDEBT_{i,t-1} + GBOR_{i,t-1}$ $\begin{bmatrix} \textit{stock of government} \\ \textit{bond held by} \\ \textit{institution } i \end{bmatrix} = \begin{bmatrix} \textit{redistributed holdings of} \\ \textit{stock of government bond} \\ \textit{held by institution } i \textit{ in } t-1 \end{bmatrix} + \begin{bmatrix} \textit{government} \\ \textit{borrowing} \\ \textit{from } i \textit{ in } t-1 \end{bmatrix}$	$i \in INSDNG$ $t \in T$ $t > 1$	Government bond holdings of domestic institutions

(*Continued*)

Table 4.10 Asset stock updating and productivity block—cont'd

(4.62)

$$GDPREAL_t = \sum_{c \in C} \sum_{h \in H} PQ_c^0 \cdot QH_{c,h,t} + \sum_{a \in A} \sum_{c \in C} \sum_{h \in H} PXAC_{a,c}^0 \cdot QHA_{a,c,h,t}$$

$t \in T$ — Real GDP at market prices

$$[real\ GDP] = \begin{bmatrix} household\ market \\ consumption \end{bmatrix} + \begin{bmatrix} household\ own \\ production\ consumption \end{bmatrix}$$

$$+ \sum_{c \in C} PQ_c^0 \cdot QG_{c,t} + \sum_{c \in C} PQ_c^0 \cdot QINV_{c,t} + \sum_{c \in C} \sum_{i \in INS} PQ_c^0 \cdot qdst_{c,i,t}$$

$$+ \begin{bmatrix} government \\ consumption \end{bmatrix} + \begin{bmatrix} fixed \\ investment \end{bmatrix} + \begin{bmatrix} stock \\ change \end{bmatrix}$$

$$+ \sum_{c \in CE} EXR^0 \cdot PWE_c^0 \cdot QE_{c,t} - \sum_{c \in CM} EXR^0 \cdot PWM_c^0 \cdot QM_{c,t}$$

$$+[exports] - [imports]$$

(4.63)

$$TRDGDP_t = \frac{\sum_{c \in CE} EXR^0 \cdot PWE_c^0 \cdot QE_{c,t} + \sum_{c \in CM} EXR^0 \cdot PWM_c^0 \cdot QM_{c,t}}{GDPREAL_t}$$

$t \in T$ — Real Trade-GDP ratio

$$\begin{bmatrix} ratio\ of \\ trade\ to\ GDP \end{bmatrix} = \frac{[real\ trade]}{[real\ GDP]}$$

(4.64)

$$ALPHAVA_{a,t} = ALPHAVA2_{a,t} \cdot \prod_{f \in FCAP} \left[\frac{\sum_{i \in INS} QFINS_{i,f,t}}{\sum_{i \in INS} QFINS^{0}_{i,f}} \right]^{tfpelasqg_{a,f,t}} \cdot \left(\frac{\sum_{t' \in T} tfptrdwt_{t,t'} \cdot TRDGDP_{t'}}{TRDGDP^{0}} \right)^{tfpelastrd_{a}}$$

$a \in A$, $t \in T$, $t > 1$ — Efficiency (TFP) by activity

$$\begin{bmatrix} \textit{efficiency} \\ \textit{term for} \\ \textit{activity } a \end{bmatrix} = \begin{bmatrix} \textit{trend} \\ \textit{term for} \\ \textit{activity } a \end{bmatrix} \cdot \begin{bmatrix} \textit{product of : ratio of all} \\ \textit{current real capital} \\ \textit{endowments } f \textit{ to inital} \\ \textit{value, raised} \\ \textit{to the relevant elasticity} \end{bmatrix} \cdot \begin{bmatrix} \textit{weighted avg. (over time)} \\ \textit{of ratios of openness} \\ \textit{to initial value, raised} \\ \textit{to the relevant elasticity} \end{bmatrix}$$

(4.65)

$$ALPHAVA2_{a,t} = ALPHAVA2_{a,t-1} \cdot \left(1 + \alpha^{\mathrm{vag}}_{a,t} + \overline{CALTFPG}_{t} \cdot tfp01_{a,t}\right)$$

$a \in A$, $t \in T$, $t > 1$ — TFP trend term by activity

$$\begin{bmatrix} \textit{trend term for} \\ \textit{activity } a \textit{ in } t \end{bmatrix} = \begin{bmatrix} \textit{trend term for} \\ \textit{activity } a \textit{ in } t-1 \end{bmatrix} \cdot \begin{bmatrix} \textit{growth adjustment} \\ \textit{factor} \end{bmatrix}$$

(4.66)

$$GDPREALFC_{t} = \sum_{a \in A} PVA^{0}_{a} \cdot \left(1 - tva^{0}_{a,t}\right) \cdot QVA_{a,t}$$

$t \in T$ — Real GDP at factor cost

$$\begin{bmatrix} \textit{real GDP} \\ \textit{at factor cost} \end{bmatrix} = \begin{bmatrix} \textit{value-added} \\ \textit{net of taxes} \end{bmatrix}$$

arguments for the definition of TFP, all equations in this block include lagged relationships. They do not apply to the first year, for which the values of the variables defined in this block are fixed.

Implicitly, this mathematical statement assumes that MAMS has a single representative household.[34] For capital, the stock of any institution (household, government and rest of world) is defined as the sum of its previous-period stock (adjusted for depreciation), new investments and exogenous adjustments (which may reflect the impact of natural disasters or institutional changes, removing parts of the capital stock from production), Equation (4.59). The evolution of labor endowments is defined in Equation (4.79).[35] For other factors (e.g. agricultural land), the growth in institutional endowments ($QFINS_{i,f,t}$) is exogenous. Except for the absence of depreciation, the relationships that hold for foreign debt, Equations (4.60) and government bonds, Equations (4.61) are identical to those used for capital. For foreign debt, the treatment is potentially more complex since the model allows for the possibility of non-paid interest (which is added to the debt) and debt relief.

This block includes further a set of equations used to define TFP for each activity. For this purpose, Equations (4.62) and (4.63) define real GDP at market prices and the real trade-to-GDP ratio. In Equation (4.64), the TFP of each activity (a variable that appears in Equation (4.14), the CES value-added function) is defined as the product of a trend term, changes due to capital accumulation and changes due to variations in economic openness (defined by the real trade-to-GDP ratio). The effects of capital accumulation and changes in openness depend on the values of exogenous elasticities – if they are set at zero, the effect is zero and then only the trend term matters. In the definition of the trend term, Equation (4.65), the first of the trend growth terms, $\alpha_{a,t}^{\mathrm{vag}}$ is invariably exogenous and set at unity unless it is changed as part of an experiment. The second term, $CALTFPG_t$ is endogenized when a certain GDP level is targeted (a typical assumption for the base run). In this context, the parameter $tfp01_{a,t}$ has been used to control relative TFP growth rates across activities; given that only relative values matter, its values may conveniently range between zero and unity. However, apart from the base simulation, all right-hand terms are

[34] For applications with multiple households, the GAMS representation of MAMS specifies how the population of each household evolves over time. Given that it adds complexity, this aspect is suppressed in this chapter. Briefly, the general principle is that the household types that exist in the base-year (characterized by patterns for generation and spending of incomes) continue to exist but grow at different rates depending on the types of labor that they control. The capital endowments of each household are updated on the basis of new investment and the size of the non-depreciated stock of the previous period, adjusted for population changes and economy-wide constraints. Other (non-labor, non-capital) factor endowments are defined as the initial *per capita* endowment, scaled upwards or downwards to ensure that total endowments across all household equals the economy-wide endowment total.

[35] In the absence of a link between education and the labor market, the core version of MAMS simplifies the evolution of labor stocks; each stock grows at an exogenous rate with the total economy-wide stock in each period being scaled to ensure that it matches an exogenous rate of labor force participation among the population in labor force age (typically 15–64).

typically either exogenous or lagged while GDP is endogenous.[36] The trade-to-GDP ratio, an indicator of economic openness (in terms of outcome, not policy stance) is defined in real terms (to avoid the impact of nominal changes, e.g. due to exchange rate depreciation) and with a potential lag (to avoid unrealistically large immediate productivity effects of changes in openness): in any time period, the numerator in the last term of Equation (4.64) is a weighted average of current and past trade-to-GDP ratios. The parameter for the length of the lag is part of the country-specific database. The final equation in this block, Equation (4.66), defines real GDP at factor cost; it is flexible unless $CALTFPG_t$ is fixed.

The fact that the elasticity parameters in Equation (4.64) are disaggregated (by activity for trade and by activity and function for capital) make it possible to specify different channels and magnitudes for the productivity effects of trade and of different types of capital stocks. Depending on the degree of disaggregation of these capital stocks and activities, the productivity effects can be more or less finely targeted. For example, if irrigation and road capital stocks are singled out, these could meaningfully be linked to agriculture (especially crop activities) and transportation services, respectively; other sectors would only be influenced indirectly by these productivity changes.[37] On the other hand, if infrastructure capital is a single capital stock, the selection of targeted sectors would have to be more general (implicitly reflecting some assumed composition of this broader spending type).

4.4.2 MDG and education module

The MDG and education module, Equations (4.67)–(4.81) specifies the mechanisms that determine the values for the indicators related to the different MDGs and educational outcomes as well as the size and disaggregation (by educational achievement) of the labor force. The rest of the economy, which was presented in the preceding sections, influences the evolution of the MDGs and the educational sector through variables related to household consumption, the provision of different types of MDG-related services, labor wages and capital stocks in infrastructure. In its turn, the MDG module influences the rest of the economy through its impact on the size, composition and productivity of the labor force. In addition, the evolution of one set of MDGs can influence other MDGs. The notation and the equations of the MDG module are, respectively, presented in Tables 4.11—4.14.

36 When developing the model base run, $CALTFPG_t$ may be endogenous or exogenous. If it is endogenous, real GDP (at factor cost) should be fixed (growing exogenously over time). If so, the analyst should review the resulting economy-wide growth in TFP as well as efficiency growth in different activities ($ALPHAVA_{a,t}$) and, if needed, adjust the targeted real GDP levels. On the other hand, if $CALTFPG_t$ is exogenous (and real GDP endogenous), the analyst should monitor overall GDP growth and, if needed, adjust either $CALTFPG_t$ or $\alpha_{a,t}^{vag}$. The estimates of initial capital stocks and depreciation rates may also have to be revisited. For non-base runs, the determinants of trend TFP growth ($ALPHAVA2_{a,t}$) are typically fixed, while real GDP growth is determined by growth in factor employment and endogenous TFP changes.

37 The GAMS representation of the model also permits productivity disaggregated by factor and activity to be influenced by these determinants as well as MDG indicators; the latter may, for example, permit inks between health indicators and labor productivity.

Table 4.11 Sets for MDG and education module

Symbol	Explanation	Symbol	Explanation
$a \in A$	activities	$i \in INSNGAGG$	aggregate (domestic) non-government institution
$b \in B$	student behavioral characteristics = {*rep* = repeater; *dropout* = dropout; *prom* = promotion; *grdcont* = continuing graduate; *grdexit* = exiting graduate; *neting1* = net (in-cohort) intake to grade 1}	$b, b' \in MBB$	mapping between b (in $BRES$) and b' (in $BLOG$): = {(*rep*, *dropout*).*grd*, *grdexit*.*grdcont*}
$b \in BLOG$ $(\subset B)$	student behavior determined by logistic function = {*prom*, *grdcont*, *neting1*}	$b, b' \in MBB2$	mapping between b (in $BRES$) and all elements b' (also in $BRES$) that are related to the same element(s) in $BLOG$: = {*rep*.(*rep*, *dropout*), *dropout*.(*rep*, *dropout*), *grdexit*.*grdexit*}
$b \in BRES$ $(\subset B)$	student behavior determined by residual scaling = {*rep* = repeater; *dropout* = dropout; *grdexit* = exiting graduate}	$c, c' \in MCE$	mapping private and public education into 1 education commodity, by cycle = {*c-edup*.(*c-edup*, *c-edupng*)} where *c-edupng* is private primary; similarly for *c-edup2*, *c-edus* and *c-edut*.
$c \in C$	commodities	$c, c' \in MCHDC$	human development service c is aggregated to c′
$c \in CEDU$ $(\subset C)$	education services = {*c-edup* = primary cycle; *c-edus* = secondary cycle; *c-edut* = tertiary cycle}; may include both private and public education	$c, c' \in MCM$	mapping between aggregate (CMDG) and disaggregated MDG service commodities (CHLTH and CWTSN) = {*c-hlt*.(*c-hlt1g*, *c-hlt2g*, *c-hlt3g*, *c-hlt1ng*, *c-hlt2ng*, *c-hlt3ng*)} and {*c-wtsn*.(*c-wtsn*)}
$c \in CEDUP$ $(\subset C)$	primary education services = {*c-edup*}	$mdg \in MDG$	selected MDG indicators = {*mdg2*, *mdg4*, *mdg5*, *mdg7w*, *mdg7s*}

$c \in CEDUT$ $(\subset C)$	tertiary education services = {*c-edut*}
$c \in CHLTH$ $(\subset C)$	health services (public) = {*c-hlt1g* = low-tech; *c-hlt2g* = medium-tech; *c-hlt3g* = high-tech}; corresponding private health services labeled with "*ng*"
$cmdg \in CMDG$	aggregate MDG (non-education) service commodities = {*c-hlt* = aggregate health in MDG functions, not in *C*; *c-wtsn* = water—sanitation services}
$c \in CWTSN$ $(\subset C)$	water—sanitation service commodities {*c-wtsn* = water—sanitation services}
$eduarg \in EDUARG$	arguments in constant-elasticity function for educational behavior = {*edu-qual* = quantity of services per student; *w-prem* = skilled—unskilled wage ratio; *w-prem2* = superskilled—skilled wage ratio; *mdg4* = under-5 mortality rate; *fcapinf* = infrastructure capital stocks; *qhpc* = *per capita* household consumption}
$f \in FEXOG$	factors with exogenous growth
$c, b, t', t \in MCYC$	MDG2 in *t* is defined as the product over selected combinations of *b* and *t'* (where $t' \in T11$) = {*prom*, *neting1*}
$mdg \in MDGSTD$	MDG indicators = {*mdg4* = under-5 mortality rate; *mdg5* = maternal mortality rate; *mdg7w* = access to safe water; *mdg7s* = access to basic sanitation}
$f, c \in MFC$	mapping between labor types and cycles of education = {*flab-n.(c-edup1, c-edup2); flab-s.(c-edus); flab-t.(c-edut)*}
$c, g \in MCGLAB$	students in cycle *c*, grade *g* are in labor force age
$c, g \in MCGLABENT$	students in cycle *c*, grade *g* are in labor force *entry* age
$c, g \in MCGMAX$	grade *g* is the last (maximum) grade in cycle *c*

(*Continued*)

Table 4.11 Sets for MDG and education module—cont'd

$f \in FLAB$	labor factors {*f-labn* = less than 12 years of education; *f-labs* = 12–14 years of education (secondary education or 2 years of tertiary); *f-labt* = more than 14 years of education (at least 3 years of tertiary)	$c, g \in MCGMIN$	grade g is the first (minimum) grade in cycle c
$g \in G$	grade (in a cycle of schooling)	$mdgarg \in MDGARG$	arguments in constant-elasticity function for MDGs = {*cmdg* = aggregate commodities; *mdg* = different MDGs; *fcapinf* = infrastructure capital stocks; *hhdconspc* = *per capita* household consumption}
$h \in H$	households (excl. NGOs) = {h = the single household}	$t \in T$	time periods
$i \in INSG$	government institution	$t \in T11$	time periods including preceding years for MDG2 calculation

Table 4.12 Parameters for MDG and education module

$\alpha_{b,c}^{edu}$	constant in logistic function for educational behavior	$ext_{b,c}^{edu}$	maximum share for educational behavior b in cycle c
$\alpha_{b,c}^{educe}$	constant in constant-elasticity function for educational behavior	ext_{mdg}^{mdg}	maximum value for MDG 7w and 7s; minimum value for MDG 4 and 5
α_{mdg}^{mdg}	constant in logistic function for MDG achievement	$grdcont_{c,c'}$	0—1 constant showing that for c' next cycle is c
α_{mdg}^{mdgce}	constant in constant-elasticity function for intermediate MDG variable	pop_t^{g1}	population in age cohort entering grade 1
α_c^{hd}	efficiency term in CES aggregation function for human development	pop_t^{lab}	population of labor force age (often 15—64)
$\beta_{b,c}^{edu}$	constant in logistic function for educational behavior	pop_t^{labent}	population in age cohort entering labor force
β_{mdg}^{log}	constant in logistic function for MDG achievement	pop_t^{tot}	total population in t
$\delta_{c,i}^{hd}$	share parameter for human development CES function	$qenr_{c,g,t}^{newoth}$	other new entrants to cycle c, grade g
$\varphi_{b,c,eduarg}^{edu}$	elasticity of behavior b in cycle c w.r.t. argument *eduarg* in educational constant-elasticity function	$shif_{i,f,t}^{0}$	share of domestic institution i in income of factor f
$\varphi_{mdg,mdgarg}^{mdg}$	elasticity of *mdg* w.r.t. argument *mdgarg* in constant-elasticity function for MDG	$demot_{c,c'}$	0—1 parameter showing that for dropouts from c' the highest cycle is c
$\gamma_{b,c}^{edu}$	parameter in logistic function for education	$shr_{b,c}^{edu0}$	base-year share for behavioral indicator behav in cycle c
γ_{mdg}^{mdg}	parameter in logistic function for non-education MDGs	$shr_{c,t}^{labent}$	share of drop-outs and leavers in cycle c that enter the labor force
ρ_c^{hd}	exponent in CES aggregation function for human development	$shr_{f,t}^{labent2}$	share of labor type f of labor force entrants without education
$demot_{c,c'}$	cycle c is the cycle preceding c'	$yrcyc_c$	years in school cycle for each education cycle c
$depr_{f,t}$	depreciation rate for factor f		

Table 4.13 Variables for MDG and education module

$EDUQUAL_{c,t}$	educational quality in cycle *c* in year *t*	$QFACINS_{i,f,t}$	endowment of labor type *f* for institution *i* in *t*
EG_t	government expenditures	$QH_{c,h,t}$	consumption of commodity *c* in *t* by household *h*
$INVVAL_{i,t}$	investment value for institution *i*	$QHA_{a,c,h,t}$	quantity consumed of home commodity *c* from activity *a* by household *h*
$MDGVAL_{mdg,t}$	value for MDG indicator *mdg* in *t*	$QHPC_t$	*per capita* household consumption in *t*
$PQ_{c,t}$	price of commodity *c* in *t*	$QQ_{c,t}$	quantity of goods supplied to domestic market (composite supply)
$PXAC_{a,c,t}$	price of commodity *c* from activity *a*	$SHR^{edu}_{b,c,t}$	share of students in cycle *c* with behavior *b* in *t*
$QENR_{c,t}$	total number of students enrolled in cycle *c* in year *t*	$WF_{f,t}$	economy-wide wage for factor *f* in *t*
$QENR^{old}_{c,t}$	number of old students enrolled in cycle *c* in year *t*	$ZEDU_{b,c,t}$	intermediate variable for educational outcome (defined by constant-elasticity function; entering logistic function)
$QENR^{new}_{c,t}$	number of new students enrolled in cycle *c* in year *t*	$ZMDG_{mdg,t}$	intermediate variable for standard MDGs (4—5—7w—7s) (defined by constant-elasticity function; entering logistic function)

MAMS focuses on the MDGs that typically are most costly and have the greatest interactions with the rest of the economy: universal primary school completion (MDG 2; measured by the net primary completion rate), reduced under-5 and maternal mortality rates (MDG 4 and 5) and increased access to improved water sources and basic sanitation (part of MDG 7).[38] The poverty MDG (MDG 1) is not targeted given the absence of tools (in MAMS and in most real-world, developing-country contexts) that policy makers realistically could use to fine-tune poverty outcomes.

MDG outcomes depend on government and private sector provision of MDG-related services as well as demand conditions for those services. Table 4.15 lists the determinants that have been included in a typical country application of MAMS, identified on the basis of available evidence, preferably sector studies underpinned by

[38] Implicitly, when MDG 4 and 5 are achieved, the expansion in health services and other determinants may be sufficient to achieve MDG 6 (to halt and reverse the spread of HIV/AIDS, malaria and other diseases). MDG 3 (elimination of gender disparity in education and empowering women) was not addressed due to data issues. However, note that, if MDG 2 is achieved, gender equality is achieved in primary education.

Table 4.14 Equations for MDG and education module

(4.67)	$QHD_{c,i,t} = \sum_{c' \in C} QG_{c',t} \Big\vert_{\substack{(c,c') \in MCHDC \\ i \in INSG}} + \sum_{c' \in C} (QQ_{c',t} - QG_{c',t}) \Big\vert_{\substack{(c,c') \in MCHDC \\ i \in INSNGAGG}}$ $\begin{bmatrix} \textit{demand for HD (MDG or educ)} \\ \textit{service c by aggregate demander i} \end{bmatrix} = \begin{bmatrix} \textit{sum of gov and non} - \textit{gov} \\ \textit{demand for HD service} \end{bmatrix}$	$c \in C$ $i \in I$ $t \in T$	Separation of human development (HD) services into government and non-government
(4.68)	$QHDAGG_{c,t} = \alpha_c^{\mathrm{hd}} \cdot \sum_{i \in INS} (\delta_{c,i}^{\mathrm{hd}} \cdot QHD_{c,i,t}^{-\rho_c^{\mathrm{hd}}})^{-\frac{1}{\rho_c^{\mathrm{hd}}}} \Big\vert_{c \in CHDCES}$ $+ \sum_{i \in INS} QHD_{c,t,g} \Big\vert_{c \in CHDPRFSUB}$ $\begin{bmatrix} \textit{aggregate demand for HD} \\ \textit{(MDG or educ) service ac} \end{bmatrix} = \begin{bmatrix} \textit{aggregation of HD demand as imperfect substit}- \\ \textit{utes (CES) or as perfect substitutes (summed)} \end{bmatrix}$	$c \in C$ $i \in I$ $t \in T$	Aggregation of human development (HD) services (i.e. MDG and education)
(4.69)	$QHPC_t = \frac{\sum_{c \in C} \sum_{h \in H} PQ_c^0 \cdot QH_{c,h,t} + \sum_{a \in A} \sum_{c \in C} \sum_{h \in H} PXAC_{a,c}^0 \cdot QHA_{a,c,h,t}}{pop_t^{\mathrm{tot}}}$ $\begin{bmatrix} \textit{real household} \\ \textit{conumption per capita} \end{bmatrix} = \begin{bmatrix} \textit{total household consumption at base}- \\ \textit{year prices divided by total population} \end{bmatrix}$	$t \in T$	Real household consumption *per capita*

(*Continued*)

Table 4.14 Equations for MDG and education module—cont'd

	Equation	Domain	Description
(4.70)	$EDUQUAL_{c,t} = \dfrac{QHDAGG_{c,t}}{\sum_{g\in G} QENR_{c,g,t}} \Big/ \dfrac{QHDAGG^{0}_{c}}{\sum_{g\in G} QENR^{0}_{c,g}}$ $\begin{bmatrix} \textit{educational quality} \\ \textit{in cycle } c \textit{ in year } t \end{bmatrix} = \begin{bmatrix} \textit{real services per student} \\ \textit{in cycle } c \textit{ in } t \end{bmatrix} \div \begin{bmatrix} \textit{real services per student} \\ \textit{in cycle } c \textit{ in base} - \textit{year} \end{bmatrix}$	$c\in CEDU$ $t\in T$ $t>1$	Educational quality
(4.71)	$QENR^{old}_{c,g,t} = \sum_{g'\in G \mid (g,g')\in mgg2} SHR^{edu}_{pass,c,t-1}\cdot QENR_{c,g',t-1} + SHR^{edu}_{rep,c,t-1}\cdot QENR_{c,g,t-1}$ $\begin{bmatrix} \textit{number old students} \\ \textit{enrolled in cycle } c\textit{, grade } g \textit{ in } t \end{bmatrix} =$ $\begin{bmatrix} \textit{passers from preceding grade} \\ g' \textit{in the same cycle } c \textit{ in } t-1 \end{bmatrix} + \begin{bmatrix} \textit{repeaters from last year still} \\ \textit{enrolled in cycle } c\textit{, grade } g \end{bmatrix}$	$c\in CEDU$ $g\in G$ $t\in T$ $t>1$	Old enrolled students
(4.72)	$QENR^{new}_{c,g,t} = SHR^{edu}_{neting1,c,t-1}\cdot pop^{g1}_{t}\Big\vert_{\substack{(c,g)\in mcgmin \\ c\in CEDUP}} + qenr^{newoth}_{c,g,t}$ $+ \sum_{c'\in C} SHR^{edu}_{cont,c,t-1}\cdot grdcont_{c,c'}\cdot SHR^{edu}_{prom,c',t-1}\cdot \sum_{g'\in G \mid (c',g')\in mcgmax} QENR_{c',g',t-1}\Big\vert_{\substack{(c,g)\in mcgmin \\ c\notin CEDUP}}$ $\begin{bmatrix} \textit{number of new students} \\ \textit{enrolled in cycle } c\textit{, grade } g \textit{ in } t \end{bmatrix} =$ $\begin{bmatrix} (\textit{cohort}) \textit{ students entering} \\ \textit{cycle } c\ (c = \textit{primary})\textit{, grade } 1 \end{bmatrix} + \begin{bmatrix} (\textit{non-cohort}) \textit{ students from outside} \\ \textit{school system entering cycle } c\textit{, grade } g \end{bmatrix}$ $+ \begin{bmatrix} \textit{enrolled in last grade } g \textit{ in preceding } (\textit{non-primary}) \\ \textit{cycle } c' \textit{ in } t-1 \textit{ who were promoted and entered first grade of } c \end{bmatrix}$	$c\in CEDU$ $g\in G$ $t\in T$ $t>1$	New enrolled students

(4.73)

$$QENR_{c,g,t} = QENR^{\text{old}}_{c,g,t} + QENR^{\text{new}}_{c,g,t}$$

$$\begin{bmatrix} \textit{total number enrolled} \\ \textit{in cycle } c, \textit{ grade } g \textit{ in } t \end{bmatrix} = \begin{bmatrix} \textit{enrolled old students} \\ \textit{in cycle } c, \textit{ grade } g \textit{ in } t \end{bmatrix} + \begin{bmatrix} \textit{enrolled new students} \\ \textit{in cycle } c, \textit{ grade } g \textit{ in } t \end{bmatrix}$$

$c \in CEDU$, $g \in G$, $t \in T$, $t > 1$

Total enrollment

(4.74)

$$SHR^{\text{edu}}_{b,c,t} = ext^{\text{edu}}_{b,c} + \frac{\alpha^{\text{edu}}_{b,c}}{1 + EXP(\gamma^{\text{edu}}_{b,c} + \beta^{\text{edu}}_{b,c} \cdot ZEDU_{b,c,t})}$$

$$\begin{bmatrix} \textit{student share with} \\ \textit{behavior } b \textit{ in cycle } c \end{bmatrix} = \begin{bmatrix} \textit{logistic function of intermediate} \\ \textit{behavior variable}(ZEDU_{b,c,t}) \end{bmatrix}$$

$b \in BLOG$, $c \in CEDU$, $t \in T$

Student behavior (logistic function)

(4.75)

$$ZEDU_{b,c,t} = \alpha^{\text{educe}}_{b,c} \cdot (EDUQUAL_{c,t})^{\varphi^{\text{edu}}_{b,c,edu-qual}}$$

$$\cdot \left(\frac{WF_{f-labs,t}}{WF_{f-labn,t}}\right)^{\varphi^{\text{edu}}_{b,c,w-prem}} \cdot \left(\frac{WF_{f-labt,t}}{WF_{f-labs,t}}\right)^{\varphi^{\text{edu}}_{b,c,w-prem}} \cdot MDGVAL_{mdg4,t}^{\varphi^{\text{edu}}_{b,c,mdg4}}$$

$$\cdot \prod_{f \in FCAPGOVINF} \left(\sum_{i \in INS} QFINS_{i,f,t}\right)^{\varphi^{\text{edu}}_{b,c,f}} \cdot QHPC_t^{\varphi^{\text{edu}}_{b,c,qhpc}}$$

$$\begin{bmatrix} \textit{intermediate variable for student} \\ \textit{share with behavior } b \textit{ in cycle } c \end{bmatrix}$$

$$= \begin{bmatrix} \textit{exogenous} \\ \textit{trend value} \end{bmatrix} \cdot \begin{bmatrix} \textit{influence of: education quality (service per student);} \\ \textit{wage premia (for } c \leq \textit{ secondary and } c \geq \textit{ tertiary, respectively;} \\ \textit{student health (proxied by MDG4); of infrastructure; and per capita house} \end{bmatrix}$$

$b \in BLOG$, $c \in C$, $t \in T$

Student behavior (constant-elasticity function defining intermediate variable)

(*Continued*)

Table 4.14 Equations for MDG and education module—cont'd

(4.76)	$$SHR^{\mathrm{edu}}_{b,c,t} = \left(1 - \sum_{\substack{b' \in \\ BLOG} \middle\| \substack{(b,b') \in \\ MBB}} SHR^{\mathrm{edu}}_{b',c,t}\right) \frac{SHR^{\mathrm{edu0}}_{b,c}}{\sum_{\substack{b' \in \\ BRES} \middle\| \substack{(b,b') \in 2 \\ MBB2}} SHR^{\mathrm{edu0}}_{b',c}}$$ $$\begin{bmatrix} \textit{student share} \\ \textit{with behavior} \\ \textit{b in cycle c} \end{bmatrix} = \begin{bmatrix} \textit{residual value (1 less sum} \\ \textit{of shares for related} \\ \textit{elements in BLOG)} \end{bmatrix} \cdot \begin{bmatrix} \textit{initial share of b in} \\ \textit{total shares for related} \\ \textit{residual elements} \end{bmatrix}$$	$b \in BRES$ $c \in CEDU$ $t \in T$	Student behavior (defined residually, given left-hand side of the logistic function for education)
(4.77)	$$MDGVAL_{mdg2,t} = SHR^{\mathrm{edu}}_{neting1,cedup,t} \cdot SHR^{\mathrm{edu}}_{prom1,cedup,t}\, yrcyc_{cedup}$$ $$\begin{bmatrix} \textit{primary school} \\ \textit{net completion rate} \end{bmatrix} = \begin{bmatrix} \textit{product of current primary rates} \\ \textit{of net intake and promotion} \end{bmatrix}$$	$t \in T$	MDG 2
(4.78)	$$labpartrat_t = \frac{\sum_{\substack{i \in INS \\ f \in FLAB}} QFINS_{i,f,t}}{pop^{\mathrm{lab}}_t - \sum_{c \in CEDU} \sum_{g \in G \middle\| \substack{(c,g) \in \\ mcglab}} QENR_{c,g,t}}$$ $$\begin{bmatrix} \textit{labor force} \\ \textit{participation rate} \end{bmatrix} = \frac{[\textit{labor force}]}{[\textit{population in labor force age—enrollment in labor force age}]}$$	$t \in T$ $t > 1$	Labor force participation rate

(4.79)

$$
\begin{aligned}
& QFINS_{i,f,t} = shif^{0}_{i,f,t} \\
& [\text{endowment of labor type } f \text{ for institution } i \text{ in } t] = [\text{share of } i \text{ in labor type } f] \\
& \cdot \{ (1 - depr_{f,t-1} \cdot QFLABADJ_{t}) \cdot \sum_{i' \in INS} QFINS_{i',f,t-1} \\
& \cdot \{ [\text{non} - \text{retired labor from previous year}] \\
& + \sum_{c,c' \in C \,\middle|\, \substack{(f,c) \in MFC \\ c \notin CEDUT}} demot_{c,c'} \cdot shr^{\text{labent}}_{c,t} \\
& \cdot SHR^{\text{edu}}_{grdexit,c',t-1} \cdot \sum_{c \in C \,\middle|\, \substack{(c,g) \in \\ mcgmax}} SHR^{\text{edu}}_{prom,c,t-1} \cdot QENR_{c,g,t-1} \\
& + \left[\begin{array}{l} \text{enrolled in non-tertiary cycle in } t-1 \text{ who were promoted from} \\ \text{their last grade, exit the school system, and enter labor force in } t \end{array} \right] \\
& + \sum_{c \in C \,\middle|\, \substack{(f,c) \in MFC \\ c \in CEDUT}} \left(shr^{\text{labent}}_{c,t} \cdot \sum_{g \in C \,\middle|\, \substack{(c,g) \in \\ mcgmax}} SHR^{\text{edu}}_{prom,c,t-1} \cdot QENR_{c,g,t-1} \right) \\
& + [\text{enrolled in tertiary cycle in } t-1 \text{, who graduate and enter the labor force in } t] \\
& + \sum_{c \in C \,\middle|\, \substack{(f,c) \\ \in MFC}} demot_{c,c'} \cdot shr^{\text{labent}}_{c' t} \cdot \sum_{g \in G \,\middle|\, \substack{(c',g) \in \\ mcglab}} SHR^{\text{edu}}_{dropout,c',t-1} \cdot QENR_{c',g,t-1}) \\
& + [\text{enrolled in school in } t-1 \text{, who drop out and enter labor force in } t \text{ at next lower level } c] \\
& + shr^{\text{labent2}}_{f,t} \cdot \left(pop^{\text{labent}}_{t} - \sum_{c \in CEDU} \sum_{g \in GRD \,\middle|\, \substack{(c,g) \in \\ mcglabent}} QENR_{c,g,t} \right) \Bigg\} \\
& + [\text{entrants from outside educational system who are of labor} - \text{force age}] \}
\end{aligned}
$$

$i \in INS$
$f \in FLAB$
$t \in T$
$t > 1$

Labor supply

(*Continued*)

Table 4.14 Equations for MDG and education module—cont'd

(4.80)	$MDGVAL_{mdg,t} = ext^{mdg}_{mdg} + \dfrac{\alpha^{mdg}_{mdg}}{1 + EXP(\gamma^{mdg}_{mdg} + \beta^{mdg}_{mdg} \cdot ZMDG_{mdg,t})}$ $\begin{bmatrix} MDG \\ value \end{bmatrix} = \begin{bmatrix} logistic\ function\ of\ intermediate \\ MDG\ value(ZMDG_{mdg,t}) \end{bmatrix}$	$mdg \in MDGSTD$ $t \in T$	MDG 4, 5, 7w and 7s (logistic function)
(4.81)	$ZMDG_{mdg,t} = \alpha^{mdgce}_{mdg} \cdot \prod_{\substack{cmdg \in \\ CMDG}} \left(\sum_{c \in C \mid (cmdg,c) \in MCM} \dfrac{QQ_{c,t}}{pop^{tot}_{t}} \right)^{\varphi^{m}_{mdg,cmdg}} \cdot \prod_{\substack{f \in \\ FCAPGOVINF}} \left(\sum_{i \in INS} QFINS_{i,f,t} \right)^{\varphi^{m}_{mdg,f}} \cdot \left(\prod_{\substack{mdg' \in \\ MDGSTD}} MDGVAL_{mdg',t}^{\varphi^{m}_{mdg,mdg'}} \right) \cdot QHPC_{t}^{\varphi^{m}_{mdg,hhdconspc}}$ $\begin{bmatrix} intermediate \\ variable\ for \\ MDG\ 4\ and\ 5 \end{bmatrix} = \begin{bmatrix} exogenous \\ parameter \end{bmatrix} \cdot \begin{bmatrix} influence\ of:\ real\ value\ for\ services \\ per\ capita;\ level\ of\ infrastructure; \\ water\ and\ sanitation\ MDGs; \\ household\ consumption\ per\ capita \end{bmatrix}$	$mdg \in MDGSTD$ $t \in T$	MDG 4, 5, 7w and 7s (constant-elasticity function defining intermediate variable)

Table 4.15 Determinants of non-poverty MDGs

MDG	Service delivery	Household consumption *per capita*	Wage incentives	Public infrastructure	Other MDGs
2: Primary education	×	×	×	×	4
4: Under-5 mortality	×	×		×	7w, 7s
5: Maternal mortality	×	×		×	7w, 7s
7w: Access to safe water	×	×		×	
7s: Access to basic sanitation	×	×		×	

econometric analysis and subject to the constraints of an economy-wide model like MAMS (including the fact that it is difficult to include finely disaggregated actions, like increasing coverage of certain types of vaccinations).[39] Beyond *per capita* real service delivery (either public or a combination of public and private), the determinants include other MDGs (e.g. better access to water and sanitation may improve health outcomes — MDG 4 and 5), as well as public infrastructure, *per capita* household consumption and wage incentives (through the ratio of labor wages of different educational levels). Other determinants should be added when evidence suggests that the effect is significant during the time frame of the analysis. One possible candidate is the impact of education on health, which may be important in long-run analyses if the educational status of the population changes significantly. The MDG and education functions may be seen as "production functions" with inputs at a level of aggregation that is similar to other parts of a typical MAMS database; while this is convenient considering the objective of applying MAMS in settings without more detailed information, it means that MAMS is not a substitute for disaggregated analysis of human development policies, which often would have to consider more additional determinants.

In the equations of this module, the treatment of the education MDG (2) is separate from the treatment for the remaining MDGs (4, 5, 7w and 7s) since, rather than targeting

[39] Econometric analysis for several countries in Latin America show that the relationships between the determinants and the non-poverty MDGs in the MAMS model tend to hold from a statistical point of view. Kamaly (2006) provides examples of the literature on health and education whose findings, although sometimes contradictory, show broad support also in sub-Saharan Africa for the inclusion of the determinants referred to in Table 4.15. Lofgren (2010) reviews the cross-country literature on MDG and education determinants.

MDG 2 directly, the model defines (and may target) specific educational behavioral outcomes that jointly determine the value for MDG 2.

4.4.2.1 Definitions for the MDG and education block

The first three equations define arguments that enter both education and MDG functions. Equations (4.67) and (4.68) in Table 4.14 define aggregate human development services (which include both MDG and education services). For each service type, Equation (4.67) separates demand into two aggregates − government and non-government, according to who is paying for the service. Typically, services paid for by the government (non-government) are also supplied by a government (non-government) activity, but this is not necessarily the case. Equation (4.68) generates an economy-wide aggregate (which below is fed into the determination of MDG and education outcomes), permitting two alternative assumptions: services paid for by government and non-government are perfect substitutes (simply summed) or imperfect substitutes (according to a CES function). Equation (4.69) defines average real household consumption *per capita* ($QHPC_t$) as total household consumption (both marketed and home commodities) at base-year prices divided by total population.

4.4.2.2 Education block

The educational component consists of Equations (4.70)−(4.79) in Table 4.14. It is disaggregated by cycle (with three cycles as a typical level of disaggregation). For each cycle, educational quality ($EDUQUAL_{c,t}$) is defined as the ratio between real services per student (aggregated services divided by total enrolment) in the current year and in the base year, i.e. in the base year, educational quality is indexed to one, Equation (4.70).

Within any cycle, the model endogenizes the following aspects of student behavior (or outcomes):

- The shares of the enrolled that are promoted from their current grade, drop out or repeat the grade next year (referred to as *prom*, *dropout* and *rep*). The sum of these shares is unity, i.e. during the school year, a student must either be promoted, drop out or become a repeater (this applies to each grade and for each cycle as a whole). Note that the term "*prom*" throughout this paper and the model refers both to students who successfully complete a grade and continue to a higher grade within the cycle and to students who successfully finish the last year of a given education cycle (and thus graduate).
- The shares among the promotees from their current grade (*prom*) who graduate from their current cycle (*grdcyc*) or continue to a higher grade within this cycle (*contcyc*). In terms of shares: $grdcyc + contcyc = prom$.
- The shares among cycle graduates who exit the school system (*grdexit*) or continue to next cycle (*grdcont*). The sum of these shares is also unity. For graduates from the last cycle, the share of those who exit is unity.
- The share of the cohort of the first year in primary school that enters school (*neting1*).

Drawing on the above information, we can define the number of enrolled students by cycle, grade and year. Note that, as a simplification, the rates of promotion, dropout and repetition are not grade-specific, but averages at the level of each cycle. Equation (4.71) defines the number of "old" enrolled students (i.e. those who were enrolled in the same cycle last year) as the sum of those who: (i) Continue within the cycle after successful completion of an earlier grade and (ii) repeat the grade they were in last year. The number of "new" enrolled students is defined in Equation (4.72) as the sum of (i) cohort entrants (only for the first primary cycle), (ii) other, non-cohort entrants entering any cycle in the educational system and (iii) graduates from the relevant earlier cycle last year who chose to continue.[40] The total number of enrolled students by cycle, grade and year is the sum of old and new students, Equation (4.73).

Equations (4.74)−(4.78) model the share variables that identify different aspects of student behavior. For each cycle, a logistic function, Equation (4.74) defines $SHR^{\mathrm{edu}}_{b,c,t}$, the shares for first year in-cohort entry, for promotees from the current grade and for promotees from the last grade who decide to continue to next cycle (i.e. *neting1*, *prom* and *grdcont*, the elements of the set *BLOG*).[41] The logistic form was selected since it makes it possible to impose extreme values for the function (e.g. for education it is a maximum of one − representing 100%) and to incorporate extraneous information about elasticities and conditions under which target values are achieved. Another advantage is that it allows for segments of increasing and decreasing marginal returns to improvements in the determinants of educational behavior. The only endogenous variable in the logistic function ($ZEDU_{c,d,t}$), is defined in a constant-elasticity function, Equation (4.75) as determined by: (i) Educational quality, (ii) wage incentives, defined as relative wage gains from continued schooling (i.e. the relative wage gain that students can achieve if they complete a cycle that is sufficiently high to enable them to climb to the next higher level in the labor market), (iii) the under-5 mortality rate (a proxy for the health status of the school population); (iv) the size of the infrastructure capital stock, and (v) household consumption *per capita*.[42] Figure 4.2 illustrates the logistic functional form

40 This category includes non-cohort entrants to the first primary year of primary school (who may represent a significant number during a transitional period of primary school expansion). It may also include immigrants from other countries.

41 The α and β parameters in the logistic functions, Equations (4.74) and (4.80) are calibrated so that: (i) Under base-year conditions, the left-hand side variables (showing student behavior shares or MDG values) will replicate base-year values and (ii) under conditions for achieving target values for MDG and education indicators derived from supporting studies, the left-hand side variables will take on values indicative of or compatible with reaching these targets.

42 In the computer program, Equations (4.75) and (4.81) (constant-elasticity functions defining intermediate variables for educational behavior or MDG achievement) are more complex in two respects: (i) The terms that are raised to exponents, which represent elasticities, are all divided by base-year values. This formulation was preferred given our desire to simulate scenarios with changes in elasticities but without any changes in simulated base-year values for left-hand-side variables. (ii) For the element *grdcont* $\in$ *BLOG*, the decision to continue to the next education cycle depends on the values for the right-hand side variables that correspond to the next cycle.

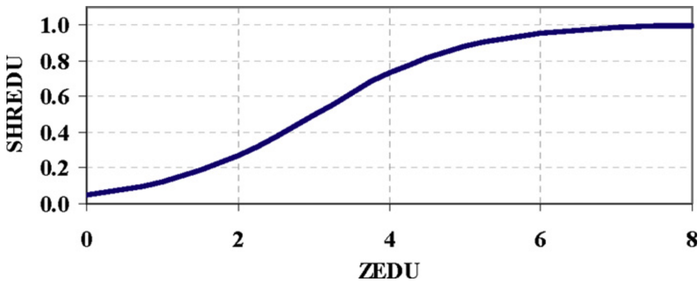

Figure 4.2 Logistic function for education.

for education. The observed base-year value for $SHR^{edu}_{b,c,t}$ is generated at the base-year value for $ZEDU_{c,d,t}$. The parameters of the function have to be defined such that the maximum share is one, the base-year elasticities of $SHR^{edu}_{b,c,t}$ with respect to each determinants of $ZEDU_{c,d,t}$ is replicated and, under values for the determinants of $ZEDU_{c,d,t}$ identified in the database, a target level for $SHR^{edu}_{b,c,t}$ is realized. In terms of the algebra, the parameters in Equations (4.74) and (4.75) are selected as follows:

- The parameter $ext^{edu}_{b,c}$ shows the extreme (maximum) value (here unity) to which the behavior share should converge as the value of the intermediate variable approaches infinity.
- The parameter $\alpha^{edu}_{b,c}$ is calibrated so that, under base-year conditions, the behavioral share replicates the base-year value.
- The parameters $\beta^{edu}_{b,c}$ and $\varphi^{edu}_{b,c,ac}$ are calibrated so that the two equations: (i) Replicate the base-year elasticities of the behavioral share ($SHR^{edu}_{b,c,t}$) with respect to the arguments of the constant-elasticity function and (ii) achieve a behavioral target (e.g. a share very close to one for *neting1*, the share of the relevant age cohort that enters first grade) under a set of values for the arguments of the constant-elasticity function that have been identified by other studies.
- The value of the parameter $\gamma^{edu}_{b,c}$ determines how the base-year point on the logistic function is positioned relative to the inflection point (where the curve switches from increasing to decreasing marginal returns as the determinants of educational behavior improve).

Equation (4.75) is calibrated so that, in the base year (under base-year conditions), $ZEDU_{b,c,t} = SHR^{edu0}_{b,c}$; note that the left-hand-side term enters the denominator of the second term in Equation (4.74).

Drawing on the shares defined in the preceding equations, the shares for repeaters, dropouts and cycle graduates exiting from the school system (*rep*, *dropout* and *grdexit*; elements in the set *BRES*) are defined residually, Equation (4.76). The formulation considers the fact that, as noted above, selected shares have to sum to unity. If more than one variable in *BRES* has to be adjusted in relation to one or more elements in *BLOG* (as is the case for the adjustment of shares for repeaters and dropouts in response to changes in the share of promotees), then all adjusted variables are scaled up or down by the same factor.[43]

Alternative indicators may be used to define MDG 2. It is here, Equation (4.77) defined as the net completion rate expressed as a period measure, i.e. the share of the population that enters the first primary grade in the current year that would graduate on time given the current rates of net entry (*neting1*) and promotion (*prom*), i.e. the measure uses current rates assuming that the rate of promotion of the current year prevails throughout their primary cycle (typically the current year and five more years).[44,45]

The labor force participation rate is defined as the labor force ($QFINS_{i,f,t}$) divided by the population in labor force age that is not enrolled in secondary and tertiary cycles, Equation (4.78).[46] Institutional labor endowments ($QFINS_{i,f,t}$ for labor) are defined as the sum of the following components, Equation (4.79): (i) Remaining labor from the preceding year, (ii) new labor force entrants among students who exited from the school system in the previous year (with separate terms for non-tertiary graduates, tertiary graduates and dropouts) and (iii) new labor force entrants from the non-student population who reach the age at which they, to the extent that they seek work, become part of the labor force. Depending on their highest completed grade, the new labor force entrants are allocated to a specific labor category.

4.4.2.13 Non-education MDG block

The treatment underlying MDG 4, 5, 7w and 7s is similar but less complex. For these, a logistic function directly defines the MDG indicators as a function of an intermediate variable that is defined in a related constant-elasticity function, see Table 4.14; Equations (4.80) and (4.81). The values for the parameters ext^{mdg}_{mdg}, α^{mdg}_{mdg}, β^{mdg}_{mdg} and $\varphi^{mdg}_{mdg,ac}$ are defined following the same principles as the corresponding parameters in the logistic and constant-elasticity functions for education. The arguments of the constant-elasticity function are similar except for that the relevant service supply is expressed in *per capita* form (not per enrolled student).

43 The equation is formulated so that it works for cases with one or more than one term in any of the sums over related shares (defined by the mappings *MBB* and *MBB2*) in either of the sets *BRES* and *BLOG*.

44 Given that we do not generate separate promotion rates for students in the relevant cohort (as opposed to students outside this cohort), we assume that the rates for in-cohort students are identical to the over-all rates for students in the cycle. In order to get a rate of 100%, the rates of net intake and promotion must both be 100%. In other words, in order for 100% of the cohort to complete the primary cycle on time, it is necessary that all of them enter at the time of their first year and then that all manage to pass each year (i.e. successfully complete each grade) up to the final year of the cycle.

45 Many MAMS applications have used a cohort variant of the net completion rate, i.e. the share of the population of theoretical primary graduation age that graduates in the current year. This is more data-demanding — assuming a six-year cycle, it requires information about the net intake rate six years earlier and the promotion rates in each year since then.

46 It is assumed that, as an acceptable approximation, students in secondary and above are in labor force age. If not, this definition should be adjusted.

4.4.3 Poverty module and alternative approaches

Poverty and inequality indicators can be computed on the basis of MAMS simulation results either through the built-in MAMS poverty module or through microsimulation modeling. The MAMS poverty module offers a choice between the following approaches, each of which is linked to the representative households (one or more) that are included in any application database and may use either household income or consumption as its welfare measure:[47]

(i) Constant elasticity of poverty with respect to *per capita* welfare for each model household.[48]

(ii) Log-normal distribution of *per capita* welfare within each model household.

(iii) Distribution of *per capita* welfare within each model household follows a real-world household survey.

Under (i), the poverty module computes the headcount poverty rate; under (ii) and (iii) it also computes the poverty gap, the squared poverty gap and the Gini coefficient.

As described in Section 4.5, if approach (i) or (ii) is selected, then the analyst has to provide data for each model household (or for an aggregation of model households); if approach (iii) is selected, microdata from a household survey is also needed. In all three cases, the change in *per capita* welfare (household income or consumption) derived from MAMS is used as an input (the "linking aggregate variable") in the module that computes poverty and inequality indicators. In case (i), the constant growth elasticity of poverty approach, the change in welfare *per capita* for each model household is used to estimate the change in the corresponding and national poverty rates. In case (ii), the log-normal approach, a synthetic household survey is generated based on a log-normal distribution with mean and standard deviation derived from the user-supplied data. Once the synthetic household survey is generated, poverty and inequality computations follow an "arithmetic microsimulation" computation in which changes in welfare *per capita* of each model household are used to estimate the counterfactual distribution of *per capita* welfare. Then, poverty and inequality indicators are easily computed. Case (iii), the real-world household survey approach, applies the second and third steps of the approach in case (ii) to microdata from a household survey.

The MAMS poverty module has the advantage of quickly generating poverty and inequality results that are fully integrated with the MAMS simulations. Among its three built-in approaches, the first, a growth elasticity of poverty, is by far the simplest but also most likely to be misleading; empirically, it is unlikely that the poverty elasticity of growth remains constant if *per capita* welfare changes significantly

47 For a discussion of the representative household approach, see Lofgren *et al.* (2003) and Agénor *et al.* (2004).

48 The use of other distributions (like the β distribution) seems less compelling since they are dominated by the survey approach and require econometric estimation.

(see, e.g. Bourguignon, 2003).[49] The remaining two approaches — (ii) and (iii) — are both based on the assumption that the distribution of welfare within the population represented by each model household does not change over time. Whether this assumption detracts from the empirical value of the analysis may depend on the disaggregation of the MAMS database, especially income sources and households; disaggregation into multiple households that are homogeneous in terms of the income sources of the database may be preferable. Whether this assumption represents a drawback may also depend on whether it is reasonably well understood how within-group distributions are likely to change; if it is not well understood, then the assumption of an unchanging distribution may be appropriate. Among approaches (ii) and (iii), the latter may be preferred since the assumption reflects the observed distribution of each household group; however, it is more data-intensive and computations may be more time-consuming (depending on survey size). The second alternative, a log-normal distribution, demands less data and computation time. It is widely accepted that it provides a good approximation for within-country income and consumption distributions (Bourguignon, 2003; Easterly, 2009); however, for any model household, it is dominated by the third approach.

Alternatively, poverty and inequality results can be generated using a microsimulation model (see Bourguignon *et al.*, 2008; Bussolo and Cockburn, 2010), either top-down, feeding CGE simulation results to a separate household model, or integrated, with the household model built directly into MAMS. In addition, the top-down approach may either use microsimulations based on randomized allocation (simpler) or based on econometric analysis to determine wages and/or sector of work. For example, the microsimulation methodology described in Vos and Sanchez (2010), which is based on randomized allocation, has been used in conjunction with MAMS in a large number of applications (see Section 4.7). The use of a microsimulation model has the advantage of relying on less restrictive assumptions but adds further complexity and is more demanding in terms of data and computation time. The empirical gain from using microsimulation analysis may critically depend on the extent to which the disaggregation of income sources in the micro database matches that of the CGE model.

4.5 MAMS DATABASE

As noted, for each application, the bulk of the MAMS database resides in one or two Excel files; one includes data needed both for the core and MDG versions and a second

[49] As noted by Easterly (2009, pp. 28—29): (i) Empirical cross-country analysis indicates that the higher the initial poverty rate, the lower the poverty elasticity of growth and (ii) the absolute value of the simulated poverty-elasticity of growth with a log-normal distribution is inversely related to the initial poverty rate and positively related to *per capita* income.

file data that only is needed for the MDG version.[50] The size of the database of a MAMS application varies widely, not only depending on model version (core or MDG), but also on the extent to which the database is disaggregated. In this section we will briefly survey the data requirements and highlight key steps and procedures involved in constructing the database.[51]

4.5.1 Data requirements

4.5.1.1 SAM

The basic accounting structure and much of the underlying data of MAMS, like other CGE models, is derived from a SAM; unless the database imposes aggregation of selected SAM accounts, the model will follow the disaggregation of the SAM.[52] Most features of a SAM for MAMS are familiar from SAMs used for other models. However, a MAMS SAM has some unconventional features related to the explicit treatment of financial flows and, for the MDG version of MAMS, a relatively detailed disaggregation of sectors (activities and commodities; government and, often, non-government) for MDG- and education-related services. Table 4.16 shows a stylized and aggregated version of a SAM designed for MAMS. Table 4.17 shows the notation that is used.[53]

As in a typical SAM, the activity accounts represent the entities that carry out production, allocating sales receipts to intermediates, factors (value-added) and (indirect) taxes. The commodities are activity outputs, either exported or sold domestically and imports. The row entries of the commodity accounts represent payments from commodity demanders; the column entries show payments to the suppliers and indirect taxes (tariffs on imports and/or a sales tax on domestic sales irrespective of whether the commodity is of foreign or domestic origin). For the MDG version of MAMS, the accounts for the government activity and commodity are disaggregated by function, matching the requirements for the analysis of the MDGs and the educational system. In

50 In addition, MAMS simulations (other than the reference simulation) are defined in a third Excel file; it is not discussed here, but could also be considered as part of the database.

51 The MAMS User Guide (Lofgren, 2011) provides a detailed explanation of the data required and suggests procedure for generating required data.

52 For background on SAMs, see, e.g. Round (2003) and Pyatt and Round (1985).

53 The SAMs in applied databases are more disaggregated. For the core version of MAMS, the only *required* change in the SAM of Table 4.16 is the disaggregation of the tax account into separate accounts for direct, import, export, value-added and other domestic indirect taxes (of course, in some of the applications, some of these tax types may not exist). For the MDG version of MAMS, the accounts for government activities, commodities and investment accounts are split by government function. Irrespective of model version, the SAM (and MAMS) may also include accounts and entries representing home consumption and transactions costs of commodity marketing (disaggregated into importation, exportation and domestic sales). For details, see Lofgren *et al.* (2002, pp. 3–7). In the SAM, any activity may sell (and produce) multiple commodities while any commodity may be sold by multiple activities.

Table 4.16 Stylized macro SAM for MAMS

	act-prv	act-gov	com-prv	com-gov	f-lab	f-capprv	hhd	gov	row	taxes	interest	cap-hhd	cap-gov	cap-row	inv-prv	inv-gov	dstk	Total
act-prv			output				cons		exports									
act-gov	interm	interm		output				cons										
com-prv															inv	inv	dstk	
com-gov																		
f-lab	va	va																
f-capprv	va								yrow									
hhd					va	va		trnfr	trnfr		int-dom							
gov							trnfr		trnfr	taxes								
row			imports			va	trnfr	trnfr			int-row							
taxes	taxes		taxes				taxes											
int-dom							int-row	int-dom										
int-row								int-row										
cap-hhd							sav							bor				
cap-gov								sav				bor		bor				
cap-row									sav									
inv-prv												inv		inv				
inv-gov													inv					
dstk												dstk	dstk					
Total																		

Table 4.17 Accounts and cell entries in stylized macro SAM for MAMS

Account	Explanation	Cell entry	Explanation
act-prv	Activity—private production	bor	Borrowing
act-gov	Activity—government production	cons	Consumption
com-prv	Commodity—private production	dstk	Stock change
com-gov	Commodity—government production	exports	Exports
f-lab	Factor—labor	imports	Imports
f-capprv	Factor—private capital	int-dom	Interest on domestic government debt
hhd	Household	int-row	Interest on foreign debt
gov	Government	interm	Intermediate inputs
row	Rest of world	inv	Investment (gross fixed capital formation)
taxes	Taxes—domestic and trade	output	Production
int-dom	Interest on domestic debt	sav	Savings
int-row	Interest on foreign debt	taxes	Taxes (direct and indirect)
cap-hhd	Capital account—household	trnsfr	Transfers
cap-gov	Capital account—government	va	Value added
cap-row	Capital account—rest of world	yrow	Factor income from rest of world
inv-prv	Investment—private capital		
inv-gov	Investment—government capital		
dstk	Stock change		

particular, these government accounts usually include: primary, secondary and tertiary education; health; water and sanitation; infrastructure (one or more); and other government. The accounts for the non-government activity and commodity are flexible, depending on the purpose of the analysis and data availability and when relevant often include MDG- and education-related sectors.

The row entries of the factor accounts in the SAM indicate that they earn value-added from domestic production activities and, for private capital, income from the rest of the world (this is less common for labor since it only applies to income from abroad for workers resident in the country of the SAM). In the factor columns, value-added is distributed to the owners of the factors.[54] The MDG version requires

54 In addition to the current entries, it is not uncommon that the government owns part of private capital and earns part of its value-added.

labor to be disaggregated by educational achievement, typically into three segments with the following achievements: less than completed secondary, completed secondary, completed tertiary. MAMS is designed to have a single factor (and SAM account) for private capital (i.e. capital used in activities that are not part of the functions of the general government).[55] MAMS includes one type of government capital per government activity (i.e. the activities that are part of the functions of the general government). However, typically, government capital does not earn value-added and, given this, it is not represented in the SAM. Lastly, the SAM may also include other optional factors, such as land or other natural resources.

The SAM includes three institutions: household, government and rest of world.[56] The household may be disaggregated further. Each institution has a current account and a capital account linked to investment accounts and the capital accounts of other institutions. This treatment is significantly different from the more common treatment where savings and investments are handled by a unified institutional account.

In the rows of their current accounts, these institutions receive value-added, transfers from other institutions, interest (for households and rest of world), taxes (for the government) and payments for the imports of the SAM country (for the rest of the world). Along their columns, the outlays of the institutions are allocated to commodity purchases (consumption for the household and the government; and the exports of the SAM country for the rest of the world), direct taxes (for the household), interest payments (for indebted institutions) and savings. It is also possible to include one or more additional institutions that carry out the functions of an off-budget donor or a non-governmental organization (NGO) — receiving transfers from other institutions (typically the rest of the world and/or the government) and using these resources to purchase services related to health and/or education. The tax account (which in MAMS applications is disaggregated according to tax type) passes on its receipts from activities, commodities and households (along the row) to the government (along the column).[57]

55 While this in some contexts may be a drawback, it has the advantage of removing the need to model how the endowments and investments of different institutions (households, government and the rest of the world) are allocated across different private capital types (perhaps disaggregated by sector); this is a key advantage given limited knowledge of this distribution and of the mechanisms that determine how it evolves over time.

56 MAMS does not separate enterprises from other domestic institutions. In the SAM, these would have been linked to factors (enterprises receive factor incomes, reflecting their ownership of non-labor factors), "other" institutions (direct tax payments and transfers reflecting institutional ownership of the enterprise) and enterprise capital accounts (which spend on investments). In the database, these "other" institutions (primarily households) directly receive the factor transfers while assuming the savings and direct tax payments that otherwise would have been done by the enterprises. Other SAM payments are not affected.

57 The SAM and MAMS may also include direct taxes levied on factor incomes (represented by payments from factor accounts to the tax account).

The (domestic and foreign) interest accounts pass on payment from the (net) borrowers to the (net) lenders. Note that the SAM (and MAMS) only captures interest payments (and related debts) of domestic institutions to the rest of the world and of the government to households. It does not capture interest payments and debts linking domestic non-government institutions.[58]

For each institutional capital account, the receipts are savings (from the current account of the same institution) and net borrowing from the capital accounts of selected other institutions (for the government from the rest of the world and the household; for the household, from the rest of the world). In addition to lending to (funding the net borrowing of) selected institutions, the outlays of the institutional capital accounts include investments of two types: payments to private and government investment accounts (one investment account per capital stock) representing gross fixed capital formation; and payments to the account for stock changes. The payments from the capital account of the rest of the world to the private investment account are FDI. This structure makes it possible for MAMS to capture, in a simple way, the structure of institutional assets (different types of capital and financial claims) and liabilities (financial debt) and how the evolution of this structure differs under alternative scenarios, including the fact that households with more rapid income growth tend to save more and acquire increasing shares of private capital and government debt.

Like most other CGE models, MAMS is a "real" model in which inflation does not matter (only relative prices matter). Given this, there is no significant gain from having a separate monetary sector. Implicitly, in the SAM, the current account of the monetary sector is merged with service activities and commodities while its capital account is merged with the government capital account. Given this, in the merged government capital account, the cells for net government borrowing from other institutions are made up of multiple items. The cell for net borrowing by the government from the household is the sum of (i) net direct borrowing by government from household (net sales of government bonds on which the government pays interest) and (ii) net increases in the claims of the household sector on the monetary sector (the differences between changes in broad money holdings and monetary sector credit to the household). In MAMS (but not in the SAM), the two items in this cell are treated separately, making it possible to consider the fact "(i)" gives rise to interest payments and a debt whereas "(ii)" is a grant to the government, providing it with "seignorage" (as the one who spends this new money first). The cell for net borrowing by government from the rest of the world is the difference between (i) net direct borrowing by the government from the rest of the world and (ii) the increase in foreign

58 The decision not to include these financial links reflects the context-specific assessment that the benefits from this extension (in the form of insights) fall short of the costs (in the form of additional data and complexity).

exchange reserves. In MAMS, these two items are not treated separately.[59] While this treatment remains simple, it captures the important fact that the government, by means of money creation, appropriates part of private savings. Given the fact that the model does not consider effects of and private sector responses to high general inflation, MAMS should not be used for scenarios under which the resources obtained via the monetary sector are so large that inflation would accelerate. The assessment of what is a prudent upper limit for this type of borrowing should draw on expertise on the macroeconomics of each country; a few percent of GDP is often a reasonable figure.

Finally, the investment and stock change accounts transform receipts from institutional capital accounts to commodity demands. For the investment accounts, these payments show the value composition of new capital stocks. The SAM for MAMS includes several investment accounts: one for the private sector and one for each government service; this disaggregation implies that investment by sector of origin and by sector of destination have to be specified. The payments of the stock change account may be negative and should be limited to goods accounts — it is not possible to stock services.

4.5.1.2 Non-SAM data

Beyond the SAM, MAMS also requires other data that is common to most CGE models. Most importantly, the required data includes elasticities to capture: substitutability between factors in production; transformability of output between exports and domestic sales; substitutability between imports and domestic commodities in domestic demand; and responses in household consumption to income changes. The required data also includes (i) debt stocks, such as domestic government debt by non-government institutions and foreign debt by domestic institutions; (ii) data on production factors — stocks, unemployment and employment (disaggregated by activity); and (iii) population data (the base-year population of each representative household, and projections for total population and population in labor-force age (typically 15—64 years old). For private capital, base-year stocks may be defined on the basis of base-year data for rents, profit rates and depreciation rates.[60] For each type of government capital, various devices may

59 Macro consistency matrices that treat the monetary sector as an intermediary often do not have any separate current account for the monetary sector. To verify the statements in this paragraph, note that the balances for government and monetary sector capital accounts can be written as (i) $I_g = S_g + B_{gm} + B_{gh} + B_{gr}$ and (ii) $B_{gm} + B_{hm} + \Delta R = \Delta M$, respectively, where g = government, m = monetary sector, h = household and r = rest of the world, I = investment, B = borrowing by first index from second index, R = foreign reserves and M = broad money. By solving (ii) for B_{gm}, substituting the resulting expression for B_{gm} into (i) and rearranging, we get the merged government—monetary sector capital account: $I_g = S_g + (\Delta M - B_{hm}) + B_{gh} + (B_{gr} - \Delta R)$, where the capital account payments to the merged government—monetary sector from the household and the rest of the world are $(\Delta M - B_{hm}) + B_{gh}$ and $(B_{gr} - \Delta R)$, respectively. For more details, see Agénor (2004, pp. 11—22), Rao and Nallari (2001, pp. 25—32, 176 and 168) and Barth and Hemphill (2000, pp. 71—74 and 101—106).

60 The following formula is used to define the base-year private capital stock: $qfcap = samrent/(netprfrat + deprrat)$, where $qfcap$ = the stock, $samrent$ = total VA to private capital in SAM, $netprfrat$ = the net profit rate (in decimal form) and $deprrat$ = the depreciation rate (also in decimal form).

be used to approximate base-year stocks. The MAMS default is to define these stocks on the basis of historical data on service growth, investments, depreciation rates and the assumption that the capital stock over time has grown at the same rate as real services. Alternatively, government capital stocks may be defined using the perpetual inventory method (PIM) or drawing on data on average capital-output ratios (ACORs) for government services.[61] For other factors such as agricultural land and natural resources, base-year stocks can typically be defined so that base-year rents are normalized to unity; data on future stock growth is also needed – as opposed to labor and capital, growth for these factors is exogenous.

The data requirements for the (optional) MAMS built-in poverty module include the headcount poverty rate for an identified year for each representative household or any aggregation of representative households; the base simulation will endogenously generate a poverty line that is calibrated to replicate the observed poverty rate for the identified year. Other representative household-specific data requirements vary depending on the approach that is followed. For the simplest (but least satisfactory approach), the only requirement is the growth elasticity (the elasticity of poverty with respect to changes in real household *per capita* consumption or income). For the log-normal approach, the user has a choice between providing the same elasticity (for the calibration year), the standard deviation of the distribution or the Gini coefficient. In case the real-world household survey approach is selected for poverty and inequality computations, the analyst has to provide microdata on the *per capita* welfare indicator, individual weights and a mapping that indicates to which model household each individual observation in the microdata belongs.

The remaining data requirements are specific to the MDG module of MAMS. This data is due to extensions to include MDG indicators and their determinants, an extended education module and relatively detailed government accounts. Both for education (for each of the three levels) and for the non-education MDGs other than poverty (labeled 4, 5, 7w and 7s), it is necessary to provide data for base-year outcomes. In education, each educational level requires rates for promotion, repetition, dropout and entry (among graduates from the previous cycle, or, in the case of primary education, out of the relevant age cohort). For education, base-year enrollment by cycle and grade and additional population data (identifying age groups relevant to education) are also required. To model how these outcomes change over time, two additional pieces of information are needed. (i) Base-year elasticities, linking outcomes to determinants, are

61 The extent to which estimates of government capital stocks matter depend on the details of the model; while estimates tend to be highly approximate, it is nevertheless empirically important to include these in order to make it possible to capture links between service expansion and required investments as well as links between infrastructure investments and required spending on operations and maintenance.

required for MDG and education rates (other than repetition and dropout rates, which are scaled residuals) with respect to a set of explanatory variables. (ii) For logistic MDG and education functions (that cover the same rates as those referred to above), a vector is required showing a non-base point — a combination of values for the outcome and the explanatory variables. This point is typically a business-as-usual projection or a projection derived from a strategy for achieving an MDG or education target. This information is used to calibrate the functions so that they replicate base-year outcomes and elasticities, reach each MDG under specified conditions and have the upper or lower limits that were specified exogenously.

4.5.2 Data sources

Within available space, it is only possible to provide a brief outline of steps involved when constructing the MAMS database; to a large extent, the details tend to be country-specific.

When constructing a SAM for MAMS or some other CGE model, the main sources tend to be existing SAMs, input-output tables and supply-and-use tables and other standard databases (both country-specific and those of international organizations, covering national accounts, fiscal data and the balance of payments). Given the need for a relatively disaggregated treatment of accounts for the government as well as human development services, government fiscal publications, public expenditure reviews and focused analysis of human development and infrastructure sectors are particularly important for the development of a MAMS SAM. A typical procedure is to start with a relatively aggregate SAM that, in a stepwise fashion is disaggregated, drawing on additional data in different areas. Tools have been developed to construct a macro SAM in Excel and to estimate a balanced, more detailed SAM from an imbalanced starting point (using cross-entropy methods).[62]

Sources with data relevant for parameters other than the SAM tend to include publications (both academic and non-academic, from governments and international organizations) and websites with analysis and statistics on trade, production sectors, private consumption, population, human development (including MDG and education sectors), infrastructure, as well as surveys (of households, labor and health conditions).[63] [See Lofgren (2011) for more detail.] In some applications, econometric analysis was undertaken when available studies did not provide satisfactory values for required elasticities (for an example, see Section 4.7).

62 For more on the cross-entropy approach to SAM estimation, using GAMS as software, see Robinson *et al.* (2001) and Robinson and El-Said (2000).

63 To exemplify, the UNESCO Institute for Statistics (www.uis.unesco.org) and the World Bank Edstats (http://go.worldbank.org/ITABCOGIV1) constitute two international sources for enrollment and other education data needed for MAMS. National data sources often provide more detail.

4.6 USER-FRIENDLY INTERFACE

The skills required to make productive use of CGE models in policy analysis are considerable, *inter alia* including strength in economics, modeling and a variety of software. The purpose behind the development of a user-friendly interface for MAMS was to reduce the skills required in terms of modeling and software, permitting the analyst to focus on policy and economics, thereby making MAMS-based policy analysis more cost-effective.[64] The analyst who uses the interface, named ISIM-MAMS, works exclusively in an Excel environment and receives substantial guidance throughout the analytical process. Knowledge of GAMS (the software in which MAMS is coded) and an editor (GAMS-IDE or other) is no longer needed.[65]

This section briefly describes the structure of ISIM-MAMS, how users at different skill levels may use and interact with it and the major steps involved in a typical application with a predefined dataset. It is aimed at practitioners interested in applying the MAMS framework or developing similar interfaces for other models.

4.6.1 Overview of the interface

ISIM-MAMS was developed using Visual Basic as an add-in for Excel 2007, later updated to also work with Excel 2010. The user is required to work in a current Windows environment and to have Excel 2007 or 2010 and GAMS installed on the computer.[66] The reason for using Excel as the front-end is that the Excel environment is familiar for most analysts, in effect removing the initial barrier for users to start working with ISIM-MAMS.

ISIM-MAMS is packaged with a set of datasets defined by country and year, often available in two versions: core and MDG (*cf.* Section 4.4). These datasets have been developed by a core team drawing on the databases of existing GAMS-MAMS applications (i.e. applications for MAMS run using GAMS and Excel without the interface). Most users of ISIM-MAMS are simply expected to do policy analysis using one or more applications, each of which is associated with an existing dataset and includes a preprogrammed reference scenario. However, advanced users may also develop a database and a reference scenario working in GAMS-MAMS and, after reading in the database as a new dataset for ISIM-MAMS (using its *Expert Mode*), shift

[64] Reducing the skills required to develop and apply economic models was also a major reason behind the initial development of GAMS (Bussieck and Meeraus, 2003, p. 138). The RunGTAP software for the GTAP model was developed with the same objective (Pearson and Horridge, 2005).

[65] ISIM is short for "I simulate." ISIM-MAMS is designed to belong to the suite of models of iSimulate – a framework developed by the World Bank's Development Economics Prospects Group. For more information, see http://go.worldbank.org/2BB8HIAHU0. ISIM-MAMS was developed by Martin Cicowiez, Fernando Consigli and Enrique Gallego.

[66] One likely drawback of relying on Excel is that reprogramming of parts of ISIM-MAMS may be required to maintain compatibility with future Excel versions.

to ISIM-MAMS for policy analysis, perhaps collaborating with a broader group of analysts. The aim is that every user, irrespective of background, finds it more convenient to carry out the policy analysis step in ISIM-MAMS rather than using the traditional GAMS-MAMS alternative.

Assuming that GAMS and Excel 2007 or 2010 are already installed on the user's computer, the first step is to install ISIM-MAMS, which comes in the form of an .exe file that, when activated, runs a standard installation routine. After installation, Excel has a new tab called ISIM-MAMS that, when selected, opens an intuitive interface ribbon with user-friendly buttons. To run ISIM-MAMS for an application (once defined), the user simply has to click on the *Run* button on the ISIM-MAMS ribbon. The ISIM-MAMS interface is connected to a database that, for each dataset, stores definitions of sets (including commodities, activities, factors and institutions) and parameters (including default elasticities, closure and rules/policies) that are used to define scenarios. The rest of the relevant country dataset (other than the application database) is stored in the ISIM-MAMS installation folder, mostly in Excel files.

Assuming that the user is satisfied to work with one of the existing datasets, the next steps are to: (i) Open Excel 2007;[67] (ii) create a new application and associate it with one of the available datasets; (iii) select the ISIM-MAMS tab (see Figure 4.3); (iv) run and optionally modify the predefined reference scenario; (v) define and run additional scenarios such as "base" (that may be identical to the reference scenario) and, most likely, other scenarios of interest; and (vi) access the results inside the same Excel file, presented in tables and graphs. Throughout the process, parameters and other items are hyperlinked to relevant segments in the MAMS User Guide (Lofgren, 2011), which is included with ISIM-MAMS. Each application resides in an Excel file (named by the user) that can be used by others who have ISIM-MAMS installed.

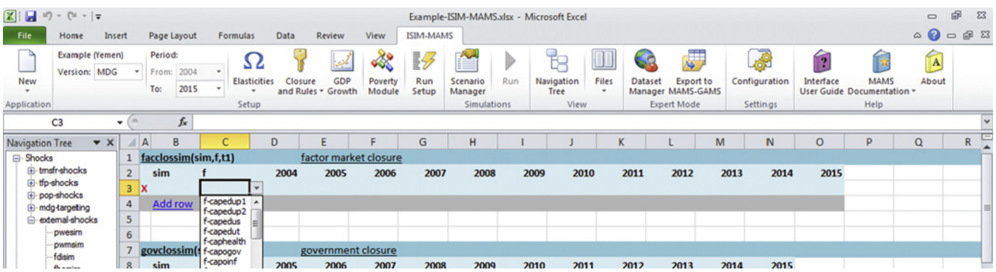

Figure 4.3 ISIM-MAMS ribbon.

67 The steps enumerated throughout Section 4.6 are the same if using Excel 2010.

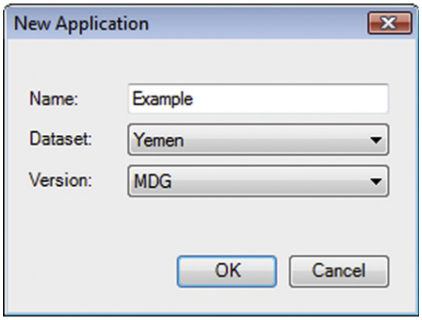

Figure 4.4 New application dialog box.

4.6.2 Using ISIM-MAMS

4.6.2.1 Selection of database and model version

This section shows how to create an MDG ISIM-MAMS application named "example" based on the "Yemen" dataset and using the MDG version of the model (see Figure 4.4).[68] ISIM-MAMS will load into Excel 2007 the data needed to define scenarios for the selected application, including the elements in the sets that are used to define shocks (e.g. the elements in the set of exported commodities are loaded to define world export prices or the elements in institution sets so as to define inter-institutional transfers).

ISIM-MAMS permits changes in and creation of application databases; the user can change selected elements of these datasets, like elasticities, closures and rules. To facilitate the navigation across the different sections of the Excel file, the user is provided with a button for the *Navigation Tree*, where the analyst can click on the element of interest (see Figure 4.3).

In addition, (advanced) users can add new country datasets to ISIM-MAMS and change other aspects of the MAMS program by editing relevant files in the MAMS installation folder, using Excel 2007 and a text editor.

4.6.2.2 Reference scenario

The first step in performing counterfactual simulations with ISIM-MAMS is the construction of a (dynamic) baseline scenario. To help the user carry out this task, ISIM-MAMS includes, for each country dataset, a predefined reference scenario. Key parameters of this scenario can be changed inside ISIM-MAMS, including the GDP growth rate, a subset of model elasticities (including those related to trade, household expenditure, the reservation wage and the impact of share of trade in real GDP on TFP), as well as closures and other rules, the latter covering the government budget, the balance

[68] As explained in Section 4.4, two versions of MAMS exist: core (a standard, dynamic-recursive CGE model) and MDG (an extended dynamic-recursive CGE model designed for MDG and human development analysis).

of payments, the savings–investment balance, factor markets and various payments, split into government and non-government depending on whether the government is involved or not. The rule chosen for any payment is overwritten if, according to the related closure setting, the payment in question is a free variable (e.g. the specification that direct taxes are determined on the basis of exogenous tax rates is overwritten if, according to the government closure rules, changes in direct taxes clear the government budget). In addition, the user can configure the MAMS Poverty Module (see Section 4.4). Specifically, the parameters of the Poverty Module allow the user to change (i) the approach to compute poverty, (ii) the welfare index (income/consumption), (iii) the initial poverty rate and (iv) the growth elasticity of poverty.

To exemplify, Figure 4.5 demonstrates how the analyst can change the elasticities of substitution between primary factors of production; the default values can always be restored. Once defined, the reference scenario can be run by clicking the *Run Setup* button; ISIM-MAMS will automatically call GAMS in order to run MAMS.

4.6.2.3 Defining and running scenarios for analysis

By default, ISIM-MAMS generates a scenario called *base*. The user can define additional scenarios and introduce policy changes and exogenous shocks, including changes in

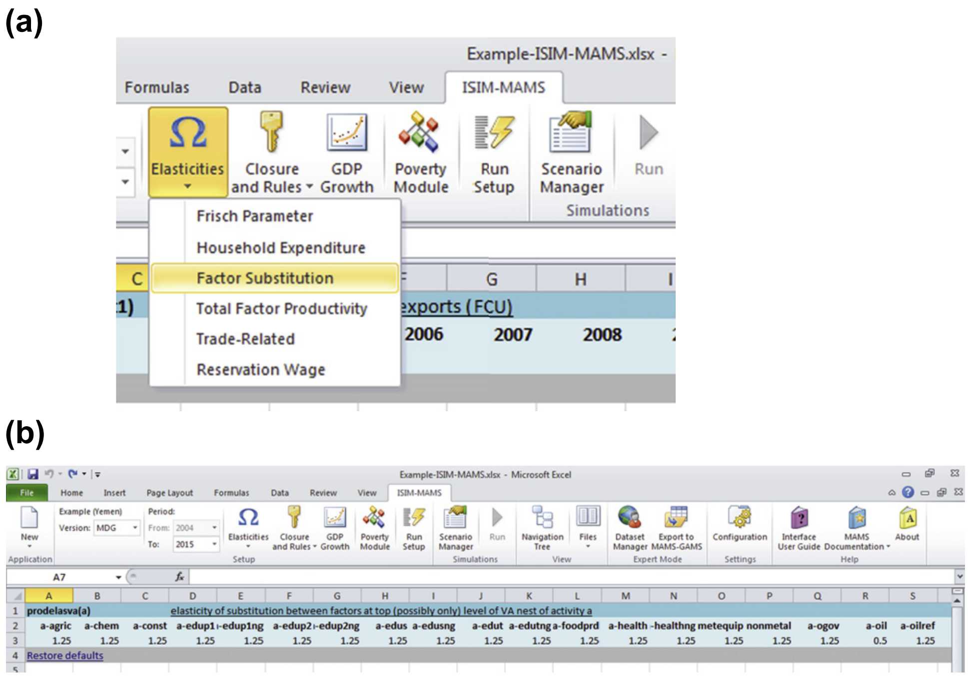

Figure 4.5 Changing the elasticity of substitution between factors of production.

world prices of exports and imports, foreign aid, taxation and public spending and its allocation. All the defined counterfactual scenarios are saved in the ISIM-MAMS application-specific Excel file. The types of changes that can be introduced relative to the reference scenario reflect what seemed relevant in light of experience from a large number of MAMS applications. The interface validates the input from the user in order to reduce the likelihood that simulations will fail to run without error.

To create a new simulation or delete an existing one, the user clicks on the *Scenario Manager* button, opening the window shown in Figure 4.6. By clicking or unclicking the box in front of each scenario, the user decides which simulations to run (there is no need to run all the defined scenarios). By right-clicking above any scenario, the user can edit the name and the explanatory text of the simulation and select the mode (whether the scenario is solved single-pass or multipass, indicated by [S] or [M] at the end of the explanatory text for each simulation). In the example, the pwm-2 simulation will be run, while the pwe-2 will not. The elements under Shocks and Closure and Rules in the *Navigation Tree* show what can be changed in the definition of the non-reference scenarios. If no changes are made for a scenario, then it is identical to the reference scenario. In order for the base scenario to function as the benchmark to which other scenarios are compared, it may be preferable to leave it unchanged (i.e. identical to the reference scenario).

More specifically, the user can make changes in a set of items, grouped into the following categories:

- External shocks: changes in (i) the world price of exports and imports, (ii) FDI and (iii) foreign borrowing.
- Total productivity shocks: changes in (i) TFP, by activity and time period, and (ii) real GDP at factor cost.

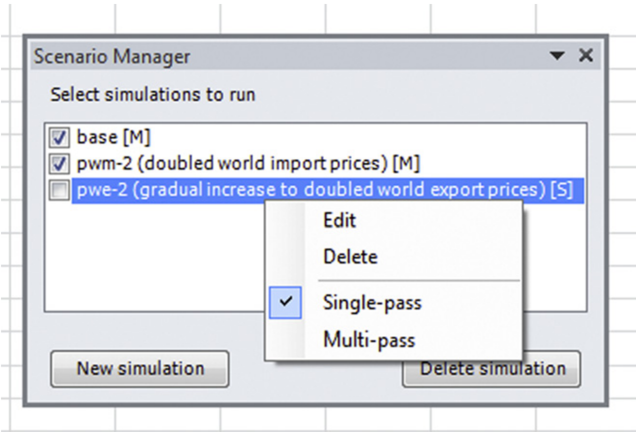

Figure 4.6 Scenario manager.

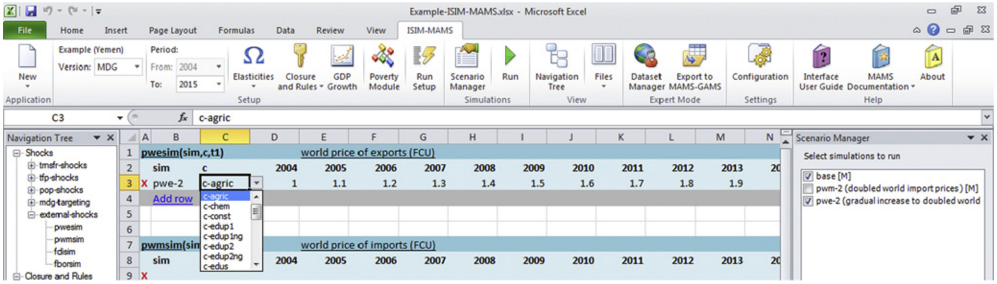

Figure 4.7 Defining a shock to the world price of exports.

- Demographic shocks: changes in (i) population size, by representative household or other population segment, and (ii) changes in the growth rate of non-labor (all) factors (core version only).
- Transfers shocks: changes in (i) transfers non-household institutions or factors and (ii) *per capita* transfers to households.
- Closures and rules: changes in closures and rules — similar to the setting of closures and rules for the preprogrammed reference scenario. Among other things, the rules section allows defining scenarios with changes in (i) government spending and receipts, and (ii) transfers between institutions.
- Targeting of MDG and/or education outcomes (only for the MDG version of the model); the analyst can impose the targeting of one or more MDG goals and/or education outcomes. The available drop-down menus help the user to select scenario name and MDG or education outcome.

As an example, Figure 4.7 shows how to define a 50% increase in the world price of agricultural exports during 2005—2008 using an application based on the "Yemen" dataset; the other shocks can be similarly defined.

4.6.2.4 Review and further processing of simulation results

Once the selected scenarios have been run with success, results can be accessed via the ISIM-MAMS interface by clicking on *Reports* via the *Navigation Tree*. In addition to providing simulated variable results as levels, growth rates and GDP shares (all accessible through a pivot table inside Excel as well as GAMS .GDX files), the interface generates predefined tables and figures (see Figure 4.8 for an example of a predefined figure). By clicking on the *Configuration* button, the user can select which preprogrammed tables are generated, start and end years for these tables, the order in which the result tables will appear and whether or not to generate a pivot table and chart with raw model results. Irrespective of the settings under *Configuration* | *Reports*, the user can access all simulation results using the report .GDX files through the *View* | *Files* menu option.

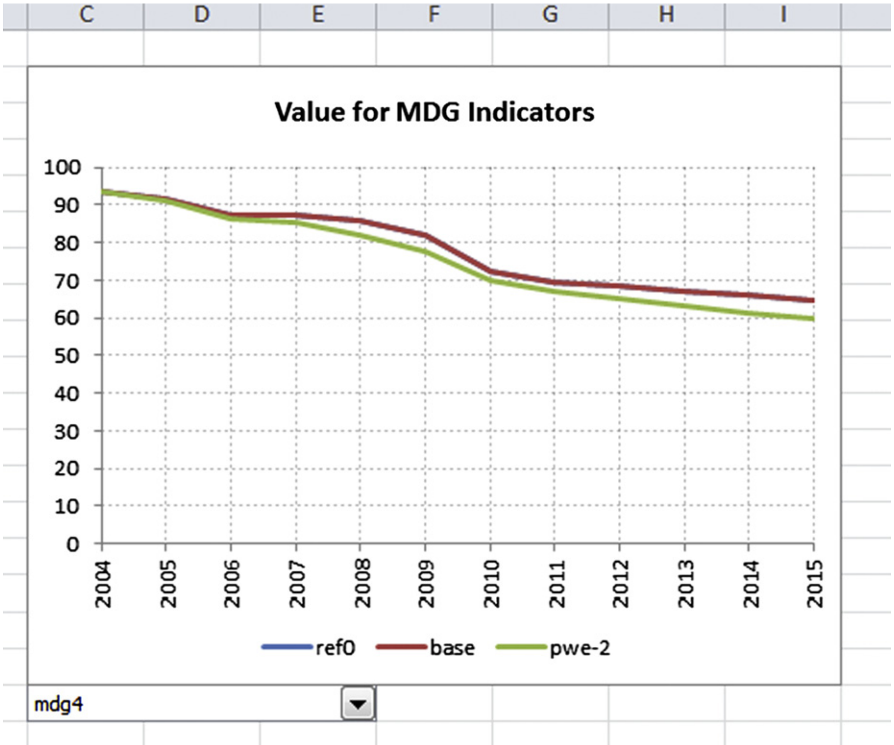

Figure 4.8 MAMS results.

4.6.2.5 Input validation and error messages

Before calling GAMS to run a selected simulation, ISIM-MAMS validates the definition of shocks, elasticities and/or closures and rules. In case errors are found, messages appear in pop-up windows and the user will have to check the red Excel cells, located in the sheets whose label also turned to red (see Figure 4.9). Besides, an error summary sheet shows the list of generated validation errors. In case the solution of ISIM-MAMS ends with an error, the user is offered the chance to inspect the ISIM-MAMS log file or the GAMS listing file (see Figure 4.10). The log and listing file viewer allows the user to navigate through the ISIM-MAMS and/or GAMS errors. The log file is intended for users with no GAMS knowledge. On the other hand, the GAMS listing file provides the raw GAMS results and error messages. In case MAMS is successfully solved, ISIM-MAMS will add or update the report sheets (i.e. it will add extra worksheets in Excel).

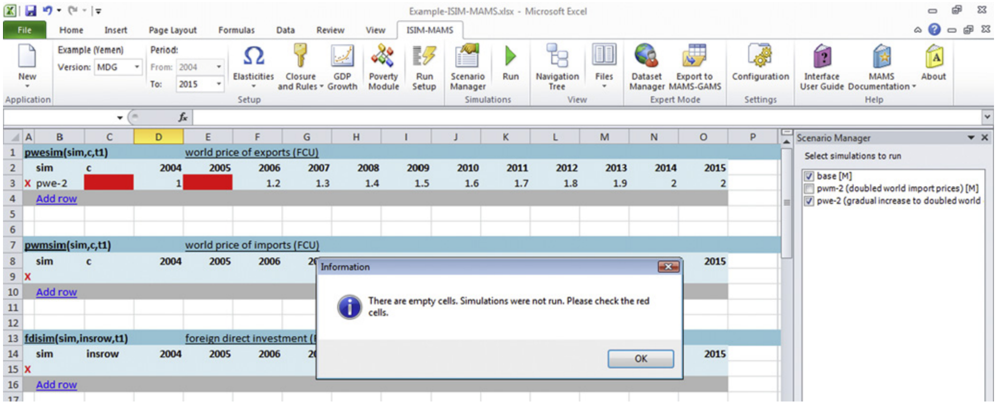

Figure 4.9 Validation errors in ISIM-MAMS.

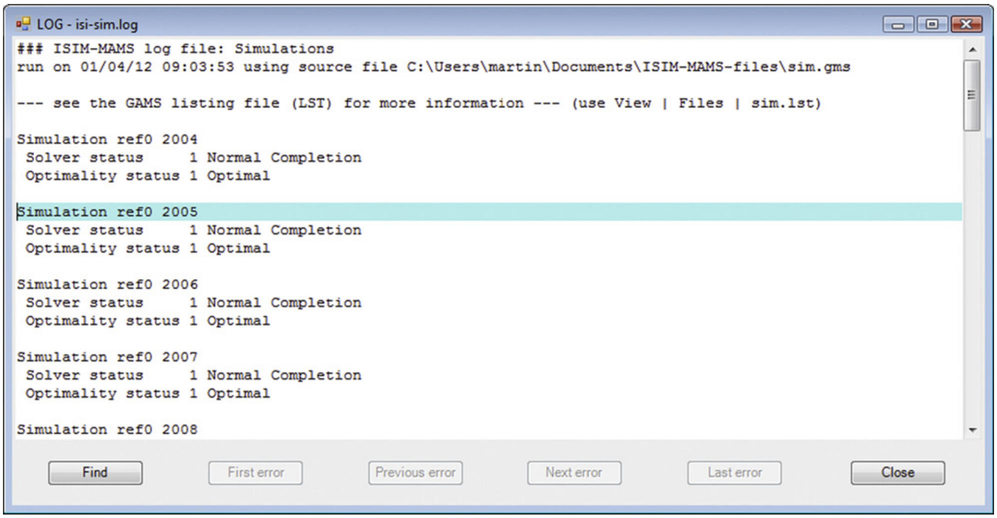

Figure 4.10 LOG/LST file viewer.

4.7 APPLICATIONS: POLICY ISSUES AND INSIGHTS

This section provides an overview of the applications of MAMS and the insights that the analyses have generated, together with a detailed account of a development prospects analysis for Yemen. Section 4.7.1 summarizes policy issues addressed, the institutional contexts of MAMS-based analysis and how the model has evolved in tandem with both the evolution of issues and the incorporation of lessons from earlier applications. Section 4.7.2 provides the reader a recent case study for Yemen while Section 4.7.3 summarizes the main insights from the wider range of studies.

4.7.1 Policy issues, institutional context and evolution of model structure

Since the initial development of MAMS in 2004 with its pilot application to Ethiopia, the framework has been applied to a large number of countries and a variety of issues. Table 4.18 lists a total of 65 MAMS applications (completed or in progress) spread over 45 countries throughout the developing world but with the strongest focus on Latin America and Sub-Saharan Africa. In terms of institutional sponsorship, these applications are roughly evenly divided between World Bank-led projects and projects in which UN-DESA has been the leading institution, typically working with the World Bank, the UNDP and developing-country analysts. Projects led by UN-DESA have invariably had a strong training component with extensive interaction with small country teams during an extended period (two years or more); World Bank-led projects have also offered extensive training to researchers from some countries, including Ghana and Uganda. The applications for which the UN had a leading role have focused on scenarios that are geared toward the objectives of the UN Millennium Declaration of 2000: reaching the MDGs by 2015. To study the possible economy-wide effects of the pursuit of these objectives, the scenarios targeted full achievement of the non-poverty MDGs by 2015 under alternative assumptions regarding the source of the required additional financing (foreign grants, foreign borrowing, domestic taxes or domestic borrowing), while tracking the resulting effect on the poverty MDG as well. After a set of initial Ethiopia applications also focused on targeting MDGs, the World Bank-led applications have been more diverse, although without departing from the overarching concern of analyzing links between fiscal policy, exogenous shocks, poverty reduction and other aspects of human development; the details of each application have reflected the priorities of World Bank country teams and developing-country governments. As shown in Table 4.18, applications have addressed often inter-related topics similar to gender, demography, foreign aid, debt sustainability, mining exports, labor markets, FDI and fiscal policy, in the latter area often simulating tradeoffs related to alternative spending allocations and their impact on poverty versus non-poverty MDGs. With few exceptions, the findings from MAMS-based applications have been presented in each country to policy makers and researchers. Among developing-country governments, those of Ethiopia and Uganda have relied on simulation results from MAMS for their MDG Needs Assessment Report and their current National Development Plan, respectively (Government of Ethiopia, 2005, pp. 45–52 and 65–66; Musisi, 2009, pp. 15–29; Government of Uganda, 2010, p. 58).

When MAMS has been applied to new issues or countries, it has typically been necessary to extend the model and its computer code. The initial Ethiopia application

Table 4.18 MAMS applications and references by country, issue, model version and context

Country	Issue	Version	Context	Key references/ status
Afghanistan	Growth, aid and mining exports	Core	A	In progress
Argentina	MDG targeting	MDG	B	Cicowiez *et al.* (2008, 2010)
Benin	MDG targeting	MDG	C	Republic of Benin and UNDP (2010)
Bolivia	MDG targeting	MDG	B	Jimenez *et al.* (2008, 2010)
	Financial crisis and MDGs	MDG	D	Jimenez (2010); United Nations (2011)
Brazil	MDG targeting	MDG	B	Ulyssea and Le Boulluec (2008; 2010)
Burkina Faso	Fiscal tradeoffs; demography	MDG	A	Gottschalk *et al.* (2009); World Bank (2011)
Chile	MDG targeting	MDG	B	O'Ryan *et al.* (2008, 2010)
	Financial crisis and MDGs	MDG	D	O'Ryan *et al.* (2010)
Colombia	MDG targeting	MDG	B	Nuñez *et al.* (2008)
Congo (Democratic Republic)	Debt sustainability	Core	A	World Bank (2007b, 2008a)
	Fiscal tradeoffs	MDG	A	Nielsen and Lofgren (2011)
Costa Rica	MDG targeting	MDG	B	Sanchez (2008, 2010)
Cuba	MDG targeting	MDG	B	Ferriol *et al.* (2008)
Dominican Republic	MDG targeting	MDG	B	Diaz-Bonilla *et al.* (2008)
	National Development Strategy	MDG	A	Diaz-Bonilla (2009)
Ecuador	MDG targeting	MDG	B	Leon *et al.* (2008, 2010)
	Financial crisis and MDGs	MDG	D	Rosero and Leon (2010); United Nations (2011)
Egypt	MDG targeting	MDG	B	Khorshid *et al.* (2012)

(*Continued*)

Table 4.18 MAMS applications and references by country, issue, model version and context—cont'd

Country	Issue	Version	Context	Key references/ status
El Salvador	MDG targeting	MDG	B	Acevedo (2008)
Ethiopia	Gender	MDG	A	Ruggeri Laderchi *et al.* (2010); World Bank (2009a)
	MDG targeting; fiscal tradeoffs	MDG	A	Lofgren and Diaz-Bonilla (2008)
	Absorptive capacity	MDG	A	Sundberg and Lofgren (2006); Bourguignon and Sundberg (2006a, 2006b)
	Demography	MDG	A	World Bank (2007a)
	Labor markets	MDG	A	World Bank (2007c)
	Public finance	MDG	A	World Bank (2006); Lofgren and Abdula (2006)
	Macro analysis of MDG Strategy	Core	A	Government of Ethiopia (2005)
Ghana	Growth; fiscal tradeoffs	MDG	A	Bogetic *et al.* (2008); Bussolo and Medvedev (2008a); World Bank (2007d)
Guatemala	MDG targeting	MDG	B	Vázquez (2008)
Honduras	MDG targeting	MDG	1, 2	Bussolo and Medvedev (2008a, 2008b); World Bank (2007e)
Jamaica	MDG targeting	MDG	B	King and Handa (2008)
Kenya	Poverty and inequality	MDG	A	World Bank (2009b)
	Growth	Core	A	World Bank (2008b); Lofgren and Kumar (2007)
	MDG targeting	MDG	5	Kiringai and Levin (2008)
Kyrgyz Republic	MDG targeting	MDG	D	Mogilevsky and Omorova (2012)
Liberia	Poverty reduction; growth	MDG	A	In progress

(*Continued*)

Table 4.18 MAMS applications and references by country, issue, model version and context—cont'd

Country	Issue	Version	Context	Key references/ status
Malawi	Policy tradeoffs	MDG	A	World Bank (2007f)
Mexico	MDG targeting	MDG	B	Ortega and Székely (2008; 2010)
	Financial crisis and MDGs	MDG	D	Ortega (2011)
Moldova	Remittances; food and oil prices	Core	A	In progress
Mongolia	Mineral exports	Core	A	Unpublished
Morocco	MDG targeting	MDG	B	Khellaf *et al.* (2011)
Nicaragua	MDG targeting	MDG	B	Sanchez and Vos (2008, 2010)
	Financial crisis and MDGs	MDG	D	Sanchez and Vos (2010); United Nations (2011)
Paraguay	MDG targeting	MDG	B	Biedermann and Corvalán (2008)
Peru	MDG targeting	MDG	B	Castro and Yamada (2008; 2010)
Philippines	MDG targeting	MDG	D	Briones *et al.* (2012)
Rwanda	Policy tradeoffs	MDG	A	Lofgren *et al.* (2009)
Senegal	MDG targeting	MDG	E	Robilliard and Chemingui (2011)
	MDG targeting	MDG	B	Diagne *et al.* (2012)
South Africa	MDG targeting	MDG	B	Kearney and Odusola (2012)
Syria	Policy tradeoffs	MDG	A	In progress
Tunisia	MDG targeting	MDG	B	Chemingui and Sanchez (2012)
Uganda	Oil exports	MDG	A	In progress
	Demography	MDG	A	In progress
	MDG targeting	MDG	B	Matovu *et al.* (2011)
	Demography	MDG	A	Kinnunen *et al.* (2009)
	Fiscal tradeoffs	MDG	A	World Bank (2007g); Lofgren and Diaz-Bonilla (2006)
	National Development Strategy	MDG	A	Musisi (2009); Government of Uganda (2010)
Uruguay	MDG targeting	MDG	B	Laens and Llambi (2008)

(*Continued*)

Table 4.18 MAMS applications and references by country, issue, model version and context—cont'd

Country	Issue	Version	Context	Key references/ status
	Financial crisis and MDGs	MDG	D	Llambí and Laens (2011)
Uzbekistan	MDG targeting	MDG	D	Olimov and Fayzullaev (2012)
Yemen	MDG targeting; fiscal tradeoffs	MDG	B	See Section 4.7.2
Zimbabwe	FDI, government and domestic private investment	Core	A	In progress
Archetype resource-poor low-income country	Aid, policy (spending, taxation) and TFP	MDG	A	World Bank (2010, pp. 107–119)
Archetype resource-rich low-income country	Aid, policy (spending, taxation) and TFP	MDG	A	World Bank (2010, pp. 107–119)

Issues:

- MDG targeting = Full achievement of one or more non-poverty MDGs by 2015 with alternative sources of additional financing.
- Fiscal tradeoffs = Within fiscal space limits, analysis of tradeoffs related to different spending priorities (typically infrastructure versus human development).
- Demography = Effects of alternative demographic scenarios (often UN projections; sometimes associated with policy changes) on MDGs and other indicators.

Versions:

- Core = Version without non-poverty MDG indicators and links between education and the labor market.
- MDG = Version with one or more non-poverty MDG indicators and links between education and the labor market.

Contexts:

- A = World Bank staff or consultants as part of World Bank analytical work; coordinated with government with in-country presentations; sometimes with full government collaboration and/or training.
- B = Developing country analysts in joint projects with UN-DESA, UNDP, World Bank and consultants; extensive training.
- C = Developing country analysts in joint project with UNDP, Gesellschaft für Technische Zusammenarbeit and consultants.
- D = Developing country analysts in joint project with UNDP, UN-DESA and consultants.
- E = Developing country analysts in joint project with UN Economic Commission for Africa and consultants.

The MAMS website at www.worldbank.org/mams may also include links to other versions of the same studies, including working papers.

had been limited to the essentials of what was needed given the priorities at hand and constraints on data and time. With few exceptions, the extensions that have been introduced in the context of different applications have been brought into the standard code as optional features (i.e. adding to the flexibility of the framework without imposing changes in the content and results of earlier applications).[69]

Accordingly, the initial model structure, developed for the Ethiopia application, was focused on MDG targeting.[70] Relative to most CGE models, the features of the initial Ethiopia application that may be non-standard and that were significant for the analysis include:

- Endogenization of the MDG and the education outcomes typically covered by MAMS (*cf.* Section 4.4) using nested logistic — constant-elasticity functions with links to the labor market.
- Disaggregated treatment of government human development and infrastructure services to capture human development and growth impacts of government actions.
- Targeting of MDG outcomes: flexing of real government service levels combined with fixing of MDG outcomes. For cases where the number of targets exceeded the number of policy tools, a mixed-complementarity formulation was used to ensure that all targets were achieved exactly for one target per tool combined with likely overshooting for other targets.[71]
- Introduction of a non-competitive import commodity in the SAM to ensure that the implicit import share of investment demand matched available data — no changes were required in the model structure relative to the static model in Lofgren *et al.* (2002), on which MAMS draws. Import intensity matters as it has strong implications for the impact of simulated spending expansion on the real exchange rate and production of tradables (including potential "Dutch Disease" effects).

As an example of a path not taken, in the context of the initial Ethiopia analysis, some simulations minimized the present value of government costs of achieving the MDGs (requiring a model solution in the single-pass mode); however, this was not pursued in later applications considering the nature of the MDG targets (which, strictly speaking,

69 So far, the only exceptions are in Kinnunen *et al.* (2009) and Ruggeri Laderchi *et al.* (2010) where the extensions, related to demography and gender (in time use, education and the labor markets), respectively, were deemed too data-demanding to be desirable in a larger number of applications at the same time as their introduction as special cases would have added unduly to the complexity of the model code.

70 Prior to the development of the general equilibrium version of MAMS, a top-down macro—micro framework was developed in which a separate macro model fed data into a partial equilibrium MDG module in which the outcomes for MDG 2, 4, 5 and 7 were computed without feedback from the MDG module to the rest of the economy. The MDG module had more detail on health (distinguishing between different types of health services) while the treatment of education was limited to primary education (Bourguignon *et al.*, 2004)

71 As noted in Section 4.4, in effect no application has had more than one excess target per tool — water and sanitation MDGs are targeted with aggregate government water-sanitation services as the policy tool; and under-5 and maternal mortality rates are targeted with aggregate government health services as the policy tool.

only are concerned with outcomes in 2015) and the fact that our understanding of time lags in the links between human development determinants and outcomes is very limited.[72]

After the initial Ethiopia analysis, MAMS was applied to a large number of countries in Latin America and the Caribbean, confronting the framework with a wider range of country features that required higher degrees of flexibility and robustness as well as various extensions relative to a model designed to work for a specific country like Ethiopia. *Inter alia*, MAMS was modified to include:

- Sectors that deviate from the default assumption that production decisions (including production quantities) are driven by profit maximization in a perfectly competitive setting. These non-standard sectors belong to two categories: (i) Natural resource-based sectors for which production volumes and factor quantities are exogenous, with a natural resource factor earning residual value-added while factors, intermediate inputs and outputs are subject to market rents and prices and (ii) utilities for which a private operator has agreed to satisfy market demand at an exogenous price and to undertake an agreed-upon investment plan (sufficient to produce demanded quantities).
- Imposition of exogenous aggregate rates of labor force participation among the population in labor-force age outside school. This was needed to ensure that education-specific attrition rates for labor generated macro outcomes that matched available trends for labor force growth.
- Reservation wages and endogenous unemployment rates for selected factors (typically limited to labor factors). By spreading responses to changing labor market conditions across employment and wages, this extension had the effect of reducing sometimes excessive year-to-year wage variations that resulted when employment was fixed; obviously, it also permits the model to generate endogenous changes in unemployment.[73]
- Optional non-government service providers in MDG- and education-related sectors, typically financed like other non-government sectors and contributing to MDG and education outcomes as perfect or imperfect substitutes of government services. This extension, also present in later Ethiopia applications, was particularly important for

72 To provide an example, if health outcomes in year *t* merely depend on the levels *in the same year t* for government services and other determinants of health outcomes, then the cost-minimizing policy for achieving the health MDGs would involve postponing expansion of government spending on health and other determinants until 2015, the final year. To avoid such outcomes, simulations targeting MDG outcomes have tended to impose gradual progress over time for the MDG indicators at rates consistent with constant growth rates for the different determinants (government services and other). In the real world, lags are likely to vary strongly depending on country context and the kinds of micro-level interventions that are pursued.

73 In addition, imposition of the assumption that labor productivity growth increases with the level of education has often been necessary to counter the tendency for less educated labor to enjoy implausibly rapid relative wage growth given its relatively slow stock growth.

Latin America and Caribbean countries where the private sector tends to play a major role in these sectors.

In addition to these changes in the model structure, various background changes were crucial to make it feasible to apply MAMS to a rapidly growing number of countries (including the simultaneous application of MAMS to 18 countries in the Latin America and Caribbean region), *inter alia*, including the programming of a large number of diagnostic checks on the databases (aborting the program if data was missing or inconsistent) and the creation of additional parameters in Excel data files that facilitate user control of an expanded number of parameters on a year-to-year basis.[74]

The more recent World Bank-led applications, which have been more diverse, have been done in close collaboration with government and World Bank country teams. Instead of imposing targets and exploring what is needed by way of financing, the emphasis has been on determining what can be achieved under alternative scenarios for financing and allocations of government spending. The changes in the model structure are numerous but have not changed the overall structure; they include:

- Fine-tuning of government closures with budget clearing via spending adjustments (via a percentage-point adjustment in real growth for one or more selected government functions that, in each period, is uniform across these functions). To exemplify, an exogenous increase in grant aid may be combined with uniform upward adjustment in human development and infrastructure services within the limits of fiscal space or, alternatively, exogenous adjustments in spending on infrastructure services may be combined with endogenous real growth adjustments in human development services.
- Creation of auxiliary equations and related variables (potentially exogenous) that permit analysts to control real growth rates and shares of GDP or absorption for the different receipts and outlays of the government as well as different non-government payments (e.g. FDI or remittances to households from the rest of the world). These extensions were often driven by the need to replicate observed macro data during the initial simulation years, which typically cover recent history, with counterfactual scenarios starting for a year in the near future.[75]
- The development of the built-in poverty module (beyond the initial formulation with a fixed growth elasticity of poverty; see Section 4.4.3).
- Broadened optional targeting of MDG and education outcomes to cover a wider range of indicators (also higher levels of education) and permit a flexible setting of target years. These extensions have been useful when the analyst has desired to

[74] To provide just a few examples, diagnostic checks verify that (i) all SAM entries are legal, (ii) if data is provided for a multiyear parameter (e.g., a set of annual growth rates), then coverage is complete over the simulation period and (iii) the activity disaggregation of factor employment data is consistent with that of SAM payments to factors.

[75] In order to avoid imposing inconsistent pieces of information, it has often been convenient to construct a very aggregate macro SAM for the most recent year with comprehensive macro data.

impose outcomes from one scenario on subsequent scenarios, constraining welfare-related changes to a smaller number of variables (private consumption and incomes, poverty and inequality).

- Disaggregation of student stocks by grade and cycle instead of only by cycle to better capture the dynamics of the educational system (including graduation and transition from one cycle to next).

The Yemen application that is presented next is based on the current MAMS version and thus is able to draw on these more recent changes in model structure.

4.7.2 Case study

4.7.2.1 Policy issues

The purpose of this section is to demonstrate a practical application of MAMS, using Yemen as a case study.[76] Yemen is one of the poorest countries in the Arab region with a *per capita* GDP of US$1160 for 2008 (WDI, 2010) and faces a wide range of developmental challenges, amplified in 2011 by deepened domestic conflict. In 2007, the country was ranked 140 out of 182 according to the Human Development Index (HDI) (UNDP, 2009). Ever since reunification in 1990, Yemen's relative position on the HDI has remained more or less unchanged and its progress towards attaining the MDGs has been very slow. At 3%, the country has one of the highest population growth rates globally, with the population expected to double in 23 years to around 40 million. This increases the demand for educational and health services, drinking water and employment opportunities. Yemen faces a severe water shortage, with available ground water being depleted at an alarming rate. Its oil production and reserves are declining with severe budgetary consequences. Moreover, the political crisis that erupted in 2011 threatens to make Yemen's prospects for rapid growth and progress on MDGs even bleaker. The case study was conducted to provide guidance to policy making once at least the minimum requirements for stability and policy making have been restored.

Social development indicators, such as child malnutrition, maternal mortality and education attainment remain discouraging. The *Fourth Five-Year Socio-Economic Development Plan for Poverty Reduction 2011—2015* (see MOPIC, 2011) indicates that about 42.4% of the population live below the national poverty line.[77] Yemen's first and second

[76] The Yemen case study is part of the project "Assessing Development Strategies to Achieve the Millennium Development Goals in the Arab Region," carried out by the UNDP/RBAS (Regional Bureau for the Arab States), UN/DESA (Department of Economic and Social Affairs), the World Bank and country teams for Egypt, Jordan, Morocco, Tunisia and Yemen. The members of the Yemen team are Mohamed Ahmed Al-Hawri (team leader; Ministry of Planning and International Cooperation), Abdulmajeed Al-Batuly (Ministry of Planning and International Cooperation), Anwar Ahmed Farhan (Central Statistical Organization), Ali Shatter (Ministry of Finance), Mohammad Pournik (UNDP), Martin Cicowiez, Ana Pacheco and Hans Lofgren.

[77] The *Fourth Five-Year Socio-Economic Development Plan for Poverty Reduction 2011—2015* is an official document that, among other things, provides projections for several variables useful for generating the MAMS reference scenario as further explained below.

MDG Reports of 2003 and 2010 concluded that Yemen was off track with respect to meeting the MDGs (see MOPIC, 2003, 2010).

MAMS for Yemen (MAMS applied to a Yemeni database) is here used to run a set of simulations that explore the economic impact of different options for creating and using fiscal space — the former refers to mobilizing resources and the latter to their possible uses.[78] In these simulations, exogenous increases are introduced for foreign aid, government allocative efficiency or TFP in the production of government services. The government makes use of the resulting addition to fiscal space to expand spending and service delivery in infrastructure and human development. The results suggest that substantial improvements could be achieved if, as a result of one (or more) of these exogenous changes, fiscal space would increase. The simulated effects differ depending on the size of the simulated exogenous shock and on how the government uses the additional resources. For the simulations that involve increased access to foreign aid, the gains are more substantial, including a reduction in the poverty rate, reductions in the under-five mortality rate, as well as a significant improvement in on-time completion of primary schooling. In general, emphasis on infrastructure leads to more rapid growth for GDP and absorption, but has less significant improvements for the MDG indicators. In addition to key MDG indicators (related to poverty, health, primary education and water and sanitation), the analysis covers the impact of the strategy on national account aggregates, major macroeconomic balances (including the government budget and the balance of payments), the size of the government relative to the rest of the economy, as well as production and trade in different sectors. In addition, our analysis confirms the importance of considering synergies and economy-wide constraints and repercussions in the analysis of major government policy changes such as an MDG strategy.

4.7.2.2 Database development

MAMS for Yemen was calibrated to a 2004 SAM and other data, developed following the procedures described in Section 4.5. The main source of information for the construction of the Yemeni SAM was the supply and in use tables for the same year. In addition, information from the Balance of Payments was the most important input to build the external accounts of the SAM. For the government accounts, data for 2004 from the 2008 Bulletin of Government Finance Statistics was used. In order to complete the SAM, data computed from the 2005 Household Budget Survey was also used. Like other MAMS SAMs, the Yemeni SAM offers a relatively detailed treatment of investment and its financing (*cf.* Section 4.5). Table 4.19 shows the accounts in the 2004 Yemeni SAM, which determine the size (i.e. disaggregation) of the model. The government is disaggregated into eight activities: four cycles of education (basic grades

78 Heller (2005) defines fiscal space as "room in a government's budget that allows it to provide resources for a desired purpose without jeopardizing the sustainability of its financial position or the stability of the economy."

Table 4.19 Accounts in the Yemen 2004 SAM

Sectors (25)	**Tax accounts (4)**
Private (17)	Commodity taxes
Agriculture	Factor taxes
Crude oil, gas and other mining	Direct taxes
Food and beverages	Import taxes
Textiles	**Institutions (3)**
Wood, paper and press	Households
Liquid petroleum products	Government
Chemical products	Rest of the world
Non-metal industry	**Interest payments (3)**
Metal and equipment	Domestic interest payments
Other manufactures	Foreign interest payments
Construction	**Capital accounts (3)**
Other services	Households
Health private	Government
Basic education grade 1–6	Rest of the world
Basic education grade 7–9	**Investment accounts (9)**
Secondary education	*Private (2)*
Tertiary education	Gross capital formation
Government (8)	Stock changes
Water and sanitation	*Government (8)*
Other infrastructure	Water and sanitation
Health government	Other infrastructure
Basic education grade 1–6	Health government
Basic education grade 7–9	Basic education grade 1–6
Secondary education	Basic education grade 7–9
Tertiary education	Secondary education
Other government	Tertiary education
Factors of production (13)	Other government
Unskilled labor	
Semi-skilled labor	
Skilled labor	
Private capital	
Natural resource	
Government capital (8)	

1–6, basic grades 7–9, secondary and tertiary cycles), health, water and sanitation, other public infrastructure and other government services.[79] In the following, the basic grades 1–6 are referred to as primary education (following international standards for the length of primary education). Owing to the focus of MAMS on MDGs, in addition to other private services, the private service sector is disaggregated into four education activities

[79] As can be seen, the official basic education cycle was split into two subcycles; the first includes grades 1–6 and the second includes grades 7–9.

(with the same cycles as in government education) and a private health activity.[80] The rest of the economic activities (agriculture and industry) are disaggregated into the 12 sectors shown in Table 4.19.

Among the factors of production, there are three types of labor: those with less than completed secondary education (unskilled), with completed secondary education but not completed tertiary (semi-skilled) and with completed tertiary (skilled). Each of these labor types is therefore linked directly to an educational cycle. The growth in the labor force and changes in its composition will in part depend on the functioning of the education system in the model.[81] The remaining factors include public capital stocks by government activity, a private capital stock and a natural resource used in oil and gas extraction.

The institutions include the government, a household (the private domestic institution, which represents both households and domestic enterprises) and the rest of the world. Each institution has its own capital account. Taxes have been disaggregated into direct, import and commodity taxes/subsidies. There is one private investment account and eight public investment accounts (one for each government sector). Lastly, the SAM includes accounts for domestic and foreign interest payments.

As explained in Section 4.5, apart from the SAM, the MAMS database includes data related to the different MDGs, the labor market and various elasticities. Most importantly, the first two data types include levels of service delivery required to meet the different MDGs, number of students at different educational cycles, student behavioral patterns in terms of promotion rates and other indicators and number of workers and initial unemployment rates by skill level (i.e. educational achievement). The elasticities include those in production, trade, consumption and in the different MDG functions. This implementation of MAMS covers MDG 2 (primary education), 4 (under-five mortality) and 7 (water and sanitation access).[82] The elasticities for the MDG functions are informed by two studies done for Yemen by Sanchez and Sbrana (2009) and Sbrana (2009) for education and water and sanitation, respectively. However, rather than using the exact point estimates from the econometric partial equilibrium analysis, we use the relative importance of the determinants in choosing the (general equilibrium) elasticities. In addition, the MAMS elasticities were adjusted in order to generate plausible trends under baseline conditions — and this procedure was, in fact, entirely used to define plausible elasticity values for MDG 4 in view of a lack of empirical studies and data to better inform the definition of these elasticities. Reflecting these adjustments, Table 4.20 shows the determinants in the MAMS

80 According to official estimates, the share of students in private institutions is 2.3, 2.0 and 14.9% for basic, secondary and high education, respectively.

81 Notice that workers are classified as "unskilled" labor unless they have completed secondary education or higher.

82 MDG 5 (maternal mortality) can also be considered in MAMS, but was left out as data was insufficient.

Table 4.20 Elasticities for the determinants of MDGs

MDG	Per student or *per capita* service delivery	*Per capita* household consumption	Wage premium	Public infrastructure	Other MDGs[a]
Basic education (grades 1–6)					
First grade net intake rate	1.563	0.195	0.004	0.781	−0.031
Promotion rate	0.466	0.039	0.001	0.155	−0.004
Continuation rate[b]	0.733	0.105	0.001	0.105	−0.020
Under-5 mortality rate	−0.865	−0.087		−0.087	−0.084
Access to safe water	0.261	0.010		0.010	−0.084
Access to basic sanitation	1.201	0.120		0.120	−0.105

[a]Refers to MDG 4 for education and MDG 7w and 7s for health.
[b]To grades 7–9 among students who were promoted from grade 6.

functions that define MDG outcomes and the corresponding elasticities used in the model.[83]

The determinants in the MDG functions include the provision of relevant services (in education, health and water and sanitation) and other indicators as *per capita* consumption and the size of the capital stock in public infrastructure, also allowing for the presence of synergies between MDGs, i.e. the fact that achievements in terms of one MDG can have an impact on other MDGs. For example, improvements in water and sanitation (i.e. MDG 7) will reduce under-5 mortality (MDG 4). In the cases of health and water and sanitation (i.e. MDG 4, 7w and 7s), service provision is expressed relative to the size of the population. For MDG 2, the treatment is slightly more complex. The arguments in Table 4.20 determine the shares of children that enter basic school (out of the cohort of 6-year olds) and successfully complete their current grade (among those enrolled in the first basic cycle). The shares that repeat their current grade or drop out from it are determined residually. The service level is measured per enrolled student – an indicator of educational quality. MDG 4 is included as a proxy for the health status of those enrolled. Wage incentives – an indicator of payoffs from continued education – are expressed as the ratio between the wages for labor at the next higher and the current levels of education.

83 Sensitivity analysis for the elasticities shows that the overall qualitative results do not change. In addition to the primary education elasticities shown in Table 4.20, the database includes the same set of data points for the higher educational levels (except for that no continuation rate is defined for tertiary education, this being a terminal level).

For the secondary and tertiary cycles, the same set of arguments enter functions that determine the shares of enrolled students that pass as well as the shares of graduates from the previous cycle that enter the first grade of these two cycles. The only differences are that the arguments for services (per enrolled student) and wage incentives are redefined to be relevant to these higher cycles and that no continuation rate is defined for the tertiary cycle (as it is viewed as a terminal cycle).

MAMS typically focuses on the net (on-time) primary completion rate as its main MDG 2 indicator; the net enrolment rate, which is the official indicator, is a less informative measure of the extent to which the relevant age group is able to complete the six-year primary cycle.[84] More specifically, in any year, the net completion rate is defined as the share of the students that would complete primary school on time if this year's net intake and grade promotion rates were to prevail during the coming six years.[85] In addition, MAMS reports other indicators related to the primary cycle, the gross enrollment rate and the gross completion rate; the latter is used by the World Bank as an alternative MDG 2 indicator.

Generally speaking, the functions for educational outcomes and the other (i.e. non-education) MDGs have all been calibrated to ensure that, under base-year conditions, base-year indicators are replicated and that, under a set of other conditions identified in the *Yemen Needs Assessment Report* (see MOPIC, 2005), the target is fully achieved. Specifically, the *Yemen Needs Assessment Report* provides estimates of government sectoral spending needs (current and capital) for the period 2006—2015, which are used to calibrate the logistic functions in the MDG module of MAMS.

Finally, the MAMS Poverty Module was calibrated under the assumption that the household income distribution follows a log-normal distribution (see Section 4.4). Specifically, a poverty rate of 42.4% for 2010 and a Gini coefficient of 0.411 were used (see Government of Yemen *et al.*, 2007; MOPIC, 2011); these two pieces of information were used to estimate the shape of the log-normal distribution and the value of the poverty line. As explained, this approach assumes that the income distribution within the representative household does not change over time.

84 According to the UN Millennium Declaration, the primary schooling target is to "ensure that, by the same date [2015], children everywhere, boys and girls alike, will be able to complete a full course of primary schooling and that girls and boys will have equal access to all levels of education" (http://www.un.org/millennium/declaration/ares552e.htm).

85 Mathematically, $NPCR_t = NIR_t \cdot (PR_t)^{\gamma}$, where $NPCR$ = net primary completion rate, NIR = net intake rate ($0 \leq NIR \leq 1$), PR = promotion rate ($0 \leq PR \leq 1$) and γ = number of grades in the primary cycle. As a simplification, MAMS assumes a uniform PR for all primary grades. This is a period measure; the corresponding cohort measure would use the relevant rates over a six-year period.

4.7.2.3 Implementation of simulations

This section presents the simulations while the next analyzes their results. The first simulation (base) is a "business as usual" scenario, which reflects current policies and trends. Taking this base scenario as a benchmark, the other simulations consider different alternatives for creating and using fiscal space.[86] This set of simulations was designed with the aim of capturing what may be feasible once Yemen has emerged from the current political impasse. In these simulations, more fiscal space is created through exogenous increases for foreign aid or government efficiency. The government makes use of the resulting addition to fiscal space to expand spending and service delivery in infrastructure and human development. Specifically, the following simulations were implemented:

- **aid-hd**: an increase in transfers from the rest of the world to the government so that they reach an average of US$69 *per capita* for the period 2011−2015, close to the average for low income countries in 2007 − aid *per capita* is increased from US$13.7 in 2010 to US$71.4 in 2011 and US$66.7 in 2015. In terms of GDP, aid reaches an average of around 10% for the period 2011−2015. The increase in government receipts is used to finance an increase in government consumption of (demand for) MDG-related services (primary education, health and water and sanitation). In addition, post-primary education also expands sufficiently to keep the same educational quality (defined as real spending per enrolled student) as in the base scenario as the sector faces increases in the number of graduates from primary school.
- **aid-infra**: similar to the previous scenario, but the increase in government spending is used to finance an increase in the public infrastructure capital stock.
- **eff-hd**: gains in the allocative efficiency of government spending via a 50% cut in the growth rate for other government expenditures (i.e. expenditures not related to human development or infrastructure) during 2011−2015 with an expansion in human development-related spending sufficient to make use of the resulting fiscal space. Thus, we assume that cost savings are realized through efficiency gains such as elimination of overlapping government functions and/or of functions that do not contribute to production in other areas.
- **eff-infra**: similar to the previous scenario but the increase in government spending is used to finance an increase in investment in public infrastructure.

The non-base simulations only deviate from the base for the period 2011−2015; during the period 2004−2010, the baseline scenario is designed to capture the main developments of the Yemeni economy. For these simulations, an underlying assumption is that

[86] In Abdulmajeed *et al.* (2011), simulations are used to assess the changes in government spending that would be needed to achieve the MDGs as well as the economy-wide effects of pursuing such an MDG strategy; their main finding is not surprising considering the magnitude of the MDG challenge: full, on-time, MDG achievement does not appear a realistic objective. In fact, the authors estimate that the required financing is unlikely to be available and, if it were, it would be extremely challenging for the government to bring about the required increases in real service delivery without strong sacrifices in efficiency.

the conflict that erupted in 2011 can be resolved promptly, permitting Yemen's government to assume its developmental functions at a level of efficiency that is similar to what has prevailed in the past.

4.7.2.4 Analysis of results

4.7.2.4.1 Base scenario

This section concentrates on the period 2011—2015. As explained, during the period 2004—2010, the baseline scenario is designed to capture the main developments of the Yemeni economy. The non-base simulations only deviate from the base for the period 2011—2015.

For the base scenario, which serves as a benchmark for comparisons, we impose the observed growth rates in real GDP at factor cost for the period 2005—2010, and an average growth of 5.2% starting from 2011, based on projections from the *Fourth Five-Year Socio-Economic Development Plan for Poverty Reduction 2011—2015.* The exogenous part of TFP growth is adjusted to generate such a growth path. GDP growth is endogenous for all non-base scenarios. In addition, we impose a decrease in the exploitation of the natural resource factor in the oil and gas extraction sector; this reflects the recent evolution and prospects of the oil and gas sector in Yemen.

In the base scenario, government consumption of education and non-education services is kept fixed as a share of absorption (total domestic final demand) at the base-year value. Transfers from government to households are kept fixed as a share of GDP. Tax rates are fixed over time, while the amount spent on commodity subsidies (basically, refined oil products) decreases gradually between 2011 and 2015, according to official projections. The ratio between domestic government debt stock and GDP increases from 10% in 2004 to about 17% during 2011—2015; domestic borrowing is adjusted accordingly. The foreign debt-to-GDP ratio increases from 30% in the base year to 33.6% in 2015, being 23% in 2009. These assumptions generate results that are consistent with recent trends (see Central Bank of Yemen, 2010).

For the base, the government fiscal account is balanced via adjustments in foreign borrowing. The base assumption for private investment is that it is fixed as a share of domestic absorption; given this, adjustments in private savings clear the savings—investment balance (i.e. savings is investment-driven). Across all simulations, the real exchange rate equilibrates inflows and outflows of foreign exchange by influencing export and import quantities. The non-trade-related payments in the balance of payments (transfers and foreign investment) are non-clearing, determined by their own rules — exogenous shares of GDP are assumed. The CPI is the model numéraire.

The rule for keeping the government account in balance is modified for non-base simulations; the counterfactual model closure rule assumes that adjustments in public spending on human development or infrastructure clear the government budget. In addition, for non-base scenarios, private investment adjusts endogenously to maintain balance between total savings (from different sources) and total investment (i.e. the model becomes savings-driven). Consequently, the model will capture the crowding-out of private investment when domestic sources of financing are used to achieve the MDGs trough increased government spending.

Among factor stocks, growth is driven by investment and depreciation for the different capital types, by a combination of demographic factors and the functioning of the educational system for the different labor categories and by an exogenous growth rate for natural resources used in the oil extraction sector. For the different types of government capital, markets are not specified; however, it is required that investment be sufficient to ensure that stocks grow at the same pace as the services that are produced. For other factors, flexible wages (or rents) clear the markets. For the different labor types, the model replicates observed unemployment rates in the base year. In other years, the unemployment rate and the wage will typically both change following a "wage-curve" formulation (see Section 4.4); declines in the unemployment rate will be combined with wage increases and *vice versa* unless unemployment is at the minimum level (set at 5%), at which point wage movements will clear the labor market in question; for the other factors with wage-clearing, supply curves are vertical leaving the adjustments to the demand side.

In the base scenario, the economy evolves according to recent trends, with most macro aggregates growing at 5–6% per year, at the upper end of this range for public consumption and investment and at the lower end for exports. Relative to GDP, export and import decrease. *Per capita* household consumption grows at a rate of 1.9% per year. The exchange rate depreciates over time, reflecting the decrease in (real) oil exports. As explained, the foreign debt-to-GDP ratio reaches 33.6% in 2015 – a level that is within the range observed for other countries at Yemen's income level. This increase in foreign borrowing brings about a net improvement in the non-trade balance (in foreign currency) and an increase in the trade deficit (also in foreign currency). However, the decline in oil exports is so large that some depreciation is still required to keep the trade deficit within the permitted limit.

As a result of growth in GDP, government service provision and household *per capita* consumption, the indicators for MDG 2 (completion of primary education), 4 (under-5 mortality rate), 7w (water access) and 7s (sanitation access) as well as poverty, all improve (see Table 4.21).[87] However, Yemen is not on track to achieve any of these MDGs by the 2015 deadline. Figure 4.11 shows the 2015 targets and the paths over time for the different MDGs.

87 The tables and graphs that follow are automatically generated by ISIM-MAMS – the Excel Interface for MAMS.

Table 4.21 Yemen simulation results

	2004	Base scenario	Non-base scenarios			
			aid-hd	aid-infra	eff-hd	eff-infra
Macroeconomic aggregates	**Billion YR[a]**	**Percent average annual growth rate, 2010–2015**				
Absorption	2536	4.9	7.1	7.3	4.9	5.0
Consumption—private	1691	4.3	5.5	5.3	4.4	4.3
Consumption—government	326	6.0	11.1	6.4	6.4	3.5
Fixed investment—private	274	4.6	6.3	6.0	4.7	4.6
Fixed investment—government	263	7.5	11.3	19.1	6.7	10.8
Exports	931	2.2	−0.3	1.3	2.0	2.7
Imports	909	3.7	6.2	7.2	3.6	4.1
GDP at factor cost	2635	5.2	5.7	6.1	5.2	5.3
Total factor employment (index)		2.9	3.7	4.2	2.9	3.0
Total factor productivity (index)		2.3	1.9	1.9	2.3	2.3
Real exchange rate (index)		2.2	−0.1	0.7	2.2	2.5
Government consumption	**Billion YR[a]**	**Percent average annual growth rate, 2010–2015**				
Water and sanitation	0.1	5.2	22.8	5.2	15.7	5.2
Other infrastructure	0.2	5.6	5.6	18.3	5.6	11.1
Health	19.6	5.4	23.0	5.4	15.9	5.4
Basic education (grade 1–6)	55.8	4.7	22.3	6.2	15.3	5.3
Basic education (grade 7–9)	16.0	6.9	9.7	7.8	8.2	7.2
Secondary education	19.5	7.0	7.5	7.7	7.1	7.3
Tertiary education	18.0	7.0	8.1	7.4	7.3	7.0
Other government	196.3	6.2	6.2	6.2	1.7	1.7
Total	325.4	6.0	11.1	6.4	6.4	3.5
MDG indicator[b]	**Value**	**Value in 2015**				
MDG 1: Poverty rate[c]	42.4	39.2	36.1	36.6	38.9	39.0
MDG 2: Net completion rate in basic education	16.8	55.2	88.7	70.4	78.9	62.4
MDG 4: Under-5 mortality rate	93.4	64.6	52.1	59.3	57.8	63.2
MDG 7w: Access to safe water	43.9	48.2	49.0	49.3	48.4	48.5
MDG 7s: Access to improved sanitation	15.9	24.1	25.5	26.9	24.4	24.9

[a]YR = Yemeni Rials.
[b]Units: % for MDG 1, 2, 7w and 7s; per 1000 for MDG 4.
[c]Base year is 2010.
Source: Authors' estimates.

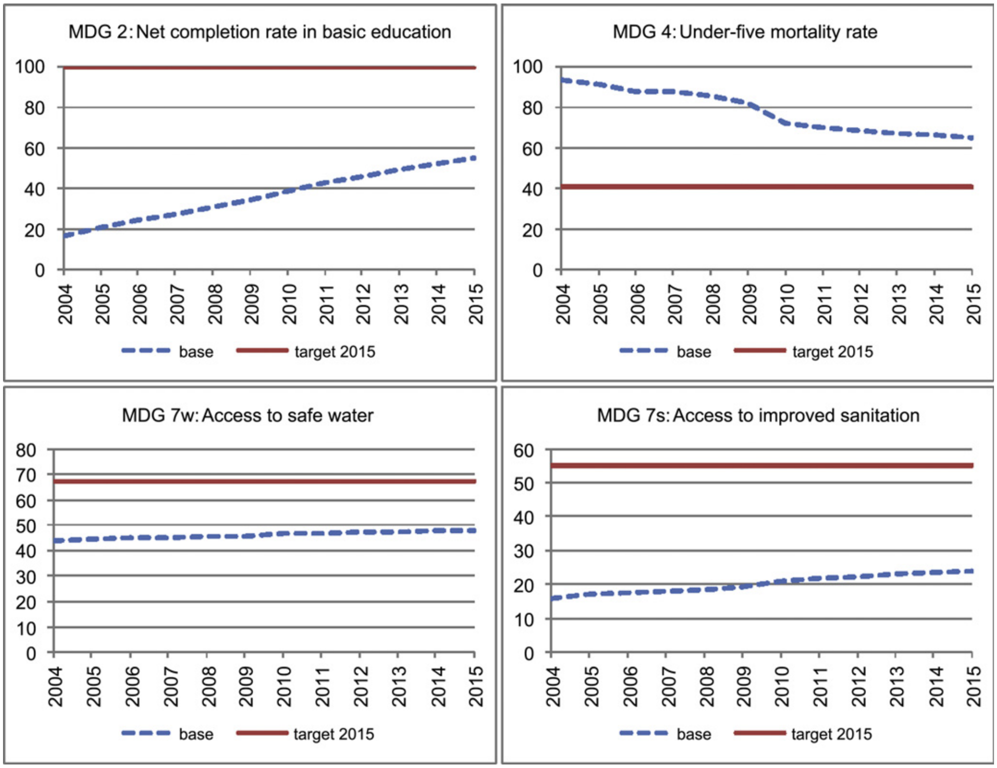

Figure 4.11 MDG targets and paths, 2004–2015.

4.7.2.4.2 Aid scenarios

In the scenarios **aid-hd** and **aid-infra**, foreign transfers are increased to around 10% of GDP during 2011–2015. In the **aid-infra** scenario, GDP growth gains 0.9 percentage points and is accompanied by expansion, not only in government demands, but also in private consumption and private investment as additional infrastructure stocks permit private incomes and savings to grow more rapidly with a positive feedback into the growth process (see Table 4.21). The appreciation of the real exchange rate strengthens this process by adding to domestic purchasing power. It represents a response to the fact that, due to the aid, Yemen is now able to have a more negative trade balance, importing more and/or exporting less. As described in Sundberg and Lofgren (2006) for the case of Ethiopia, such aid-induced "Dutch Disease" effects can be a serious concern if, in the future, these trade deficits are unsustainable and if the economy becomes locked into a structure that is unable to expand production of tradables. However, these concerns should be weighed against the benefits of foreign aid, indicated by the simulation results.

For the **aid-hd** scenario, the acceleration of growth in GDP is weaker – the GDP growth rate increases by 0.5 percentage points. MDG 2, 4, 7w and 7s all improve more strongly, as government consumption of primary education, health and water and sanitation increases. The average GDP share of government current and capital spending in MDG-related commodities reaches 10.5% during 2010—2015, starting from the 4.5% for the baseline scenario. The additional public spending in education and health (i.e. scenario **aid-hd**) has a positive impact on the relative demand for skilled workers, pushing up their relative wage. In fact, the wage gap between skilled and unskilled workers is (on average) 11% higher than in the base scenario — this result reflects a bottleneck in the form of a shortage of highly educated labor (e.g. teachers and nurses) to provide these services. In the long run, beyond 2015, the end-year of our simulations, however, the combination of increased education spending and high wages for highly educated labor, both of which make it attractive for students to remain in school and obtain secondary and tertiary education degrees, would lead to an increase in the supply of highly educated labor and a decreasing wage gap between skilled and unskilled workers.

In the **aid-infra** scenario, infrastructure spending promotes growth and the MDGs. Infrastructure has a direct positive impact on education and health MDG indicators because it facilitates the delivery of these services (e.g. more infrastructure lowers the cost of getting to schools for both teachers and students). There is also an indirect effect through higher growth — higher *per capita* income increases private demand for education and health services.

In both aid scenarios, the 2015 poverty rate is lower than for the baseline, mainly as a result of a decrease in unemployment, a higher average wage, a decrease in the wage gap between unskilled and semi-skilled labor and an increase in non-labor income. Moreover, the poverty effect would be larger if a multidimensional measure of poverty were considered instead of only monetary poverty.

In this set of scenarios, it is important to consider the tradeoff between the eventual competitiveness loss caused by aid induced "Dutch Disease" and the long-term gains of improving MDGs.

4.7.2.4.3 Efficiency scenarios

For the **eff-infra** scenario, annual growth in GDP accelerates by 0.1 percentage points. The government reallocates spending from consumption to investment, as infrastructure is more capital-intensive than other government services. MDG 2, 4, 7w (water) and 7s (sanitation) all improve. For the **eff-hd** scenario, the acceleration of growth in GDP is weaker (i.e. positive, but less than 0.1 percentage points). The government provision of primary education, health and water and sanitation services grows 5.7 percentage points more than in the base scenario. Certainly, this expenditure shift helps to promote the MDGs. The resulting improvements are stronger for MDG 2 and 4 and less so for MDG 7w and 7s. By 2015, the poverty rate is 0.3 percentage points lower than for the base.

Interestingly, the simulations show that spending on human development is better for poverty reduction than spending on infrastructure, in spite of more rapid GDP growth in **aid-infra** and **eff-infra** compared to **aid-hd** and **aid-infra**, respectively. This result reflects that, relatively speaking, the human development scenarios benefit labor incomes and that labor is owned by the households, whereas the infrastructure scenarios benefit capital and natural resource incomes, which to a significant extent are owned by the government and the rest of the world. As a consequence, in the infrastructure scenarios an important share of income leaks into spending that has a weaker link to household consumption and poverty reduction.

Overall, according to our results, under "business-as-usual" conditions up to 2015, Yemen will not reach the targets for the MDGs that are covered by our analysis. However, important improvements can be achieved if additional resources are spent on infrastructure and/or human development without losses in efficiency. In addition, progress can also be made if government spending efficiency is improved. Under some of the scenarios (**aid-hd** and **aid-infra**), there is a "Dutch Disease" effect, which may harm growth in the production of tradables during the period of these simulations. In future analysis, it would be important to assess the effects of different policies over a longer time horizon, in particular considering the fact that indicators related to human development should lead to stronger gains in future decades.

4.7.3 Summary of insights from MAMS applications

The MAMS country applications may be divided into two groups, with the first focused on an analysis of requirements and general equilibrium repercussions of pursuing full achievement of key MDGs by 2015 and the second being more eclectic, but typically looking at the impact of alternative scenarios for public spending (in terms of total resource envelopes and sector priorities), financing (domestic and foreign) and efficiency of public service production and delivery. The Yemen analysis presented above belongs to the second group.

With regard to MDG strategies, the many applications confirm that initial country conditions are the major determinant of whether achievement of the MDGs is feasible or not. For countries, like Ethiopia, for which full MDG achievement would require progress at speeds that go far beyond the historical record of virtually any other country, on-time achievement would accordingly require rates of expansion in grant aid and government services that seem infeasible, at least without a serious deterioration in government efficiency and would create imbalances between government and private sector growth (Lofgren and Diaz-Bonilla, 2008). This outcome is a reflection of the manner in which the targets are defined, and suggests that countries in this category may be better off pursuing poverty and human development targets that are home-grown, reflecting the initial situation, government priorities and plausible scenarios for foreign aid and domestic resource mobilization (*cf.* Easterly, 2009). At the other end of the spectrum of developing countries, comparative cross-country analysis of MAMS results for countries in the Latin America and Caribbean region (which tend to be more middle income) indicate that, even if the prospects for achieving each MDG vary considerably across countries, the required additional financing (which often has to be domestic) of well-conceived programs (covering human development services and infrastructure) are relatively modest and feasible, especially in settings with good income growth for the poorer groups in the population (Vos *et al.*, 2010, pp. 9—12).

Across the board, the second, eclectic group of applications has generated relatively uniform findings related to sectoral allocation of government spending, domestic versus foreign financing, foreign aid and "Dutch Diseases" and government efficiency. These insights may be summarized as follows:

- *Spending on human development versus infrastructure.* The findings in this area indicate that: (i) Marginal changes in infrastructure spending tend to have a more positive impact on production and income growth than human development (i.e. health, education and water—sanitation) spending, especially within a shorter time frame (e.g. within the next five years); (ii) while strategies that on the margin expand spending on human development tend to have more positive human development outcomes than scenarios expanding infrastructure spending, the fact that they tend to generate reduced growth in household incomes noticeably mitigates the gains in human development outcomes while reducing the pace of poverty reduction; and (iii) a relatively balanced expansion of government spending in multiple areas with identified gains (especially public infrastructure and human development services) tend to generate overall outcomes that seem more attractive to policy makers. Such scenarios may also be more feasible politically since they permit a larger number of government functions to expand in real terms, albeit at different rates.
- *Income distribution.* A major short- to medium-run effect of scenarios focused on scaled-up human development spending is a switch in relative wages in favor of the more educated, reflecting that an expansion of health and education sectors leads to a disproportionate increase in demand for relatively educated labor. A byproduct of such scenarios is a general increase in the wages of educated labor throughout the economy (also in the private sector), putting sectors that are intensive in educated labor at a relative disadvantage. In the long run, this relative-wage switch may be reversed as scaled up education spending raises the supply of educated labor, giving rise to the opposite long-run challenge of absorbing rapidly growing highly educated labor stocks with acceptable wage growth, something that requires rapid economic growth and structural changes that, in different sectors, permit productive use of more educated labor.

- *Domestic financing versus foreign aid*. Reliance on domestic financing (taxes or borrowing) to cover rapid expansions in government spending on human development tends to give rise to difficult tradeoffs between the poverty and non-poverty MDGs as the former tend to suffer while the latter gain, reflecting the reallocation of resources from private demand (consumption and investment) to government demand. Reliance on grant aid for marginal financing makes it easier to address these tradeoffs; whether receipt of sufficient additional grant aid is likely or not depends on country context.
- *Foreign aid and "Dutch Disease"*. Whether foreign aid expansion leads to "Dutch Disease" effects is an empirical question, primarily depending on the marginal import share of government spending. "Dutch Disease" effects may be stronger for scenarios that emphasize human development spending given that human development sectors are relatively non-traded, with domestic wages representing a large share of input costs, whereas investment spending often has a large import share. The symptoms of "Dutch Disease" are a decline in export growth and an increase in import growth. Whether this should be viewed as a disease depends on whether, in the future, an export/import growth reversal is both needed and difficult to bring about.
- *Government efficiency (allocative and productive)*. Simulations suggest that improvements in allocative efficiency, via seemingly feasible marginal reallocations over time of government resources from areas with little or no return to human development and/or infrastructure can lead to noticeable improvements in performance. The same applies to increases in productive government efficiency in different areas of service delivery except for that it is difficult to assess the extent to which such efficiency improvements are feasible.

These findings have been generated by a consistent framework that incorporates a fair amount of economic behavior. They also seem intuitive, supported by basic economic logic. Nevertheless, given the complexity of these issues and uncertainty about parameter values, it is important not to take the exact quantitative results at face value but rather to view the results as aids to thinking that should be cross-checked against insights based on other methods and pieces of analysis. The development of streamlined validation procedures could add to our confidence in the results generated by MAMS and other CGE models.

4.8 CONCLUSION

This chapter presented MAMS, a CGE model created for strategy analysis in developing countries: the context in which it was developed, its design features, mathematical structure, database and user-friendly interface. In our discussion of applications, we survey the countries and issues that have been covered and summarize the findings generated, also including a detailed presentation of a Yemeni case study. In addition to the policy-relevant findings, the MAMS experience has also taught lessons of broader relevance to policy-oriented CGE modeling:

- Contrary to frequent assertions, our experience confirms that applications of CGE-based policy analysis are not necessarily time-consuming or high-cost.[88] Model-based analysis would be very costly if, for every study, a new model were built from scratch. However, this is rarely done and should in effect only be done as part of a training program. Data intensity and time needed for data work are highly dependent on the issues addressed, country context and previous experience. We find no reason to think that it is significantly different for CGE modeling compared to other approaches that try to respond to a similar set of questions. Advances in data availability and computational technology should permit streamlining of the development of the bulk of the required datasets.
- Instead of starting new applications using a relatively unchanging bare-bones model, productivity of model-based analysis can over time be enhanced significantly if a framework is applied repeatedly and gradually enhanced as part of a learning process. The benefits may include reduced coding time; fewer and more easily corrected errors (as corrections are carried over to subsequent work and diagnostic checks can be built into the code); higher payoffs from the development of supporting materials (such as manuals and interfaces).
- When interacting with clients in governments and elsewhere, the relevance and persuasiveness of the analysis often depends on the ability of the model to replicate data (frequently expressed in terms of real growth or GDP shares) for years more recent than the model base year and, as a starting point for the analysis, to generate scenarios that match those of other frameworks (e.g. International Monetary Fund projections). In order for this to be feasible, the CGE model must include a wide range of alternative rules for defining payments and related quantities (if any). Similarly, in order to be able to address fiscal policy questions in a flexible manner, it is important to be able to quickly draw on a wide range of alternative clearing mechanisms for the government budget, covering individual or combinations of receipt or spending items.
- The relatively extensive skill set that is required (economics, policy, software and programming) remains a major barrier in the way of a fuller exploitation of the potential of CGE modeling as workhorses for the analysis in areas

[88] For example, World Bank (2003, p. 82 and 88) states that the time required to do analysis with a CGE model ranges from "a few months to a year, depending on the existence of a SAM, or of another CGE model built to address a different [sic] question" and, with specific reference to a CGE model with representative households along the lines of Lofgren *et al.* (2002), that "between six months and a year is needed to collect data and work with simulations …."

where they have a comparative advantage (*cf.* the roles of the IS-LM and monetary programming models of Hicks and Polak, respectively, in open-economy macro analysis). In order to permit policy analysts to focus on economics, policy and communication, other requirements should be minimized. One promising avenue may be the development of applications that permit the conduct of simulation analysis over the internet without requiring installation of (or familiarity with) specialized software. This would require fuller exploitation of advances in computational technology and internet-based communication as well as increased division of labor and teamwork among researchers.

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