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MULTIMOD Mark III

The Core Dynamic and Steady-State Models

Douglas Laxton, Peter Isard,
Hamid Faruqee, Eswar Prasad, and Bart Turtelboom

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The following symbols have been used throughout this paper:

. . . to indicate that data are not available;

n.a. to indicate not applicable;

— to indicate that the figure is zero or less than half the final digit shown, or that the item does not exist;

– between years or months (e.g., 1994–95 or January–June) to indicate the years or months covered, including the beginning and ending years or months;

/ between years (e.g., 1994/95) to indicate a crop or fiscal (financial) year.

"Billion" means a thousand million.

Minor discrepancies between constituent figures and totals are due to rounding.

The term "country," as used in this paper, does not in all cases refer to a territorial entity that is a state as understood by international law and practice; the term also covers some territorial entities that are not states, but for which statistical data are maintained and provided internationally on a separate and independent basis.

Preface

This study, prepared in the Economic Modeling and External Adjustment Division (EMEAD) of the Research Department, describes the Mark III version of MULTIMOD, the IMF's multiregion macroeconometric model. The development of MULTIMOD Mark III resulted from a major effort during 1997 to incorporate several basic changes into the Mark II version. Douglas Laxton, senior economist, took command of the project and is largely responsible for the work that has been done. Peter Isard, Division Chief, interacted closely with Laxton, both in the ongoing decision-making process that accompanied the technical work and in managing the preparation of this paper. Hamid Faruqee was integrally involved in developing the analytic framework that underpins the new specification of consumption and saving behavior, and in drafting Section V. Bart Turtelboom contributed significantly to the development of the investment equations and prepared Section VI. Eswar Prasad prepared Sections VII and VIII.

The Mark III version retains many of the features of earlier versions of MULTIMOD. It thus reflects substantial past work on the Mark II version by Paul Masson, Steven Symansky, and Guy Meredith, and on the Mark I version by Masson, Symansky, Richard Haas, and Michael Dooley. As Deputy Division Chief of EMEAD from 1987 to November 1995, Symansky also contributed to a series of refinements of the core Mark II model, along with the development of several extended versions of the Mark II model. Similarly, Meredith continued to work on MULTIMOD after completion of the initial version of Mark II, contributing to the foundations for the Mark III investment function. Masson and Meredith provided numerous constructive comments on an initial draft of this study, as did Peter Clark and Thomas Krueger.

To an important extent, the conceptual improvements in the Mark III version reflect feedback from users outside the IMF. We are particularly grateful for comments and encouragement received from Ralph Bryant, John Helliwell, and Assaf Razin. Others outside the IMF have contributed importantly in more technical ways. We thank Richard Black for help with programming the macro used to derive the steady-state analogue model; Michel Juillard and Peter Hollinger for their efforts in developing a reliable solution algorithm for solving forward-looking models; Hope Pioro for general programming assistance and help in creating the computer modeling system; and Irene Chan for work on the database.

Within the IMF, the construction of the Mark III model and the preparation of this study involved extensive research assistance from Susanna Mursula and Dirk Muir, who provided outstanding support. Norma Alvarado and Helen Hwang also played major roles in the project, preparing the manuscript and shepherding it carefully toward publication. Elisa Diehl of the External Relations Department edited the study and coordinated its production. The authors alone are responsible for the shortcomings of the model and its analysis; the opinions expressed are theirs and do not necessarily reflect the views of the IMF.

I Introduction

Overview

MULTIMOD (MULTI-region econometric MODel) was initially designed to analyze the macroeconomic effects of industrial country policies on the world economy. Since it was first described and documented by Masson and others (1988), the model has been extended in a number of directions, primarily for the purpose of increasing its usefulness in assisting with the IMF's multilateral surveillance over the policies of its members. A first set of revisions and extensions of the model, leading to MULTIMOD Mark II, was described by Masson, Symansky, and Meredith (1990). A number of additional changes have subsequently been implemented and were recently consolidated into MULTIMOD Mark III.

This paper describes the Mark III generation of MULTIMOD and its key properties in a manner intended to be intelligible to a wide spectrum of macroeconomists. It includes a discussion of the evolution, philosophy, and basic structure of the model (Section II), sections on the major innovations in the core version of MULTIMOD Mark III (Sections III–VII), and a discussion of several extensions of the model and the applications for which they have been developed (Section VIII). A summary description is provided in Box 1. Other boxes present selected simulations describing the responses of macroeconomic variables to different types of shocks; see table of contents. The results of additional "standard simulations" that can be performed on the model (and compared with Mark II simulations)—as well as a technical guide to MULTIMOD that will be of interest primarily to economists engaged in constructing and simulating structural macroeconometric models—will be provided on the IMF's internal Web site and will be released at some point on its external Web site (http://www.imf.org). The Web sites will also be used as vehicles for disseminating information in a timely manner about future extensions of MULTIMOD. It is anticipated that MULTIMOD will continue to evolve over time, not only as a reflection of ongoing efforts to refine the behavioral equations of the model, but also to incorporate changes in the core set of countries and country groups.[1]

What's New?

Macroeconometric models evolve for at least four reasons. The first simply reflects the fact that the initial stages of model construction necessarily involve simplifications, and the passage of time provides opportunities for specification improvements and extensions of coverage. A second reason is that the leading issues for macroeconomic policy evolve with the performance of economies and the thinking of economists, challenging the model builder to anticipate and adapt. A third reason is that access to new or more extensive data sets facilitates the empirical evaluation of behavioral hypotheses. And fourth, advances in computer hardware and software, and in algorithms for solving large nonlinear systems of equations, continue to loosen the technical constraints on the scale and complexity of the models.

The Mark III version of MULTIMOD differs from its predecessor in several important respects. New features include a core steady-state analogue model, a new model of the inflation-unemployment nexus, an extended non-Ricardian specification of consumption-saving behavior, and improved specifications and estimates of investment behavior and international trade equations. In addition to these changes in model specification, the introduction of a new solution algorithm has greatly increased the robustness, speed of convergence, and accuracy of the simulations and made it easier to develop certain modified versions of MULTIMOD that were difficult to solve with the Mark II algorithm.

Because the theoretical foundations of MULTIMOD include the premise that economic agents

[1]Work on a more extensive disaggregation of the developing and transition economies is under way, and changes in the core set of industrial countries and country groups will be required in the context of European Economic and Monetary Union.

Box 1. MULTIMOD: Summary of the Mark III Generation

MULTIMOD is a dynamic multicountry macro model of the world economy that has been designed to study the transmission of shocks across countries as well as the short-run and medium-run consequences of alternative monetary and fiscal policies. It has several variants, the current versions of which are referred to as the Mark III generation. The core Mark III model includes explicit country submodels for each of the 7 largest industrial countries and an aggregate grouping of 14 smaller industrial countries. The remaining economies of the world are then aggregated into two separate blocks of developing and transition economies. Extended versions of MULTIMOD include separate submodels for many of the smaller industrial countries, and work has been initiated on expanding the analysis of the developing and transition economies.

The basic structure and properties of MULTIMOD are meant to represent well-established views about how modern industrial economies function and interact with each other. A consistent theoretical structure is employed for all industrial economies, and cross-country differences in the behavior of agents (or the functioning of markets) are reflected in different estimated parameter values. The model converges to a balanced-growth path that is characterized by a full stock-flow equilibrium in which debtor countries service the interest payments on their net foreign liabilities with positive trade balances.

The MULTIMOD modeling system includes a well-defined steady-state analogue model for each country and for the world economy as a whole. These steady-state models serve two roles. First, they are used to construct terminal conditions for the dynamic models. Second, they can be used to study the long-run effects of shocks that have permanent consequences for saving, capital formation, output, real interest rates, real exchange rates, and so on. The basic structure of MULTIMOD is simple enough that it is fairly straightforward to estimate additional country models for the smaller industrial economies.

Despite the focus on medium- and long-run properties, MULTIMOD also exhibits important short-run Keynesian dynamics that result from significant inertia in the inflation process. The MARK III generation features a nonlinear relationship between unemployment and inflation that reflects short-run capacity constraints and insider-outsider influences on wage setting. The asymmetric property of the Phillips curve provides a fundamental role for stabilization policies that is absent from linear models of the business cycle.

MULTIMOD assumes that behavior is completely forward looking in asset markets and partially forward looking in goods markets, but it is possible to study the effects of shocks under alternative assumptions about expectations formation and the degree of policy credibility. The model is solved with state-of-the-art simulation algorithms that have been designed specifically for such systems of equations.

Consumption-saving behavior is based on an extended Blanchard-Weil-Buiter paradigm in which

form their expectations in a forward-looking manner, the medium- and long-run properties of the model have an important influence on its predictions of the short-run responses to exogenous policy adjustments or other shocks. In this connection, one of the important new features of the Mark III generation is its more appealing approach to defining the long-run properties of the model's baseline path. As noted in Section II, the database for MULTIMOD simulations consists of the projections over a five-year horizon from the IMF's *World Economic Outlook*. In constructing a baseline path for MULTIMOD Mark II, the projected behavior of economic variables beyond that horizon was constrained to be consistent with the simplifying assumptions that primary fiscal and trade balances converge gradually to zero (thereby gradually stabilizing the stocks of public and international debt relative to GDP) and that the real rate of interest converges to the steady-state rate of growth.

These assumptions are not imposed in constructing baselines for MULTIMOD Mark III. Instead, as described in Section III, the projected behavior of economic variables beyond the five-year horizon of the *World Economic Outlook* is tied to terminal conditions determined endogenously and consistently from a system of steady-state analogue equations, SSMOD. Among other things, SSMOD has the property that the real interest rate exceeds the rate of growth,[2] and so MULTIMOD is now capable of providing a more appealing characterization of the macroeconomic effects of fiscal adjustments and a richer analysis of sustainability issues.

MULTIMOD Mark II did not focus explicitly on the unemployment rate and characterized inflation simply in terms of the GDP deflator, with no atten-

[2]A no-Ponzi-game condition—that asymptotically the real interest rate must exceed the growth rate—is often imposed in optimizing models that are used for policy analysis; see, for example, the discussions of basic infinite-horizon models and overlapping-generations models in Blanchard and Fischer (1989). In MULTIMOD, the difference between the steady-state levels of the real interest rate and the growth rate depends on the parameters of the production function, the rate of depreciation, the rate of time preference, and the level of world government debt.

agents are assumed to have finite planning horizons. The model has been extended to allow for realistic age-earnings profiles and for the fact that a significant proportion of consumption is constrained by disposable income insofar as households are unable to borrow against future labor income streams.

Investment behavior is based on Tobin's *q* theory, according to which the desired rate of investment exceeds the steady-state rate as long as the expected marginal product of capital is greater than its replacement cost. The model allows for significant adjustment costs.

MULTIMOD has a standard specification of import and export behavior that embodies the notion that countries trade in diversified products. Import volumes are a function of the main components of aggregate demand, with import contents of the different components calibrated on the basis of information from input-output tables. Exports are modeled to approximately represent the mirror image of the foreign import demand functions.

Exchange rates and interest rates are related by an adjusted interest parity condition that can allow for persistent risk premiums. MULTIMOD provides a fundamental role for the real exchange rate, both in equilibrating aggregate demand and supply in the goods market and in ensuring that flow relationships are consistent with consumers' desired rates of asset accumulation. The short-run properties of the model to some extent mimic the properties of the Dornbusch overshooting model insofar as asset market prices are free to jump, while wages and other prices are characterized by stickier intrinsic and expectational dynamics.

The fiscal policy instruments include government absorption, distortionary capital taxes, and nondistortionary labor taxes (labor supply is exogenous). In the core version of MULTIMOD, government absorption is exogenous and the aggregate tax rate is endogenized to ensure that the ratio of government debt to GDP converges to a target level. However, in the short run, it is possible to treat all three fiscal instruments as exogenous variables.

Given the forward-looking nature of MULTIMOD, the fundamental role of the monetary authorities is to provide an anchor for inflation expectations. This can be accomplished in many ways. Options available in the core version of Mark III include fixed exchange rates, money targeting, inflation targeting, and nominal income targeting.

MULTIMOD has not been designed to be a forecasting tool. The baseline corresponds to the medium-term *World Economic Outlook* projections, which reflect the detailed knowledge and judgments of the IMF's country economists. These medium-term projections are then extended into a model-consistent balanced-growth path where the real interest rate is greater than the world real growth rate.

MULTIMOD is available to the public and can be obtained through e-mail to multimod@imf.org.

tion to the consumer price index (CPI). This has now changed, giving MULTIMOD several other new features. In particular, as described in Section IV, Mark III includes a new model of the inflation process. The domestic GDP deflator is determined by an expectations-augmented Phillips curve, and the CPI is determined by a weighted combination of the prices of domestically produced goods and the prices of imported goods. The Phillips curve relationship is asymmetric around the natural rate of unemployment, which has important implications for the design of macroeconomic stabilization policies.

Thanks to a debate rekindled by Barro (1974), it has become widely appreciated over the past two decades that the effects of fiscal policy on macroeconomic behavior in a forward-looking model depend on the extent to which the private sector expects that public sector imbalances will be evened out over time, so that an increase in the current fiscal deficit, for example, can be anticipated to imply a higher future tax burden, other things equal. However, the sensitivity of private sector behavior to policy adjustments can also depend importantly on factors other than the nature of expectations. In this regard, a second new feature of MULTIMOD Mark III is the manner in which the specification of consumption-saving behavior reflects the composition of wealth, the finite life cycles of households, and constraints on the ability of households to borrow against their future lifetime income streams. In Mark II, private consumption was assumed to be directly proportional to the sum of human wealth (that is, discounted after-tax labor income) and financial wealth, with human wealth discounted over an infinite horizon. In Mark III, the hypothesized behavior of private consumption has been modified in several respects, as described in Section V, embodying the assumptions that individual households optimize their consumption-saving behavior over finite lifetimes and face liquidity constraints on their abilities to borrow against future income. The two key parameters of the new consumption-saving model—the intertemporal elasticity of substitution and the share of consumption that is sensitive to disposable income—are estimated from the time-series properties of consumption after a realistic structure is imposed on life-cycle age-earnings profiles obtained from cross-sectional data.

The macroeconomic effects of policy actions or other exogenous shocks depend importantly on the responsiveness of aggregate demand to interest rates and exchange rates. Accordingly, finding realistic specifications for the behavior of investment and international trade volumes and, in particular, capturing their sensitivities to interest rates and exchange rates are key challenges in macroeconomic modeling. In this regard, MULTIMOD Mark III reflects efforts to improve the specifications of both the investment and the trade equations, as described in Sections VI and VII.

II The Philosophy and Basic Structure of MULTIMOD

What does fiscal consolidation imply for domestic output growth and inflation, and what are the spillover effects on other economies? To what extent do the macroeconomic consequences depend on whether fiscal consolidation is achieved through expenditure reductions or tax increases? How do the reactions of monetary authorities influence the outcomes? How sensitive are the effects of fiscal consolidation to the magnitude of the associated changes that take place in market interest premiums, which reflect, inter alia, the "market's" degree of confidence about the prospects for macroeconomic stability? How should monetary authorities react, in the absence of constraints on their discretion, to an unexpected decline in the saving rate or to the loss of productive capacity associated with a natural disaster? How do different forms of monetary policy "rules" compare in terms of their implications for the expected levels and variances of output growth and inflation rates? These are some of the issues that central banks and other policy authorities confront in their attempts to promote price stability and macroeconomic growth.

Over the past several decades, a number of policymaking institutions and academic researchers have developed macroeconometric models to help shed light on such issues.[3] These models provide frameworks that can take account of many aspects of macroeconomic behavior simultaneously, allowing model builders to explore the implications of their preferred theories of economic behavior while also imposing macroeconomic consistency on the analysis.

[3]Among the earliest of these models, each focusing on only a single economy, were Klein and Goldberger (1955), Klein and others (1961), and Duesenberry and others (1965). Bryant, Hooper, and Mann (1993) provides descriptions of, and references to, a number of the multicountry macroeconometric models that are currently in use; see also Edison, Marquez, and Tryon (1987), Gagnon (1991), Helliwell and others (1990), McKibbin and Sachs (1991), and Meredith (1989).

Philosophical Underpinnings

Considerable variety has emerged in the underlying philosophies and basic structures of the macroeconometric models that different modeling groups have chosen to develop. Among other things, this variety has reflected differences in three related considerations: the importance attached to short-term forecasting among the possible purposes that the models have been constructed to serve; the assumptions that have been adopted in the treatment of expectational variables; and the attitudes that model builders have taken toward the Lucas critique (see Lucas, 1976)—that is, toward the possibility that the coefficients in econometric equations may be altered by changes in policy regimes.

MULTIMOD has been designed to assist the IMF with its multilateral surveillance over the macroeconomic policies of member countries, but not to provide short-term forecasts. As such, its main purpose is to analyze how the effects of policy actions are transmitted over the medium term with particular interest in the analysis of actions by countries where policy adjustments have relatively large spillover effects on the world economy.

Unlike models that are designed to generate their own forecasts of a set of endogenous variables based on historical data and assumptions about the future evolution of various exogenous variables, MULTIMOD incorporates an externally generated baseline forecast of the world economy that reflects the detailed knowledge and judgments of the IMF's country economists. The baseline forecast is updated on a regular basis in association with the process of preparing the IMF's semiannual *World Economic Outlook* reports.[4] Once the baseline forecast is specified, MULTIMOD can be used to ana-

[4]The procedure for making a system of estimated equations consistent with an externally generated baseline forecast essentially involves solving for, and imposing, a set of residuals under which the estimated model generates the baseline solution. Strictly speaking, the *World Economic Outlook* baseline projects only over a five-year horizon. The manner in which the baseline path is extended beyond this horizon is discussed in Section III.

lyze the effects on that baseline of scenarios that involve changes in policies in major countries or certain other exogenous changes in the macroeconomic environment.

Because MULTIMOD is designed to analyze how a prespecified baseline forecast would be affected by policy changes or other exogenous shocks, the model can abstract from many of the special factors that are often present in forecasting models, and that likewise need to be taken into consideration in generating the *World Economic Outlook* projections that provide the judgmental baseline for MULTIMOD.[5] The ability to abstract from many special factors subsumed in the baseline forecast endows MULTIMOD with the virtue of simplicity, which is an attractive characteristic. Simplicity makes it easier to comprehend and assess the results of model simulations and also reduces the computer capacity and time required to solve the model.

Models that are relied upon to generate short-term forecasts are sometimes constrained to adopt compromises in specification forms—including in their treatment of expectational variables—for purposes of improving their accuracy as short-term forecasting tools. MULTIMOD has not been so constrained; its component equations have been estimated in forms that can be regarded, for the most part, as structural equations derived from models of optimizing behavior.[6]

The treatment of expectations in macroeconometric models has been an area of considerable controversy. The main alternative to assuming that expectations are forward looking and model consistent is to base the specification of expectations on backward-looking regressions of relevant variables on historical values of themselves and other variables. Most models, including MULTIMOD Mark III, incorporate a mixture of the two extremes,[7] but typically with a strong inclination toward one extreme or the other. Advocates of adaptive backward-looking expectations, who tend to place high priority on short-term forecasting accuracy, have argued that macroeconometric models with model-consistent expectations perform relatively poorly in replicating the observed persistence and variability in business cycles. This argument is not very forceful, however, for models like MULTIMOD, in which inflation expectations reflect a mixture of backward-looking and model-consistent (forward-looking) elements, since such models are capable of generating large and persistent business cycles. Advocates of model-consistent expectations argue that their models are less vulnerable to the Lucas critique than models with backward-looking expectations. The validity of this criticism, however, is also difficult to judge. Those who reject it point out that the Lucas critique is simply "a possibility theorem, not an existence theorem," claiming that an "extensive search of the literature reveals virtually no evidence demonstrating the empirical applicability of the Lucas critique" (Ericsson and Irons, 1995, p. 39).

We are not comforted by the latter argument. It is easy to derive nonsensical policy implications from mechanical simulations of any model that embodies a reduced-form specification of inflation expectations, particularly when the latter specification does not include a forward-looking model-consistent component. For example, models that embody a Phillips curve and the assumption that inflation expectations are entirely backward looking, which is convenient and fairly common in the macroeconometric models used by central banks and other national authorities,[8] can lead mechanically to policy inferences that are inconsistent with the implications of the long-run natural rate hypothesis (LR-NRH). Indeed, a number of economists have argued that faulty logic, associated with the use of macroeconomic models that embodied backward-looking inflation expectations and thereby failed to provide a channel for "regime changes" to affect inflation expectations realistically, was largely responsible for excessive monetary accommodations in the 1970s.[9]

[5]Indeed, in many contexts the effects of shocks, measured as deviations from the baseline path, are largely independent of the specific baseline forecast.

[6]Loosely speaking, the main criteria for incorporating an estimated equation specification are that the specification should be based to a large extent on underlying theory and should not generate an unrealistic degree of macroeconomic variability when embedded into the MULTIMOD system of equations. Thus, in comparison with models for which short-term forecasting accuracy is a high priority, MULTIMOD has been estimated with a relatively low willingness to sacrifice theoretical foundations in order to obtain better goodness of fit.

[7]See Helliwell (1993). Model-consistent expectations appear to be relatively more attractive for asset markets, and adaptive expectations more popular for markets with greater inertia in price adjustment.

[8]For example, the Federal Reserve Board's FRB/Global Model (see Levin, Rogers, and Tryon, 1997) relies on backward-looking ("limited-information") expectations as its base case, although it can also be simulated under the assumption of model-consistent expectations.

[9]Among those who blame misleading economic theories for the "great inflation" in the United States in the late 1960s and 1970s, Taylor (1996, p. 184) notes that during that period, "the idea that there is a long-run Phillips curve trade-off began to appear in textbooks, newspapers, and even the *Economic Report of the President*; the inflation cost of an overheated economy, according to this theory, was simply a higher rate of inflation, not rising inflation." Studies by economic historians, such as De Long (1996), add support for this view by rejecting the alternative hypothesis that supply shocks (especially oil price shocks) were the main source of the rise in inflation. Taylor also emphasizes the coincidence in timing between the monetary disinflation of the 1980s and the incorporation into macroeconomics of more reasonable models of expectations and price adjustment, attributable largely to research started by Lucas (1972).

MULTIMOD has fixed weights on backward- and forward-looking components for inflation expectations, which reflects an attempt to separate intrinsic dynamics (in particular, the inertial effects of wage-price contracting lags) from expectational dynamics.[10] This specification can also lead mechanically to nonsensical policy inferences, which makes it incumbent upon model users to reflect on the appropriateness of the fixed-weight specification for the type of analysis that is being undertaken and perhaps to vary the weights (to capture credibility effects) in certain policy experiments. For example, under a mechanical application of MULTIMOD that treated announced inflation targets as completely credible (that is, that set inflation expectations equal to the announced inflation targets), a Ponzi-game policy of announcing future disinflation but repeatedly postponing the implementation could generate the nonsense result of a free lunch—a drop in inflation with no loss of output or an opportunity to lower interest rates and achieve both inflation reduction and output gains. Although the scope for such nonsense could be reduced by replacing the fixed-weight specification of inflation expectations with a model in which expectations reflected the credibility of monetary policy, appropriately defined, at present macroeconomists do not have a firm understanding of how such a model should be specified.

The treatment of inflation expectations, with a positive weight on model-consistent forward-looking expectations, makes MULTIMOD consistent with the LR-NRH. This gives MULTIMOD the property of money neutrality: money supply or price level shocks have no effect on the steady-state values of real variables, other things equal. To a close approximation, MULTIMOD also exhibits monetary superneutrality: as long as inflation rates remain moderate, changes in the rate of growth of the money supply have almost no effect on the steady-state values of real variables.[11]

While MULTIMOD's formulation of inflation expectations attempts to capture the inertial effects of wage-price contracting lags, as well as forward-looking elements, the core version of Mark III uses pure forward-looking model-consistent solutions for exchange rate and interest rate expectations in the interest parity equation and the term structure equations. The assumption that asset-market expectations are completely model consistent is unrealistically strong, although at this stage we regard it as more attractive than the available alternatives.[12] However, Mark III has been coded in a manner that allows users to modify the treatment of expectations; it is straightforward to model exchange rate and interest rate expectations as blends of backward- and forward-looking components and to allow for time-varying weights in modeling inflation expectations.

The long-run properties of models with forward-looking expectations have been difficult to study in the absence of steady-state analogue models. With the arrival of Mark III, such a steady-state analogue model has now been developed for MULTIMOD,[13] as described in Section III. The steady-state model can be used both as an interpretive device for understanding long-run comparative statics and to determine model-consistent terminal conditions for dynamic analysis.

Simulations of Mark III—which involve simultaneous solutions of both the steady-state model and the dynamic model—can be regarded as follows. The solution to the steady-state model represents a position of simultaneous stock and flow equilibrium. Loosely speaking, households determine the steady-state level of wealth, firms determine the stocks of physical capital, governments determine the levels of their debts, and, for each country (or block of countries), the reconciliation of these stock positions comes through the net foreign asset position. In this context, the reconciliation of stocks and flows in the long-run steady state, both within countries and for the world as a whole, imposes conditions on the steady-state levels of real exchange rates and interest rates. Real exchange rates must be consistent with generating the trade and current account flows that are associated with steady-state stocks of net foreign assets (or ratios of net foreign assets to GDP), while the level of interest rates must be consistent with global balance between saving and investment or, equivalently, with global consistency between net foreign asset stocks and current account flows.

The solution of the dynamic model describes the evolution of macroeconomic variables en route to full stock and flow equilibrium. Given the long-run equilibrium values of the endogenous variables in

[10]By intrinsic macroeconomic dynamics, we mean those dynamics that may be assumed to be invariant to the types of policy experiments that are being considered. Of course, for enormous changes in policy rules, contract length as well as the degree of nominal indexation may change, and it then becomes difficult to determine precisely what is structure. However, by assuming that inflation expectations partly reflect the model-consistent solution, MULTIMOD at least makes some attempt to control for the first-order effects of the Lucas critique.

[11]The departure from strict superneutrality reflects the fact that MULTIMOD embodies an "inflation tax."

[12]In this regard, analysis of how rational agents form expectations when it takes time to learn about the nature of various policy changes and other exogenous shocks remains an important area for additional research.

[13]In this respect, the methodology for solving MULTIMOD Mark III is similar to that for solving the Bank of Canada's Quarterly Projection Model—see Laxton and Tetlow (1992) and other references cited in Section III.

MULTIMOD, as determined from the steady-state analogue model, the time paths of the endogenous variables are determined by solving the dynamic model under the assumption of model-consistent forward-looking expectations.[14] The solution process involves an iterative procedure that imposes consistency between the model's final solution values for the endogenous variables and its simultaneous solutions for the values of ex ante expectations about these variables.

History and Country Disaggregation

The development of MULTIMOD was a continuation of work on a precursor model known as MINIMOD (see Haas and Masson, 1986). The precursor model was disaggregated into two regional blocks—the United States and an aggregate rest-of-the-industrial-world region—with the equations for each region based on the same theoretical framework. The parameters of MINIMOD were obtained not by direct estimation but rather by simulation of a more extensive model with a quarterly database.

Unlike MINIMOD, MULTIMOD is largely estimated and uses annual data. The first published version of MULTIMOD (see Masson and others, 1988) divided the world into seven blocs: the United States, Japan, Germany, an aggregate of the other Group of Seven industrial countries, an aggregate of the remaining industrial countries, a group of high-income oil-exporting developing countries, and an aggregate of the remaining developing countries. This country disaggregation reflected both the priorities that were attached to modeling the effects of policy changes in the largest countries, which tend to have the greatest spillover effects on the world economy, and the relatively limited availability of data for developing countries. For the same two reasons, the models for the developing country blocs were specified with relatively little detail on monetary and fiscal policy variables, but with emphasis on trying to capture realistically the behavior of the current account positions of these blocs in order to be able to impose a realistic consistency constraint on world saving and investment.

The country disaggregation in MULTIMOD has been extended over time. Both the Mark II and the core Mark III versions include separate models for each of the Group of Seven countries, an aggregate of the remaining industrial countries, and the two groups of developing countries. As an alternative to treating the industrial countries other than the Group of Seven as a single bloc, a modified version of the Mark II model, which includes 14 individual European countries, has been developed for analyzing issues relating to the European Union.[15] By contrast, only limited analysis has been conducted with the two developing country blocs. Apart from redefining the bloc of high-income oil exporters,[16] the aggregation scheme for the developing and transition economies remains the same as in the Mark I version.[17]

Commodity Disaggregation and Behavioral Units

MULTIMOD can be regarded as a slight modification of a model in which each industrial country (or bloc of industrial countries) produces a single differentiated product—its "main composite good," which is perceived to be an imperfect substitute for other countries' main composite goods. The industrial country models disaggregate oil from total production and absorption, but oil production for these countries is treated as exogenous and most macroeconomic variables of interest are not significantly affected by the behavior of oil consumption. The main developing country model, as well as the international trade accounts, distinguishes among three categories of tradable goods—main composite goods, oil, and primary commodities other than oil—and, in addition, the main developing country block includes nontradables as a fourth category of goods.[18] The inclusion of explicit behavioral hypotheses about production (or net exports) of oil, primary commodities, and nontradables in the main developing country model, along with an explicit hypothesis about the availability of external finance to the main group of developing countries, adds important elements of reality to MULTIMOD's characterization of the aggregate current account position of the developing countries and, thus, the equal and

[14]As noted earlier and elaborated in Section V, inflation expectations are only partially forward looking.

[15]See Masson and Symansky (1992), Masson and Turtelboom (1997), and the discussion in Section VIII below.

[16]In Mark III, the group comprises six high-income oil exporters—Kuwait, Libya, Oman, Qatar, Saudi Arabia, and United Arab Emirates—corresponding to the *World Economic Outlook* group of capital-exporting developing countries. The work program for the near future includes redefining the aggregation scheme for the nonindustrial economies and enhancing the models of their macroeconomic behavior.

[17]A modified version of the Mark II model disaggregates the main developing country bloc into four separate groups: Western Hemisphere, Africa, the group of four newly industrialized economies, and an aggregate of the other non-oil developing countries. See Bayoumi, Hewitt, and Symansky (1995) and the discussion in Section VIII below.

[18]The group of net creditor developing countries is assumed to produce only oil.

opposite aggregate current account position of the industrial countries.

Each of the industrial country models is structured around five types of behavioral units: households, firms, nonresidents, the fiscal authorities, and the monetary authorities. Households supply labor, consume domestically produced and imported goods, and accumulate wealth. Firms hire labor, invest, and produce output for domestic and foreign markets. Nonresidents engage in international trade and financial borrowing and lending with domestic residents. The fiscal authorities control the level of government spending, choose a target trajectory for government debt, and set tax rates consistent with government spending and the debt target. The monetary authorities guide short-term nominal interest rates according to postulated reaction functions that may be specified in a variety of ways.

The Supply Side and the Unemployment-Inflation Nexus

Many of the macroeconometric models that are currently employed in policymaking institutions include well-articulated supply sides along with Phillips curve relationships that hypothesize a short-run trade-off between inflation and unemployment while also embodying the restrictions of the long-run natural rate hypothesis (that is, the hypothesis of no long-run trade-off). Most of these cases, however, incorporate *linear* short-run Phillips curves, which are difficult to reconcile with observed asymmetries in labor market data, and which also substantially weaken the rationale for short-run stabilization policies. By contrast, the core Mark III version of MULTIMOD includes *nonlinear* Phillips curves.

As in Mark II, the Mark III production function for each country's main composite good is specified as a Cobb-Douglas relationship between capacity output and two factor inputs—the labor force and the real net capital stock—with a constant growth rate of total factor productivity. The labor supply is exogenous, and the solution for the unemployment rate reflects, inter alia, the short-run Phillips curve and equations that describe the dynamic evolution of inflation expectations and the nonaccelerating inflation rate of unemployment (NAIRU); see Section IV for further discussion.

Consumption, Investment, and International Trade

The demand side of the industrial country models is largely described in Sections V–VII, which focus respectively on the behavior of consumption, investment, and international trade in countries' main composite goods. The supplies of, and demands for, oil and primary products in industrial countries, and the structure of the developing country models, are described later in this section.

The aggregate consumption function for the main composite goods (Section V) is based on an optimizing model of life-cycle behavior. The main variables explaining a country's consumption are its human wealth (the expected discounted value of current and future after-tax labor incomes plus any transfers from the government) and its nonhuman wealth (physical capital plus claims on the government plus net foreign assets).[19] Individual consumers are assumed to have model-consistent expectations about their future after-tax income streams, but also to have finite lives. The latter property implies that fiscal policy actions have non-Ricardian effects on the economy. The model incorporates a nonlinear relationship between labor earnings and age (estimated from data for the United States), in which an individual's relative earnings rise in the early part of his working life and subsequently decline. In the core version of Mark III, it is assumed that households face liquidity constraints on their abilities to borrow against their future incomes, which augments the non-Ricardian properties of the model.[20]

Investment demand (Section VI) is modeled in the spirit of Tobin (1969), extended by allowing for adjustment costs, with the net change in the capital stock reflecting the gap between the market value of existing capital and its replacement cost. Gross investment equals net investment plus depreciation, where the rate of depreciation is exogenous.

The volume of imports of main composite goods (Section VII) depends on both relative prices and a measure of domestic activity. The activity variables used in the Mark III trade volume equations (unlike the normal unweighted measures used in many trade equations, including the Mark II specifications) are weighted sums of the components of ag-

[19]The discount rate that enters the calculations of human and nonhuman wealth includes the exogenous rate of population growth and the after-tax interest rate applicable to saving (the nominal riskless rate of interest plus a premium that reflects both the credit risk on personal income and the probability of death).

[20]As discussed in Section V, the issue of whether fiscal policy has non-Ricardian effects continues to be actively debated as an empirical proposition. The rationale for adopting the Mark III consumption-saving specification in a model used for policy analysis comes partly from the appeal of the theoretical framework, but also reflects a balancing of the prospective welfare costs of type 1 and type 2 policy errors. Fiscal policy actions based on erroneous prescriptions from a non-Ricardian model when the "true model" was Ricardian would presumably tend to be less costly than fiscal policy inaction based on erroneous analysis with a Ricardian model when the "true model" was non-Ricardian.

gregate domestic absorption (that is, private consumption, private fixed investment, and government expenditure) and exports, where the weights reflect import propensities calculated from recent input-output matrices for each country. In reality, for many countries, the data show large differences among the import shares of the different expenditure components, and for these cases this new feature of the trade volume equations can significantly enhance the plausibility of MULTIMOD's analysis of the macroeconomic effects of changes in government expenditure. In addition to their dependence on domestic absorption, import volumes are related to the ratio of the import price deflator to the deflator for non-oil GNP.

For purposes of consistency, MULTIMOD specifies each country's export volume equation in a form that broadly resembles the import volume equations of its trading partners. In particular, export volumes are related to two variables. The first is a foreign activity variable, defined as a weighted average of foreign-country import volumes (where the weights reflect the base-period shares of the home country's exports accounted for by the foreign countries or country groups). The second variable is a real competitiveness index, defined as a weighted sum of the logarithms of export prices of a country's trading partners relative to home-country export prices (where the weights capture the sensitivity of home-country exports to competition in third markets from foreign countries). The latter price measure is based on the IMF's Information Notice System trade weights.[21]

Fiscal Policy: Government Spending, Taxes, and Debt

For each industrial country, the basic fiscal policy instruments in MULTIMOD are generally specified as the level of real government spending, a basic tax rate defined as the ratio of total tax revenues to nominal GDP, and the tax rate on capital income.[22] The effective tax rate on labor income can be derived from the basic tax rate and the tax rate on capital income; a number of other fiscal variables—including the budget balance and the stock of government debt—are constructed from the spending and tax rate variables through various definitional identities.[23] When simulating the effects of fiscal policy changes, the fiscal variables need to be adjusted in a consistent manner. This is illustrated in Box 2, which examines the spillover effects of a 10 percent increase in government debt that is generated by temporarily reducing taxes by 2 percent of GDP for five years.

The settings of the fiscal policy instruments are not based on estimated behavioral equations. In most simulations, however, the behavior of the basic tax rate is governed by a reaction function (or feedback rule) with imposed parameters. The inclusion of such a reaction function is intended to preclude unrealistic model solutions in which the stock of government debt grows without bound relative to GNP.[24] The specification in the core Mark III model (which is unchanged from the Mark II specification) assumes that the basic tax rate is adjusted in response to both the level of, and the change in, the gap between the actual ratio of government debt to GNP and an exogenous target ratio of government debt to GNP.[25] The parameters of the reaction function, which were originally chosen on the basis of earlier work that studied the dynamics of MINIMOD (see Masson, 1987), are set at levels that make the model stable and, in particular, that tend to induce the ratio of government debt to GNP to return to its baseline path over the horizon typically used for model simulations. By changing the specification and parameters of this feedback rule, MULTIMOD can be applied to study and compare the stabilizing properties of different types of fiscal policy reaction functions.

Monetary Policy

MULTIMOD can be simulated under a variety of monetary policy reaction functions. The Mark III model treats short-term nominal interest rates as monetary policy instruments and can accommodate interest rate adjustment rules that are consistent with either fixed exchange rate bands, money targets, inflation targets, nominal income targets, or other macroeconomic objectives, including combinations of inflation and output or employment objectives.

For many applications, it has been traditional to include two different forms of monetary policy reaction functions in simulations of MULTIMOD Mark II.

[21]Measures of nominal and real effective exchange rates are also constructed in MULTIMOD using the IMF's Information Notice System weights (for a description of these weights, see McGuirk (1987) and Zanello and Desruelle (1997)).

[22]For the developing country blocs, the public and private sectors are essentially treated as an aggregate, with no separation between government spending and private spending and no explicit treatment of taxes.

[23]One of the modified versions of MULTIMOD (see Section VIII) includes indirect taxes as well as the direct taxes on labor and capital incomes.

[24]For some purposes, it is appropriate to "turn off" the tax rate reaction function and to allow debt to accumulate under a constant basic tax rate.

[25]See the discussion in Masson, Symansky, and Meredith (1990), pp. 11–12.

For France, Italy, and the aggregate of industrial countries that are not part of the Group of Seven, the monetary authorities have been assumed to adjust short-term interest rates in response to movements in their exchange rates vis-à-vis the deutsche mark. For the United States, Japan, Germany, the United Kingdom, and Canada, the monetary authorities have been assumed to adjust short-term interest rates in response both to the gap between a target for the stock of money and its actual value and to the gap between potential output and actual output.

Although money targeting is no longer widely practiced among industrial country central banks, the traditional reaction function specifications remain the "default option" for the core Mark III model and are the basis for most of the illustrative simulations presented in this paper.[26] These traditional specifications can easily be modified by model users. The reason that they remain in the core model is that we have not yet been able to undertake the detailed country-by-country analysis that seems warranted before replacing the present default options with a new set of specification forms and parameter values.[27]

It is widely recognized that, in reality, the macroeconomic effects of unexpected shocks can depend importantly on how policymakers react. Consistently, the effects of shocks in MULTIMOD depend intimately on the assumptions about monetary policy reaction functions, so that any "quantification" of multipliers in MULTIMOD is conditional on the nature of the monetary policy response. Box 3 illustrates the degree to which key government expenditure multipliers in the Mark III model are sensitive to the nature of monetary policy reaction functions.

Partly in light of such sensitivity and because we intend to change the reaction functions in the core model over the next year or so, we provide only a limited set of simulation results in this paper. However, interested readers can find a more extensive set of "standard simulations" at the MULTIMOD Web sites, and can compare these Mark III simulations with analogous Mark II simulations reported in Appendix I of Masson, Symansky, and Meredith (1990).[28]

[26]As with the fiscal policy feedback rules, the parameters of these monetary policy reaction functions are imposed, with parameter values set at levels that make the model stable.

[27]We plan to undertake such an analysis over the next year in conjunction with regrouping some of the industrial countries in the context of European Economic and Monetary Union.

[28]To the extent that the Mark III and Mark II models embody the same reaction functions, comparisons of "standard simulations" of the two models can be revealing. However, for models with forward-looking expectations, which take account inter alia of the nature of policy behavior, the optimal forms of monetary policy reaction functions are model specific, and one can question the meaningfulness of comparing standard simulations of models with either different optimal policy reaction functions or common suboptimal reaction functions.

Money supplies in MULTIMOD are described by a single monetary aggregate for each industrial country—the monetary base—which includes both currency and the reserves of commercial banks held with the central bank.[29] The estimated money demand equations relate (the logarithm of) real money balances—the monetary base divided by the absorption price deflator—to (the logarithm of) real domestic absorption and the short-term nominal interest rate. The money demand equations for the industrial countries were estimated jointly (see Masson, Symansky, and Meredith, 1990, pp. 12–13). These equations affect the macroeconomic responses to shocks only in cases in which monetary policy reaction functions are assumed to involve interest rate adjustments in response to deviations of money supplies from target paths.

Oil, Primary Commodities, and Nontradables

MULTIMOD recognizes that the performance of the world economy can be affected considerably by changes in the prices of oil or non-oil primary commodities and also that net exports (or imports) of these goods can be important components of the external balances of individual countries and country groups. In contrast to its treatment of main composite goods, for which each country is assumed to produce a differentiated composite, MULTIMOD assumes that oil and non-oil primary commodities are each homogeneous goods with a single world market price. The price of oil is treated as exogenous, while the price of primary commodities is perfectly flexible and varies endogenously to clear the market.

The global supply of oil is assumed to be perfectly elastic at the world market price. Oil production by each of the industrial countries, however, is treated as exogenous (perfectly inelastic), whereas production by the two developing country blocs is assumed to respond passively to the global demand for oil at the given price, with the net exports of each of the two blocs providing a fixed proportion of the excess of industrial country demand over industrial country supply.[30]

[29]Neither of the developing country models contains a monetary sector.

[30]These assumptions, which are retained from the Mark I model, are consistent with the paradigm that the Organization of Petroleum Exporting Countries sets the price of oil and serves as residual supplier. It may be noted that inventories of oil are not explicit in the model; changes in inventories are implicitly included in consumption.

Box 2. The Spillover Effects of Government Debt

Increasing international financial integration has expanded the markets in which governments can sell their debt. In principle, this development provides greater scope for governments to smooth taxation and spending and for countries to smooth consumption over time in the face of temporary shocks. But capital market integration also implies that the fiscal policies of one country will affect other countries. In a world with highly integrated capital markets, a country that issues an amount of debt that is globally significant will thereby raise real interest rates throughout the world and crowd out private investment in all countries. An important policy implication is that countries that issue large stocks of debt not only may reduce their own living standards, but also may impose significant spillovers on other countries by pushing up the world real interest rate.

Recent empirical evidence has found significant effects of world government debt on real interest rates. (See, for example, Tanzi and Fanizza, 1995; and Ford and Laxton, 1995.) This is consistent with other empirical evidence suggesting that government deficits reduce national and world saving because consumers increase their saving by less than the full amount of the future taxes that will be necessary to finance the higher level of debt. As a consequence, there will be a tendency to overconsume available resources, with resulting higher real interest rates and a lower world capital stock. This tendency to overconsume available resources in the short run by reducing the capital stock also lowers the sustainable level of consumption in the long run.

Box 9 provides a more extensive discussion of the aggregate crowding-out effects of the buildup in government debt in the industrial countries, along with estimates suggesting that there could be very significant benefits for the world economy if governments reduced their debts. Here, we focus on the spillover effects of one country's debt on living standards in other countries.

To illustrate, the table presents estimates of the own-country effects and spillover effects that would be associated with a temporary five-year tax cut that increases the debt-to-GDP ratio of the United States by 10 percentage points.[1] Specifically, taxes are reduced by 2 percent of GDP for five years, and then allowed to rise to stabilize the debt-to-GDP ratio at a steady-state level that is 10 percentage points higher than the baseline level.[2] The simulations are based on monetary policy reaction functions that broadly resemble the policy environment of the early 1980s, with monetary targets in Canada, Germany, Japan, the United Kingdom, and the United States and fixed exchange rates (versus the deutsche mark) in France and Italy.

As seen in the table, in the short run, lower taxes result in strong expansion of real consumption and GDP in the United States, with positive spillover effects on the world economy. With higher real interest rates, however, capital accumulation slows in both the United States and other industrial countries, and by year 4 real GDP levels are below baseline, with steady-state GDP 0.3 percent below baseline in the United States and 0.4 percent below baseline in other industrial countries. Steady-state consumption is 0.7 percent below baseline in the United States and 0.2 percent below baseline in other industrial countries, reflecting the effects of lower per capita real income. The long-run effects on consumption are larger in the United States because net foreign assets fall in the United States and rise in the other countries.

[1]To put the size of this shock into perspective, the ratio of net debt to GDP of the United States increased from an average of 26 percent during 1978–80 to 56 percent in 1995; see International Monetary Fund (1996).

[2]This is implemented through adjustment of the basic tax rate on nominal GDP, holding constant the tax rate on capital income. In the steady state, the basic tax rate must exceed the baseline level to finance the increased interest burden that results from higher government debt and higher interest rates.

The specification of oil consumption by industrial countries is based on estimates, using pooled data, of an error-correction model in which the same long-run and short-run price elasticities and long-run activity elasticities are imposed across all countries. The short-run responses of oil consumption to activity, as measured by GDP, are allowed to differ across countries. The long-run elasticity with respect to GDP is constrained to be unity, while the long-run elasticity with respect to the relative price of oil (that is, the ratio of the price of oil to the country's GDP deflator) is estimated to be less than unity (in absolute value). The specifications and estimated coefficients are described in more detail in Masson, Symansky, and Meredith (1990, pp. 6–7).

MULTIMOD includes the production of non-oil primary commodities, which represents only a small share of the aggregate output of the main developing country group (but is relatively important for some regions within this group). Output (and exports) of primary commodities by the main developing country bloc reflects productive capacity, which is treated as perfectly inelastic in the short term but responsive over time to changes in relative price (or, implicitly, to changes in the profitability of production).[31] The industrial countries and the high-income oil export-

[31]The paradigm is a crop harvest or production from mines, where individual producers are too small to influence the price and where the marginal costs of expanding contemporaneous supply are infinite.

Effects of a Five-Year Temporary Tax Cut That Permanently Increases the Debt-to-GDP Ratio of the United States by 10 Percentage Points

	Year 1	Year 2	Year 3	Year 4	Year 5	Steady State
Real GDP						
United States	0.7	0.3	—	–0.1	–0.1	–0.3
Other industrial countries	0.3	0.1	–0.1	–0.1	–0.1	–0.4
Capital stock						
United States	—	–0.2	–0.4	–0.6	–0.8	–1.2
Other industrial countries	—	–0.1	–0.2	–0.3	–0.3	–1.2
Real interest rate (10-year)						
United States	0.6	0.6	0.6	0.5	0.4	0.1
Other industrial countries	0.2	0.2	0.2	0.2	0.2	0.1
Consumption						
United States	1.3	1.1	0.9	0.9	1.0	–0.7
Other industrial countries	0.4	0.2	—	–0.1	–0.2	–0.2
Unemployment rate						
United States	–0.3	–0.2	–0.1	—	—	—
Other industrial countries	–0.1	–0.1	—	—	—	—
GNP deflator						
United States	0.3	0.7	1.2	1.6	1.8	0.8
Other industrial countries	–2.3	–2.1	–1.8	–1.4	–0.7	1.6
Net foreign assets						
United States	0.1	—	–0.2	–0.4	–0.7	–5.6
Other industrial countries	0.4	0.4	0.5	0.6	0.7	2.9
Real exchange rate						
United States	2.2	2.2	2.1	1.8	1.2	–0.9
Other industrial countries	–1.0	–1.0	–0.9	–0.8	–0.5	0.5

Note: In percent deviations from baseline for all variables except the real interest rate and unemployment rate, which are percentage point deviations from baseline.

ing countries are treated as if they do not produce primary commodities.[32] The industrial country consumption (and import) equations for primary commodities are based on an error-correction model that regresses the change in imports on (current and lagged) changes in GDP and relative prices, as described in more detail in Masson, Symansky, and Meredith (1990, pp. 7–8). The price of primary commodities is perfectly flexible and clears the market.

For the main developing country bloc, MULTIMOD also identifies a composite nontradable good. Insofar as these countries are assumed to face a balance of payments financing constraint (described below), the presence of a nontradables sector is important for capturing the expansionary effects of export growth. The demand for nontraded goods in the main developing country bloc reflects an assumption that consumption and investment are split (in endogenously determined proportions) between nontradables and other goods. Output of nontradables is assumed to be perfectly elastic (entirely demand determined) at an exogenous price; there is no capacity constraint on nontradables production, and there is assumed to be sufficient slack in the developing country economies to increase the output of nontradables without shifting resources out of other sectors. Without such scope to expand the production and

[32]Implicitly, any actual outputs and exports of primary commodities by the industrial countries are aggregated with their outputs and exports of the main composite goods.

Box 3. Government Expenditure Multipliers Under Alternative Monetary Policy Reaction Functions

This box illustrates the effects of an increase in government expenditure under alternative assumptions about monetary policy. The simulations are conducted on the Japan bloc of the model. The specific experiment that we consider is a permanent increase in government expenditures of 1 percent of baseline GDP[1] that results in a 10 percentage point increase in the ratio of government debt to GDP. For the first 10 years of the shock, tax rates are held fixed; in the eleventh year, the basic tax rate is allowed to rise to stabilize the debt-to-GDP ratio. The main point of the box is that there is no such thing as a pure fiscal shock; the short-term effects of fiscal policy depend intimately on the reaction of the monetary authorities. To illustrate, we consider three possible assumptions for monetary policy: exchange rate targeting, inflation targeting, and money targeting. In each case, we assume that the authorities rely on a short-term interest rate as the instrument to adjust in pursuing their target.

Money targeting and exchange rate targeting can be implemented in Mark III by specifying the following reaction function,

$$rs_t = rs_{t-1} + \alpha(m_t - m^*_t) + \beta(er_t - er^*_t),$$

where rs is the short-term nominal interest rate, m is the level of money balances (in logs), er is the nominal exchange rate, and the asterisks denote the desired levels of money balances and the nominal exchange rate. A fixed exchange rate can be imposed by choosing a very large value for β and setting α equal to zero. Similarly, it is possible to keep money balances close to their desired levels by setting β equal to zero and choosing an appropriate value for α. For the case of money targeting, we have chosen a value for α that keeps money balances close to desired levels but does allow small deviations from the targets in the short run.

[1]Because of the nonlinear properties of Mark III, the effects of fiscal shocks depend on whether the economy is initially in excess demand or supply. These simulations were conducted on a baseline that assumes that output is equal to potential.

For present purposes, we define inflation targeting broadly as a rule that adjusts the short-term nominal interest rate in response to changes in expected inflation and movements in both the inflation rate (π_t), and the output gap (y_t), where inflation is measured using the GDP deflator. This is implemented with the following equation,

$$rs_t = rr^*_t + \pi^e_t + \mu(\pi_t - \pi^*_t) + \nu(y_t - y^*_t)$$

where rr^*_t, π^*_t, and y^*_t are the baseline values for the real interest rate, the inflation rate, and the output gap, and π^e_t is the level of inflation expectations. For illustrative purposes, we focus on the case $\mu = \nu = 1$.[2]

The table reports the shock-minus-control values for real GDP, money balances, the short-term interest rate, the nominal exchange rate, and the GDP deflator. Under each of the three reaction functions, the shock has positive short-run effects on real GDP and the GDP deflator, although the magnitudes of these effects depend on the particular reaction function. Under fixed exchange rates, real GDP increases by more than the increase in government expenditures in the first year. In this case, because the monetary authorities are targeting the nominal exchange rate, short-term interest rates are unchanged and the increase in nominal aggregate demand implies a significant increase in the level of nominal money balances.

The short-run effects on GDP are considerably smaller under money targeting and inflation targeting, because monetary conditions tighten to counteract the expansionary effects of the shock. Under money targeting, short-term interest rates increase by 40 basis points in the first year and this, combined with a 4.0 percent appreciation of the yen, reduces the short-run output effects from 1.5 percent to 0.6 percent. Under inflation targeting, the short-term interest rate increases by 100 basis points, the nominal exchange rate appreciating by

[2]These weights are fairly similar to the Taylor rule; see Taylor (1993).

consumption of nontradables, an expansion of developing country exports would not have significant multiplier effects on aggregate output, but would simply lead to an equal increase in imports.

Financing Constraints and Absorption for Developing Countries

As described earlier, MULTIMOD divides the developing and transition economies into a group of six high-income oil exporters and the main developing country bloc. The larger bloc, which includes a great majority of the IMF's developing country members, is assumed to face constraints on external financing.

The constraint on external financing, a legacy of the debt crisis of the 1980s, is a key feature of the main developing country model. The availability of financing is assumed to depend on the expected future growth of exports and on the gap between the prevailing ratio of net debt interest payments to exports and a long-run benchmark level of that ratio.[33] In combination, the availability of external

[33]Debt interest payments are calculated net of interest receipts on international reserve assets.

Effects of a 1 Percent of GDP Permanent Increase in Government Expenditure in Japan Under Alternative Monetary Policy Reaction Functions

	Year 1	Year 2	Year 3	Year 4	Year 5
Real GDP					
Exchange rate target	1.5	1.2	0.4	–0.2	–0.5
Inflation target	0.4	—	–0.1	–0.2	–0.2
Money target	0.6	0.1	–0.1	–0.2	–0.3
Money supply					
Exchange rate target	1.3	3.1	4.4	5.0	4.9
Inflation target	–0.4	–0.3	–0.1	0.2	0.4
Money target	—	0.3	0.4	0.5	0.5
Short-term nominal interest rate					
Exchange rate target	—	—	—	—	—
Inflation target	1.0	0.7	0.6	0.5	0.5
Money target	0.4	0.4	0.4	0.4	0.3
Nominal exchange rate					
Exchange rate target	—	—	—	—	—
Inflation target	4.8	3.9	3.2	2.6	2.0
Money target	4.0	3.7	3.3	2.9	2.5
GDP deflator					
Exchange rate target	1.1	2.7	4.0	4.7	4.8
Inflation target	0.2	0.6	0.9	1.2	1.5
Money target	0.3	0.7	1.0	1.1	1.2

Note: In percent deviations from baseline for all variables except the short-term interest rate, which is percentage point deviations from baseline.

4.8 percent, and there is an even smaller increase in output in the first year.

Under fixed exchange rates, the nominal exchange rate is not free to jump in response to the changing cyclical conditions of the economy, and, with forward-looking exchange rate expectations and interest rate parity, there is no pressure for the nominal interest rate to change; the adjustment process thus takes considerably longer. In this case, movements in real monetary conditions can be affected only by movements in the price level, and because prices are sticky in MULTIMOD, fiscal expansions can result in a significant and persistent business cycle. By contrast, under inflation targeting, the short-run effects of the shock are considerably smaller and the economy returns to potential considerably faster.

financing, the level of exports, and the level of net debt interest payments impose a constraint on the sum of imports and the change in international reserve holdings. A second relationship between the latter two variables, in which the ratio of international reserves to imports adjusts over time toward a target level, is included in the core version of MULTIMOD to determine the balance between imports and the change in reserves.

Absorption in the main developing country model is disaggregated only into consumption and investment; private and government demands are not distinguished in the data, and there is no role for fiscal or monetary policies. Consumption is assumed to depend on a measure of current and lagged disposable income that includes the available flow of external financing. The latter incorporates changes in the net foreign asset position and debt levels, including valuation effects arising from changes in interest rates and exchange rates. Investment is determined from the national income accounts residually as the sum of domestic saving (production minus consumption) and net saving from abroad (imports minus exports). Implicitly, however, the determination of the supply of external financing (net saving from abroad) in a forward-looking framework takes into account the marginal product of capital in contributing to the expected future growth of exports.

Consumption and investment expenditures by the main group of developing countries are assumed to reflect demands for both main composite goods and nontradable goods. Investment purchases are allocated between increments to capital in the main composite goods sector and capital accumulation in the non-oil primary commodities sector; nontraded goods and oil are assumed to be produced without capital goods. The allocation of investment among sectors depends on the relative price of main composites and primary commodities, which is regarded as an indicator of the relative rates of return in the two sectors.[34] Once in place, capital is assumed to be immobile between sectors.

For the bloc of six high-income oil-exporting countries, it is assumed that imports are not constrained by available external financing. Their outputs of main composites and non-oil primary commodities are not treated explicitly, and the price of their domestic output is identified with the price of oil.

Consistent with the lack of explicit treatment of non-oil output, the model for the high-income oil exporters includes specific equations for imports of main composites and non-oil primary commodities, but does not explicitly model the domestic demands for main composites or primary commodities. Import volumes are assumed to depend, however, on aggregate domestic activity variables, as well as on the ratio of the price of imports to the price of oil.

Accounting Identities, Arbitrage Conditions, Interest Rates, and Exchange Rates

As consistency requirements, MULTIMOD imposes both the national income accounting identities that individual country models must satisfy and a parallel set of identities at the global level. At the national level, the difference between saving and investment must equal the current account balance or, equivalently, the sum of net exports of goods and nonfactor services plus net receipts from factor services and transfers. At the global level, saving and investment must be equal, such that national current account balances sum to zero.

MULTIMOD also imposes two types of arbitrage conditions on interest rates and exchange rates. One of these constrains each country's long-term nominal interest rate to be consistent with the time path of its expected short-term interest rates. The core version of MULTIMOD requires that the long-term interest rate equal the expected return from holding a series of comparable short-term securities, but it is possible to introduce modifications that allow for liquidity or risk premiums. The second type of arbitrage condition links interest rates and exchange rates. The core model imposes the uncovered interest parity condition, requiring that interest rate differentials (on equal-maturity assets denominated in two different currencies) equal expected rates of change in exchange rates (between the same two currencies), but this can be modified to allow for interest premiums.

The accounting identities play a major role in determining the steady-state values of interest rates and exchange rates. Loosely speaking, one can think of the identity between global saving and global investment as a condition that pins down the steady-state values of real interest rates—that is, nominal interest rates adjusted for expected changes in price levels (absorption deflators). Similarly, one can think of the identities between national saving-investment balances and current account positions as conditions that pin down the steady-state values of real exchange rates. And, given the expected long-run equilibrium (that is, steady-state) values of interest rates and exchange rates, together with the assumption that expectations about interest rates and exchange rates are model consistent, one can think of the two sets of arbitrage conditions as pinning down the entire expected future time paths of interest rates and exchange rates.[35]

[34]Neither the data nor the model is adequate for considering other factors relevant to the sectoral allocation of investment.

[35]This description is oversimplified, of course, because it takes as given the steady-state levels of saving and investment. In general, the steady-state values of saving, investment, and most other variables depend on exogenously specified assumptions about certain variables and key parameters; see Section III.