Multisectoral models of developing countries: A survey

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Chapter 18

MULTISECTORAL MODELS

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1. Introduction and scope

Multisectoral models appear in economics whenever questions of economic structure are at issue. While they have long been used to provide the analytic and empirical underpinnings of comprehensive economic planning in socialist countries, they have also been widely used in non-socialist settings. In developing countries, they have been used to analyze issues including long-term growth and structural change, investment allocation, choice of development strategy, income distribution, trade policy, and structural adjustment to external shocks. Given that changes in economic structure largely define the process of development, multisector models – where multi might be as few as two – have always been among the indispensable tools of a development economist.

There have been a number of surveys of multisectoral models applied to developing countries up to the early 1970s.[1] Since that time, there has been a major shift both in the questions to which models have been addressed and in the types of models used. This survey focuses on multisectoral, economywide models developed in the last ten to fifteen years. There is no coverage of models of individual sectors, or of multi-country models. At the other end of the aggregation spectrum, short-run macro models also will not be considered.[2] There is, however, consideration of multisectoral models which seek to explore the medium-term impact of short-run stabilization policies.

2. Typologies of models

There are a number of different ways to classify models. One approach is by mathematical structure or methodology: optimization or simulation, static or dynamic, and linear or non-linear. Another is according to policy focus. Models can also be classified by theoretical type or by the nature of the underlying theoretical paradigm.

[1] See Taylor (1975), other chapters in Blitzer, Clark and Taylor (1975), and also Manne (1974).
[2] They are the subject of a separate survey by Arida and Taylor in Chapter 17 of this Handbook.

2.1. Mathematical structure

In the 1950s, the linear input–output model was the only technology available. Static "multiplier" models were used a great deal and there was active work on linear dynamic models.[3] Dynamic input–output models have been a mainstay of development planning and are still in use in various forms today.[4] Their technological and demand assumptions are simple, but such linear models are very useful because they capture major elements of interdependence in an economy. In the past decade, there has been a great deal of new work on multiplier models in the framework of an extended input–output model based on a Social Accounting Matrix (SAM). The SAM provides an excellent framework for exploring both macroeconomic and multisectoral issues and is a useful starting point for more complex models.

In the 1960s, the development of efficient computer programs for solving linear programming (LP) models provided a way to introduce choice and optimization into policy models and also offered the possibility of introducing prices explicitly into the analysis. While widely used in academic exercises, economywide LP models never really caught on among policy-makers in developing countries. There are serious theoretical and practical difficulties in using economywide LP models, which have led to a relative decline in their use in the past decade.[5]

The problems fall into three categories. First, the linearity assumptions tend to lead to unrealistic specialization and extreme behavior, especially in dynamic models. Modellers sought to control this tendency by adding ad hoc constraints, but these made the models more difficult to interpret. Second, in dynamic models, there is a problem in specifying appropriate terminal constraints. The model's dynamic behavior in later periods is sensitive to assumptions made about the post-plan period, especially the role of sectoral capital stocks in the terminal year. While a difficult problem in any dynamic model, optimizing models are especially sensitive to variations in assumptions concerning terminal conditions. Third, there are problems with the interpretation of shadow prices generated by programming models.

A correctly formulated non-linear programming model will generate shadow prices which can be interpreted as competitive market prices. In particular, a single-consumer model in which the maximand is utility and the constraint set reflects the production technology will generate shadow prices which can be

[3]There was also a great deal of theoretical and practical concern about the stability properties of the linear dynamic model. See Dervis, de Melo and Robinson (1982, ch. 2), for a discussion of the dynamic input–output model.

[4]Albeit in more sophisticated forms than the original models. These models are discussed further below.

[5]These problems have been discussed in detail in other surveys. See Taylor (1975), Manne (1974), and Dervis, de Melo and Robinson (1982, ch. 3).

interpreted as market prices, with the consumer satisfying his budget constraint and producers maximizing profits. Multi-consumer models will also work, but only with appropriate weights for the objective function, and the determination of those weights becomes part of the problem.[6] In practice, modellers specified many demanders and imposed a number of constraints designed to make the primal behave realistically, capturing structuralist rigidities that characterize developing countries.[7] They did not worry much about the behavior of the dual price system.

In the later work with linear programming models, modellers sought to improve the treatment of prices in such models. The goal of this work, however, was not explicitly to simulate market prices, but rather to be able to use the shadow prices for policy analysis (for example, to generate shadow prices for project analysis).[8] Two economywide applied models represent the high point of this literature and reflect major advances in the art of multisectoral modelling: the Evans (1972) model of Australia and the Goreux (1977) model of the Ivory Coast.[9] The Evans model has perhaps the most careful treatment of foreign trade of any linear programming model and the Goreux model incorporates features of multilevel planning in which price signals play a crucial role for planners. In neither model, however, can the shadow prices be interpreted as market prices. Both have multiple demanders and, in order to prevent unrealistic behavior, imposed many ad hoc constraints which cannot be interpreted as representing constraints facing actors in a market economy.

In the early 1970s, work was started on a new type of non-linear, multisectoral model which sought to simulate the workings of a market economy, solving for both market prices and quantities simultaneously. These computable general equilibrium (CGE) models can be seen as a natural outgrowth of input–output and LP models, adding neoclassical substitutability in production and demand, as well as an explicit system of market prices and a complete specification of the income flows in the economy. The first developing country application was Adelman and Robinson (1978), which started an extensive literature.[10]

[6]For a discussion of the theoretical issues, see Ginsburgh and Robinson (1984).

[7]See, for example, Chenery (1971) and Adelman and Thorbecke (1966) for examples of such economywide LP models.

[8]Bruno (1975) provides an excellent statement of this approach. See also Taylor (1975).

[9]There was also work to integrate programming models of individual sectors in a consistent multi-level framework that sought to compute shadow prices in a way that could be seen as reflecting market prices. The work on Mexico described in Goreux and Manne (1973) is an excellent example of this strand. See also Westphal (1975).

[10]At about the same time, starting from the theoretical work of Scarf on fixed-point algorithms, CGE models were also being built for developed countries. These models concentrated primarily on issues of tax incidence and had a very different focus from the models of developing countries. See Scarf and Shoven (1983) and Shoven and Whalley (1984).

In the 1970s, major advances were made in solution techniques that permitted the implementation of CGE models. There are four different approaches that were pursued. First, the solution of a CGE model can be formulated as a problem in finding a fixed point in a mapping of prices to prices through excess demand equations. This approach was pioneered by Herbert Scarf, and variations on his fixed-point algorithm have been used to solve a number of CGE models of developed countries.[11] A second approach involves treating a CGE model as just a collection of non-linear algebraic equations and attacking them directly with numerical solution techniques. This approach was used by Adelman and Robinson (1978) and a number of others since then.[12] A third approach involves first linearizing all the equations of the CGE model and then solving the linear approximation by simple matrix inversion. This approach was used in the first applied CGE model formulated by Johansen (1960) and has been used in a number of applications since then.[13] Finally, as noted above, it is possible to construct a non-linear programming model whose solution yields shadow prices that can be interpreted as market prices. The general approach of using programming techniques to solve CGE models is described in detail in Ginsburgh and Waelbroeck (1981), who also survey the other techniques.[14]

All of these techniques work. At this time, CGE models can be solved routinely and cheaply. Implementing a CGE model now is significantly easier than developing an economywide LP model was in the 1970s.[15] In fact, with the further development of non-linear programming methods, many of the shortcomings of LP models have been overcome, and it is now possible to integrate optimization with a more complete specification of market systems, including endogenously determined prices.[16]

[11]See Scarf and Hansen (1973).

[12]Dervis, de Melo and Robinson (1982, appendix B), describe the approach in detail. Within this framework, there are variations depending on how one chooses to attack the system of equations.

[13]See Dixon et al. (1982) who apply this technique in an enormous CGE model of Australia. They extend the method considerably and show how approximation errors arising from the linearization can be eliminated.

[14]For discussions of computation techniques, see, for example, Takayama and Judge (1971) and Dixon (1975). Manne, Chao and Wilson (1980) simultaneously developed an approach very close to that of Ginsburgh and Waelbroeck (1981). Chenery and Raduchel (1979) use non-linear programming to solve a stylized model that is almost, but not quite, a CGE model. Norton and Scandizzo (1981) suggest a way of using a piecewise linear programming formulation to solve a CGE model, but their approach can only work for a one-consumer economy, an overly restrictive specification.

[15]The World Bank has developed three different approaches to providing solution packages for CGE models. One package starts from models developed by Dervis, de Melo and Robinson (1982) and has been used in a number of applied models. Another, the "transactions value" (TV) method, starts from a social accounting matrix presentation of a CGE model and is described in Drud, Grais and Pyatt (1984). A third starts from a general non-linear programming package called GAMS and is described in Meeraus (1983).

[16]Some work in this vein is described at the end of the survey in the section on directions for future research.

2.2. Policy issues

Another way of classifying models is according to the issues that they seek to address. The early work with input–output and LP models was largely concerned with questions of sectoral allocation of investment, international trade, and the implications of different development strategies in the medium to long run. The main focus was on growth and structural change in production and foreign trade, and on the size and timing of the required domestic and foreign investment.[17] However, these models are not well suited to analyze mixed market economies in which autonomous decision-making by various economic actors and market mechanisms largely determine resource allocation. Linear programming and input–output models do not capture market mechanisms through which incentive instruments such as taxes and subsidies affect the economy. While they do provide a consistent economywide framework, which is very valuable in itself, they do not provide a way to relate solution variables to actual policy decisions.[18]

In the early 1970s, international attention shifted to a concern about income distribution.[19] Although there was some imaginative work using input–output models to analyze distributional issues, the shift in policy interest generated further pressure to include prices and incomes directly in models.[20] The focus on income distribution arose from a growing concern that rapid growth and structural change did not suffice to reduce poverty and that large groups of poor people were not benefiting from growth.[21] Two broad questions provided the focus of modelling work: (1) What were the distributional implications of different development strategies? (2) How could one design policy packages that would reduce the incidence of poverty and ameliorate the worsening of the distribution that seemed inevitably to accompany industrialization? It was to address these questions that the first CGE models were built for developing countries: the model of Korea by Adelman and Robinson (1978) and, later, the model of Brazil by Lysy and Taylor (1980).[22]

The work on income distribution proceeded throughout the 1970s. However, the first oil crisis again focused attention on foreign borrowing so that by the

[17]See Kornai's chapter in Blitzer, Clark and Taylor (1975). He discusses the adequacy of the then existing planning methodologies for examining these questions.

[18]Taylor (1975) provides a good survey. See also Blitzer, Clark and Taylor (1975), Adelman and Thorbecke (1966), and Chenery (1971).

[19]In some countries, such as India and Brazil, there was serious policy concern about distributional issues much earlier.

[20]See Weisskoff (1970) and Cline (1972) for input–output models with a distributional focus. Chenery and Duloy (1974) discuss the problems of integrating distribution into the "standard" planning models.

[21]The seminal international comparative work espousing this view was Adelman and Morris (1973), which led to a continuing controversy about who benefits from growth.

[22]Work on these models was started in the early 1970s, and the Korea model is discussed in the Taylor (1975) survey and in Chenery et al. (1974).

time of the second crisis in 1977–78, policy-makers both in developing countries and in international agencies were preoccupied with issues of foreign debt. Policy analysis focused on questions of "structural adjustment". How could countries bring about the changes in the structure of production and trade required to adapt to lower levels of foreign resources? What macroeconomic adjustments were required, and what was their impact on medium to long-run growth and structural change? The term "structural adjustment" has become something of a catch-all, and will be used here to mean an adjustment to some shock that requires not only compositional changes in production, resource allocation, demand, and relative prices, but also changes in macroeconomic aggregates such as income, investment, absorption, consumption, and government expenditure.

In the face of a foreign exchange crisis leading to a complete halt in growth, issues of income distribution and poverty alleviation faded into the background. Policy-modellers also reacted to the shift in priorities and turned their attention to improving the treatment of foreign trade in multisectoral models, particularly CGE models. Most of the multisector models built in the last decade have been concerned with such trade issues, and they will provide a major focus of this survey.

2.3. Analytic, stylized, and applied models

In developing countries, most of the work on empirical multisector models has been driven by policy concerns. In all policy analysis, there is a tension between theoretical simplification and empirical realism. In judging empirical models, it is necessary to keep this tension in mind. One can classify models along a continuum running from analytic to applied. Analytic models are designed to explore the implications of various sets of theoretical postulates, with as few assumptions as possible about the magnitudes of parameters. The principle of Occam's Razor in science holds that simplification in theoretical work is a virtue, and an important part of analytic model-building is to find the sparsest set of assumptions required to explain a set of stylized facts. Thus, analytic models are deliberately simplified to focus attention on important assumptions and causal mechanisms. In this process, the stylized facts are often exaggerated, which simplifies an analytic model and allows mathematical analysis of its properties.

In evaluating analytic models which focus on the logical implications of different sets of assumptions, empirical realism is not the most relevant criterion. An analytic model is useful if it isolates important effects while retaining a reasonable specification or some heuristic validity. There is clearly a tradeoff between empirical relevance (i.e. the range and complexity of issues that can be considered in a model) and analytic tractability. Analytic models are usually narrowly focused with, whenever possible, a preference for a partial rather than a general equilibrium approach. The application of Occam's Razor strongly favors smaller models.[23]

By their nature, analytic models will be limited in their applicability. Many economic phenomena that can be isolated in particular analytic models work in contradictory directions, and the net effects in a real economy depend on the values of various parameters. When an analytical model does not suffice, the next line of attack is to draw on empirical work and to build a stylized numerical model. Stylized numerical models have two main uses: (1) to analyze problems that are too difficult to solve analytically or that have ambiguous implications that depend on particular parameter values, and (2) to illustrate the numerical order of magnitude of various effects whose analytic properties are well understood.

Typically, stylized numerical models are more complex than analytic models, since wider applicability is desired and simplicity is no longer required. Stylized numerical models nonetheless tend to stay close to their underlying analytic models. Since the goal is to explore particular causal mechanisms, simplicity is desirable. Stylized models are still a long way from models which seek to capture in a realistic way the variety of important effects that might impinge on a particular policy problem facing a particular country.

Applied models differ from stylized models in two important ways. First, they broaden further the range of stylized facts that are incorporated. Second, they seek to capture important features of a particular economy or situation. For example, while a stylized model can represent a number of similar countries (e.g. oil-importing, semi-industrial countries), an applied model would be built for a particular country. By including more institutional detail, applied models are more specific and narrow.

Moving from analytic to stylized to applied models allows increased institutional specificity, as well as the inclusion of a wider range of economic phenomena. The tradeoff, of course, is that the additional detail and size may obscure the major causal mechanisms that drive the model, without adding any empirically significant effects. Since different types of models permit different insights, it is often desirable when analyzing various problems to move back and forth between analytic, stylized, and applied models. There are costs and benefits to operating at each level that must always be balanced, and it is generally true that the analysis of any particular problem will be improved by using more than one kind of model.

The advantages and disadvantages of using models at different levels are clearly evident in analyzing the impact of different policies on the economy. In such analysis, one can distinguish between strategic planning and policy analysis.

[23]Although one should not confuse size and complexity. Small models can be quite complex, and large models can be quite simple theoretically.

Strategic planning, for example, might involve the choice of an appropriate medium to long-term development strategy. Should a country follow an inward-looking, import-substitution strategy or an outward-looking strategy that relies more on export-led growth? Policy analysis would then concern the appropriate choice of policies to support the strategy. For an inward-looking strategy, should one rely on tariffs or quantity restrictions? What levels of tariffs or restrictions? At what level should the exchange rate be pegged, and for how long? The distinction is analogous to the difference between strategy and tactics. Policy analysis must involve detailed analysis and careful consideration of the special circumstances of a particular economy, while questions of strategic planning can be more widely applied and generalized.

In general, analytic models do not yield specific policy recommendations. At that level, the stylized facts being considered are usually too stylized to be realistic enough for policy analysis. The policy conclusions that can be derived from analytic models tend to be general statements such as: "free trade is good", "price distortions are bad and attempts to fix prices are terrible", "quantity restrictions on imports are worse than tariffs", or "do not ignore market mechanisms". And even in these cases, there is an active industry among economists who delight in thinking up counterexamples. For similar reasons, a stylized numerical model can only rarely be used for policy analysis, since it is usually too simplified to capture the institutional and country detail required to provide good numerical estimates of the impact of various specific policies.

While the three types of models are different, the boundaries between them are often fuzzy. They really represent different points along a continuum of models that differ in size, scope, and focus. The differences are, however, significant and much of the criticism of particular models often amounts to taking a stylized numerical model to task for not being an applied model, or vice versa.

The multisector models applied to developing countries that are discussed in this survey all fall in the continuum from stylized to applied. Their location on this continuum affects the standards by which they should be judged. All models should be transparent in the sense that the modeller should be able to trace any effect the model produces back to features of its theoretical structure or to particular parameter values. With their focus on the institutional details of a particular economy, applied models will be inherently more difficult to interpret. The test is whether the gain in institutional detail generates more realistic empirical results. Stylized models, on the other hand, are often designed to reflect common features of a class of countries. While the models are often easier to handle, the question is whether country-specific effects are empirically important enough to offset the commonalities that the models are designed to explore.

It is also often possible to simplify an applied model after the fact. Experimentation often leads to insights about the empirical importance of model specifications that could not be determined a priori. Given the results, one can then move toward a more stylized numerical model which still captures the major mechanisms that turned out to be empirically important in the applied model.

2.4. *Theoretical paradigms*

All multisector models start with the input–output model, which captures sectoral interdependence arising from the flow of intermediate goods among sectors. Even with its strong linearity assumptions, input–output models and their extensions into social accounting represent powerful tools for applied general equilibrium analysis. The later computable general equilibrium (CGE) models build on the input–output core, adding non-linear equations and endogenous prices. All these models are essentially structural, with explicit specification of supply and demand behavior. The extensions to non-linear models incorporating substitution possibilities and prices only reinforce the essential microeconomic spirit of the models. As Dervis, de Melo and Robinson (1982, p. 6) state: "Walras rather than Keynes is the patron saint of multisector analysis".

While multisector models applied to developing countries are Walrasian and neoclassical in spirit, most modellers quickly abandoned many of the strong assumptions of neoclassical theory when faced with the problem of capturing the stylized facts characterizing these economies. The assumptions of perfect competition, perfectly functioning markets with flexible prices, and free mobility of products and factors are not sustainable in actual economies. Instead, modellers have incorporated a variety of "structuralist" rigidities into their models that seek to capture non-neoclassical behavioral relations, macro imbalances, and institutional rigidities characteristic of developing countries. Such deviations from the Walrasian paradigm lead to methodological problems that have concerned some writers. For example, Bell and Srinivasan (1984), Srinivasan (1982), and Shoven and Whalley (1984) all express concern about models which incorporate what they consider to be ad hoc features not rooted in traditional theory. Shoven and Whalley (1984, p. 1046) put the problem well:

> Unfortunately, the problem is, the models that make major departures from known theoretical structures can become difficult to interpret. The conflict between modellers' desire to build realistic models which seek to capture real features of the policy issue at hand, and to stay within the realm of developed economic theory is something that seems to be increasingly apparent in some of the more recent models.

While the conflict is real, using a model with clean theoretical roots in a situation where its assumptions are not satisfied will not yield valid empirical results or aid in policy analysis. And while deviations from the standard neoclassical paradigm certainly do give rise to problems of interpretation, such problems can also be seen as a challenge to theorists.

One problem is that applied modellers often seek to draw on strands of theory outside the paradigm of Arrow–Debreu general equilibrium theory. The concept of equilibrium imbedded in the neoclassical general equilibrium model underlying all multisector models is that of flow equilibrium in product and factor markets. There are additional equilibrium concepts that one might want to capture in a model, reflecting different underlying analytical theories. A second concept is that of equilibrium in aggregate "financial" or "nominal" flows, which defines a notion of macro equilibrium – the heart of Keynesian macroeconomics. A third concept is that of equilibrium in asset markets, defining another form of macro equilibrium. Fourth, there is intertemporal equilibrium involving expectations – adaptive, rational, consistent, or whatever – in an explicitly dynamic framework. The four equilibrium concepts are not independent, and it is an open question how adequate are theoretical and empirical models that only include one or two of them.

In applications to developing countries, modellers have often justified the imposition of "structuralist" constraints on their flow-equilibrium models by citing theoretical literature on macro adjustment, political economy, uncertainty, incomplete markets, temporary equilibrium, implicit contracts, and the like. The typical approach is not to incorporate such theoretical features directly into the empirical model, but instead to impose constraints on the model which are essentially ad hoc in that they are not related to any endogenous rational behavior of agents. The justification for this approach is the current inadequate state of theory.

For example, many modellers have persuasively argued for the need to incorporate notions of macro equilibrium into multisector models. However, the theoretical literature on the micro foundations of macroeconomics, while suggestive, gives little concrete guidance to the empirical modeller.[24] There is as yet no acceptable reconciliation of micro and macro theory, and the Walrasian model is an uneasy host for incorporating macro phenomena. Thus, while there are many multisector models with macro features, they all have an ad hoc flavor reflecting this theoretical tension. The open question, which will be discussed further below, is whether the tradeoff between empirical relevance and theoretical purity implicit in the marriage of Walras and Keynes in an empirical model is justified by the results.

It is important to note, however, that moving beyond the Walrasian paradigm in multisector models does not mean abandoning all notions of equilibrium. In a

[24]Discussion of this literature is beyond the scope of this survey. For an entry point, see Hahn (1978) and Weintraub (1979). Some of the issues are discussed further below in the context of stylized and applied models.

transparent model, it is feasible to sort out the effects of non-neoclassical specifications on the results and so clarify the limits of "standard" theory in explaining model behavior. While the definitions of equilibrium are not the same as in a neoclassical model, they are no less rigorous. Malinvaud (1977) has put the general point very well:

> The type of consistency that is assumed to exist between individual decisions is specific to each equilibrium theory. For the study of (Keynesian) employment it can only be a short-run consistency which will be quite different from the long-run consistency that one will want to consider when studying, for instance, industrial structure.

As we shall see, structuralist models have a lot of structure.

3. Input–output and social accounting

Just as the national income and product accounts (or NIPA) provide the statistical foundation for macro models, the input–output accounts underlie multisector models. There are many good treatments of the input–output accounts, so they will not be covered here.[25] However, issues such as income distribution and structural adjustment require analysis that goes beyond the sectoral production accounts to include income and expenditure flows that are captured in the national income and product accounts. The development of social accounting matrices (SAMs) was motivated by the need to reconcile the NIPA and input–output accounts within a unified statistical framework. The work was greatly influenced by Sir Richard Stone, who was the major architect of the United Nations System of National Accounts (SNA).[26]

3.1. *Social accounting matrices*

Figure 18.1 provides a representative SAM that forms the underlying statistical basis for a number of models of developing countries. The "activities" account includes the sectors as defined in input–output tables and the matrix of intermediate flows (or "use" matrix) appears as cell (2, 1) in the SAM. The "commodity" account can be seen as representing the domestic product market, buying domestic goods from activities and imports from the rest of the world, and selling

[25]See, for example, Chenery and Clark (1959), Bulmer-Thomas (1982), United Nations (1973), and Miller and Blair (1985).

[26]See United Nations (1968, 1975), Stone (1966), and Stone and Stone (1977). Pyatt and Round (1985) provide an excellent introduction to SAMs and their uses, especially the chapter by King (1985).

Receipts:	Expenditures: 1 Activities	2 Commodities	3 Factors	4 Enterprises	5 Households	6 Government	7 Capital acct.	8 World	9 Total
1 Activities		domestic sales				export subsidies		exports	total sales
2 Commodities	intermediate demand				household consumption	government consumption	investment		total demand
3 Factors	factor payments								value added
4 Enterprises			gross profits			transfers			enterprise income
5 Households			wages	distributed profits		transfers		foreign remittances	household income
6 Government	indirect taxes	tariffs	factor taxes	enterprise taxes	direct taxes				government receipts
7 Capital acct.				retained earnings	household savings	government savings		net capital inflow	total saving
8 Rest of world		imports							imports
9 Total	total payments	total absorption	value added	enterprise expenditure	household expenditure	government expenditure	total investment	foreign exchange	

Figure 18.1. A representative social accounting matrix.

the goods to all domestic purchasers. In this definition, exports are assumed to be sold directly to the rest of the world by activities. The commodity account so defined is especially useful in models that focus on international trade, since the column sum of commodities equals total absorption (including intermediate inputs).[27] Note that since the commodity account is defined separately from activities, they need not have the same sectoral definitions. Entry (1,2) in the SAM provides the mapping from activities to commodities, and is sometimes called the "make" matrix.[28]

The rest of the SAM traces the flow of income from producing sectors to factors of production – entry (3,1) – and then on to "institutions", which represent the various economic actors in the economy. The SAM provides a complete account of the circular flow in the economy. Depending on the problem at hand, the various accounts can be specified at different levels of aggregation. For example, if the focus is on the distribution of income, it would be important to disaggregate the household accounts. If the focus is on tax incidence, it would be important to provide details of the tax flows, perhaps creating separate tax accounts differentiated by type of tax.

The point is that the definition of the SAM should be tailored to the problem being analyzed, and there is no standard SAM that can serve all purposes. For example, some analysts who wish to focus on distributional questions reorder the accounts, starting with the factor accounts at the upper left and moving the activity and commodity accounts to the lower right.[29]

While the definitions of the accounts in a SAM will vary, all SAMs satisfy certain conventions. The rows and columns represent the income and expenditure accounts of the various actors, and must always balance. A SAM is thus defined as a square matrix, with the totals of corresponding rows and columns always being equal. The conventions of double-entry bookkeeping guarantee that there will be no leakages or injections into the system and every flow must go from some actor to some other actor.

There are two different kinds of entries in a SAM. First, there are entries which reflect flows across markets, with payment moving in one direction (from column account to row account) and some commodity moving in the opposite direction. Accounts 1 to 3 in Figure 18.1 are of this type, representing the flow of goods and

[27]Another definition is often used which includes exports in the commodity account. In this case, the account defines total supply, not just domestic supply.

[28]"Use" and "make" matrices are also sometimes provided as part of the input–output accounts, with the same sectoral definitions. The approach allows for the possibility that a particular activity may produce more than one commodity.

[29]See King (1985). Pyatt and Round (1977) discuss a number of SAMs and motivate the shift in the order of the accounts depending on the focus of the analysis, although changing the order is somewhat confusing for those used to starting from an input–output matrix.

services across product markets and of factors across factor markets.[30] Second, there are entries which represent nominal flows that have no real counterpart, i.e. no transaction across a product or factor market. In terms of the national income and product accounts, all such flows represent "transfers", since no productive activity or real exchange occurs – no value added is produced or new product sold. However, with an eye toward macro theory, one can distinguish between pure transfers and financial transactions that involve the sale of assets.

For the purpose of this survey, I shall use the term "nominal flow" to describe all entries in the SAM denominated in currency units, whether or not the transaction can be seen as a price times a commodity flow. "Financial flows" are nominal flows which involve the exchange of assets (that is, the entries in the capital account) even though the table does not keep track of asset balances. These financial flows summarize the workings of the financial system, collecting savings from various actors (along the row) and using the funds to purchase new capital goods (investment) in the column. "Transfers" include all other non-market nominal flows among agents, including pure transfers such as welfare payments and involuntary transfers such as tax payments. While financial flows and transfers have no real counterparts, they nonetheless represent important economic transactions, reflecting the institutional structure of the economy and assumptions about the behavior of various actors. These flows largely define the macroeconomic structure of the economy and must be captured in any model that is concerned with distributional issues or macro adjustment.

Figure 18.2 presents an aggregated macroeconomic SAM, which should provide a convenient starting point for economists more familiar with the NIPA than with input–output tables. All entries represent macro aggregates and the factor, household, and enterprise accounts have been aggregated into a single household account. Consistent with the NIPA, intermediate flows have been assumed away or netted out. Activities produce GDP (X) along the first row and pay out gross domestic income (Y) down the first column. In contrast to the SAM in Figure 18.1, the commodity account includes exports, so the row sum equals aggregate demand while the column sum reflects aggregate supply. The standard macro identities are set out in Figure 18.2 below the SAM. They follow immediately from the defining assumption of the SAM that corresponding row and column sums must be equal.

As in the SAM in Figure 18.1, the first two rows and columns reflect transactions across product and factor markets, while the remaining accounts include financial flows and transfers of the sort captured in macro models. This

[30]For purposes of economic analysis, it is very convenient to define the accounts such that the price at which a commodity or factor is exchanged is the same in every entry along a given row. While easy to do in theory, this principle is difficult to achieve in practice.

Receipts:	Expenditures: Activities	Commodities	Households	Government	Capital account	World	Total
Activities		X					GDP
Commodities			C	G	Z	E	demand
Households	Y						income
Government			T^{h}				taxes
Capital acct.			S^{h}	S^{g}		B	savings
Rest of world		M					imports
Total	domestic income	supply	← expenditure		→	foreign exchange	

Variables:

X = output (GDP)
C = household consumption
G = government consumption
Z = investment
E = exports
Y = income (value added)
T^{h} = taxes
S^{h} = household savings
S^{g} = government savings
B = balance of trade
M = imports

Macroeconomic identities:

(1) $Y = X$ Domestic income = domestic product
(2) $X + M = C + G + Z + E$ Aggregate supply = aggregate demand
(3) $Y = C + S^{h} + T^{h}$ Household income = expenditure
(4) $S^{g} = T^{h} - G$ Government savings = taxes minus expenditure
(5) $Z = S^{h} + S^{g} + B$ Investment = savings
(6) $B = M - E$ Balance of trade (= foreign savings)

Figure 18.2. A macroeconomic SAM.

SAM does not include assets or, indeed, distinguish investment by sector of destination, and so cannot portray the workings of financial markets. Disaggregation to include investment by sector of destination is relatively easy and is standard in many models. There has also been work to extend the SAM accounting framework to include assets, but there are few multisectoral models that attempt to include asset markets explicitly.[31]

3.2. Linear models in a SAM framework

To go from a set of accounts to a model requires more assumptions. The simplest way is to divide the columns of the input–output accounts by their sums and assume that the resulting coefficients are fixed over time. The result is the static input–output model, which is probably the most widely used tool in the world for analyzing issues in which the structure of production is a major focus. The model is solved to yield multipliers through which changes in final demand are translated into changes in sectoral output. These multipliers provide a way to do comparative statics analysis of the impact of exogenous changes in various coefficients, or in the size and composition of final demand (including, for example, foreign trade), on sectoral production and, perhaps, employment.[32]

The essence of an input–output model, and of its SAM extensions, is to capture linkages in a general equilibrium framework that allows the computation of indirect as well as direct effects of an exogenous shock. One strand of work has sought to measure the linkages and define indicators of the degree of complexity of an economy.[33] Some of this work was motivated by Hirschman's notion that one should invest in sectors with very strong forward and backward linkages, and so take advantage of the "pull" and "push" the investment would have in promoting the growth of linked sectors.[34] More recently, measures have been developed which decompose input–output and SAM multipliers into direct and indirect effects.[35] These decomposition measures indicate how important empiri-

[31]See United Nations (1975) for a description of SAMs which include assets. Models that explicitly include asset markets are discussed below.

[32]Static input–output models and their uses are surveyed in Blitzer, Clark and Taylor (1975) and Dervis, de Melo and Robinson (1982). Chenery, Robinson and Syrquin (1986) discuss and apply various comparative statics decomposition procedures with input–output models. See also Stone (1984).

[33]See, for example, Rasmussen (1965) and Robinson and Markandya (1973).

[34]See Hirschman (1958). Measures of sectoral linkages are discussed by Chenery and Clark (1959), Yotopoulos and Nugent (1976, chs. 15 and 16), Torii and Fukasaku (1984), and Kubo, Robinson and Syrquin (1986).

[35]The original inspiration for this work was provided by Richard Stone. See Stone (1985). Various decompositions are discussed by Pyatt and Round (1979) and Robinson and Roland-Holst (1987). Defourny and Thorbecke (1984) present generalized SAM decompositions which include the others as special cases.

cally are the indirect linkages, and how different are SAM-based multipliers compared to simple input–output multipliers.

Decomposition measures can be used to address questions such as: "When is it feasible to ignore indirect linkages and stay with partial-equilibrium analysis?" and "When is it important to consider the institutional linkages incorporated in a SAM, rather than capture only the linkages embodied in intermediate flows in an input–output table?" The answer to both questions appears to be "often". Simply arraying national data in a SAM framework provides a lot of information about the structure of an economy. The decomposition measures indicate both qualitative information about the main causal linkages at work and quantitative information about the magnitudes of the indirect and direct effects.

Within the SAM framework, one simple way to create a model is to assume the various column coefficients are all constant. However, since the matrix is square and the coefficients in every column will sum to one, there are no exogenous elements and hence no multipliers. One approach is to specify one or more accounts – columns and rows in the SAM – as being exogenous. For example, the standard input–output model can be derived from the SAM by combining the activity and commodity accounts and specifying all other accounts exogenously. The final demands become exogenous, and the value-added coefficients are no longer in the square matrix of coefficients to be inverted.

Extending the input–output model to include more accounts in the SAM requires that we assume that various expenditure coefficients are fixed. It thus becomes important to define accounts so as to make this interpretation reasonable. For example, in the SAM in Figure 18.1, the distribution of nominal income between wages and profits would be assumed fixed, as would be the average tax and savings rates of enterprises and households. Also, the sectoral composition of nominal consumption, government, and investment expenditure would be assumed fixed. Such assumptions represent a considerable extension of the fixed-coefficients technology in the standard input–output model.

In models based on the SAM, an important question is which accounts are to be assumed exogenous. Standard practice is to pick one or more of the government, capital, and rest of the world accounts, justifying the choice on the basis of macroeconomic theory.[36] The resulting multiplier models are completely demand driven, since no constraints on supply are specified, and are thus Keynesian in spirit. For example, assume that only the investment account is exogenous and solve for the resulting multipliers. Changes in investment provide the "injection" that drives the model and the various savings rates provide the "leakages" that permit the model to be solved. For a given change in investment (perhaps sectorally differentiated), the model will solve for the equilibrium levels of all

[36]See Pyatt and Round (1979) and Stone (1985) for a general discussion of multipliers in a SAM framework and the choice of exogenous accounts.

endogenous accounts such that the change in nominal savings equals the nominal value of the change in investment.

Given that we are choosing among three accounts (capital, government, and the rest of the world), there are seven different combinations of exogenous accounts – each one singly, three pairwise combinations, plus all three together. Each of these choices defines a different macro "closure" to the SAM model. In each case, a shock is defined as a change in elements of the exogenous columns. The nature of the adjustment will depend on the size and structure of the coefficients in the endogenous accounts and of those in the excluded rows (which define the leakages). Of course, the computed multipliers will be sensitive to the choice, and the resulting model must be defended in terms of theory and empirical realism for the particular problem under study.

The choice of macro closure in the SAM framework serves to open the model. If a single account is taken as exogenous, the fact that the endogenous accounts all will balance at a new equilibrium guarantees that the exogenous account will also balance since the SAM as a whole must balance. Any SAM-multiplier model satisfies a variant of Walras' Law – if all accounts but one balance, then the last must also balance. If two or more accounts are set exogenously, then only their sum must balance, given a solution for the endogenous accounts.

This issue of macro closure appears again in the context of CGE models. It is useful to see the problem first in the SAM framework, since the macro issues are very similar and can easily be obscured in the additional detail of non-linear functions, many sectors, and various choices of equilibrating mechanisms. Another point to note is that any model in the SAM framework, or any model that provides a complete account of the circular flow, will have financial and transfer accounts for which there are no corresponding real flows. Such a model thus has an implicit macro structure, no matter how well hidden. The problem of macro closure cannot be avoided.

One major use of multiplier models in the SAM framework has been to explore issues of income distribution. Two early models in this tradition are Cline (1972) and Weisskoff (1970). They sought to explore the linkages from the distribution of income to the structure of demand to the structure of production and hence back to employment and income distribution. Both authors extended the standard input–output model in order to trace the links from value added to demand, but without explicitly using the SAM framework.[37] During the 1970s, a number of more ambitious and complete SAM-multiplier models designed to explore issues of income distribution were built. See Pyatt and Thorbecke (1976) and Thorbecke (1985) for surveys of this work.[38]

[37]In a later extension of his model, Weisskoff (1985) recognized that he had implicitly been working with a SAM, and discusses his new model in the SAM framework.

[38]This work is also discussed in Chapter 17 by Adelman and Robinson in this Handbook.

3.3. Prices and static SAM models

Any input–output model has a dual price system, which can be seen as a set of cost prices in a linear framework. There is an extensive literature which uses input–output models to trace out cost linkages as an element in benefit–cost analysis. For example, the literature on effective protection and domestic resource costs is largely based on the static input–output model.[39] In an economy where domestic tradables are perfect substitutes for goods traded on the world market, the domestic price of every tradable good will equal its world price. In addition, subject to an aggregate balance of trade constraint, net exports or imports should provide the mechanism by which supply and demand are equated for tradable sectors. Jan Tinbergen suggested an extension of the input–output model to capture this phenomenon. The resulting "semi-input–output" model has been used for a variety of purposes in a number of countries.[40] One important application has been to generate shadow prices for the purposes of cost–benefit analysis.[41]

The semi-input–output model has also been extended in the SAM framework. For example, Bell and various coauthors have developed a multiplier model using a regional SAM with links to the rest of the economy to explore the impact of a large agricultural project on its surrounding region. Their technique shares with the semi-input–output model the assumption that tradable goods should be valued at world prices, but also considers expenditure multipliers in the SAM framework.[42] These models represent an elegant marriage of benefit–cost analysis with SAM-based multiplier analysis. The framework permits the analysis of the impact of large projects, while standard benefit–cost methods usually must assume that all projects are marginal.

3.4. Linear dynamic models

The dynamic input–output model provided the first approach to endogenizing investment in the input–output model. Using a vector of fixed capital–output ratios, the model links changes in investment by sector of destination to changes in sectoral output. Then, using a matrix of capital coefficients, the model translates demand for investment by sector of destination into demands for

[39] The literature on DRCs and ERPs is beyond the scope of this survey. See Corden (1974), Bhagwati and Srinivasan (1978), and Balassa and Associates (1971) for discussions of the concepts and their uses.

[40] See Tinbergen (1966). Kuyvenhoven (1978) provides extensive discussion of the method, with applications to Nigeria.

[41] In a series of articles, Bell and Devarajan (1980, 1983, 1985) have explored the use of the semi-input–output model as a framework for project evaluation.

[42] See Bell and Hazell (1980), Bell, Hazell and Slade (1982), and Bell and Devarajan (1985). See also Greenfeld and Fell (1979).

investment goods by sector of origin – the investment column in the input–output table or SAM. While the model includes a theoretically clean definition of dynamic equilibrium, it shares with its one-sector cousin, the Harrod–Domar model, a distressing tendency toward instability.[43] However, patched up in various ways, applied models based on the dynamic input–output model have been widely used in developing countries.

Dynamic input–output models have been extended in a number of ways designed to make them more useful in an applied setting. These applied models stay relatively close to their input–output antecedents, adding features such as gestation lags and constraints on aggregate investment, employment, or the balance of trade. Models in this tradition, however, do not seek to include nominal flows or prices. The intent is to stay within the input–output framework, but to move beyond the demand-driven input–output model, where final demand is exogenous, to models incorporating various constraints on supply as well. Such models have been used by the planning agencies of a number of developing countries, and variants were also developed for some developed countries.[44] More recently, dynamic input–output models have been developed which incorporate macro constraints in a non-linear framework, but still avoid any consideration of prices.[45]

In the past decade, a number of dynamic simulation models have been developed which start from a core dynamic input–output model, but which then include macro aggregates and a number of relationships derived from macro models. Such models often start from an explicit SAM framework and may focus on distributional as well as macro issues. Some include a few non-linear equations. Some also use cost prices to calculate nominal flows endogenously, but they do not specify any price adjustment mechanism to equilibrate supply and demand.[46] Thorbecke (1985) describes such models focused on distributional issues as "first generation" models, in contrast to "second generation" CGE

[43]See Dervis, de Melo and Robinson (1982, ch. 2), for an extensive discussion of the dynamic input–output model and its mathematical structure. Note that while the model is a multisector analogue to the Harrod–Domar model, the nature and sources of its unstable growth are more complex. The early applications are surveyed by Taylor (1975).

[44]Typical applications of such extended models include Sri Lanka, Colombia, Korea, India, Chile, and Turkey. These models are surveyed by Clark (1975). Applied dynamic input–output models of developed countries include the model of the United States by Almon et al. (1974) and the Cambridge model of the United Kingdom developed under the direction of Richard Stone, described in Stone (1981). See Tsukui and Murakami (1979) for a general theoretical discussion and a model of Japan.

[45]See, for example, Kubo, Robinson and Urata (1986) who use a stylized dynamic input–output model applied to Korea and Turkey that incorporates non-linear constraints on cumulative investment and foreign capital inflows. The model is used to explore the implications of pursuing an outward-looking versus an inward-looking development strategy.

[46]Examples of such models include: Korea, Gupta (1977a); Indonesia, Gupta (1977b); Iran, Pyatt et al. (1972); Colombia, Thorbecke and Sengupta (1972); Thailand, Grais (1981); Egypt, World Bank (1983); Dominican Republic, McCarthy (1984); and China, World Bank (1985). A number of these models start from the World Bank's Revised Minimum Standard Model (RMSM), which is essentially a two-gap macro model that can be applied to almost any country.

models, and surveys a few using the underlying SAM to provide a framework for comparison.

All of these are applied models and focus on policy concerns in particular country settings. To an academic reader, these models seem cluttered with ad hoc specifications designed to capture institutional features of the particular countries. In some cases, the clutter makes it difficult to see exactly what is driving the models. They all include a number of strong linearity assumptions but, in the dynamic models, it is difficult to tell if such assumptions lead to instabilities since there is in no case any discussion of steady-state properties. In the models that stay close to the SAM framework – for example, the Iran, Colombia, and Thailand models – it is relatively easy to sort out the causal linkages at work. The SAM framework imposes a structure that helps achieve the goal of transparency in an applied model.

Assumptions about fixed coefficients and cost prices limit the applicability of all linear input–output and SAM-based models, static and dynamic. These models reveal much about the structure of the economy and focus on important indirect as well as direct causal linkages. However, they are inherently limited in their ability to reflect the workings of a multi-market economy in which price adjustments play an important role and in which there are important substitution possibilities in both production and demand. Supply and demand interactions are largely beyond their scope, and they cannot capture policy choices that work through price incentives. To capture such features, non-linear models are required. Such computable general equilibrium models emerged in the early 1970s, along with the required computer software needed to solve them.

4. Computable general equilibrium models

In the literature on developing countries, computable general equilibrium (CGE) models represent an incremental step in a long tradition of work with multisector programming models.[47] A CGE model works by simulating the interaction of various economic actors across markets. Optimizing behavior of individual actors is assumed and is incorporated in equations describing their behavior, which essentially describe various first-order conditions for profit and utility maximization. The CGE framework requires a complete specification of both the supply and demand sides of all markets, including all the nominal magnitudes in the circular flow. The models are thus structural in spirit, capturing market mechanisms explicitly.

[47] See Devarajan, Lewis and Robinson (1986) for an extensive bibliography of work dealing with CGE models of developing countries.

The SAM accounts provide the underlying data framework for CGE models, with an income–expenditure account for each actor in the model. Neoclassical general equilibrium theory provides the analytical underpinnings. The body of mainstream neoclassical theory provides a powerful framework of analysis, with its systematic accumulation of useful taxonomies and formal analytical results. In many applications to developing countries, however, the framework has been stretched to accommodate a variety of structuralist features. In trying to judge the validity and applicability of the many non-neoclassical specifications that have been incorporated into CGE models, it is useful to start from the neoclassical paradigm and to establish a standard approach to describing the features of a general equilibrium model.

4.1. The structure of a CGE model

A general equilibrium model can be usefully described in terms of the following components.[48] First, one must specify the economic actors or agents whose behavior is to be analyzed. A simple Walrasian model would include only producers and households. Most CGE models add other actors such as government and the rest of the world – additional institutions in the SAM framework. Second, behavioral rules must be specified for these actors that reflect their assumed motivation. For example, producers are typically assumed to maximize profits subject to technological constraints and households to maximize utility subject to income constraints. Third, agents make their decisions based on signals they observe. For example, in a Walrasian model, prices are the only signals agents need to know. Fourth, one must specify the "rules of the game" according to which agents interact – the institutional structure of the economy. For example, assuming perfect competition implies that each agent is a price taker and that prices are flexible – markets exist and work perfectly.

The specification of the institutional structure and of the signals agents observe and react to are, of course, closely related. For example, under perfect competition, actors need only know prices. Alternatively, if some market is monopolistic, then one must specify that the monopolist makes supply decisions based on information about the demand functions of the demanders, not just the market price. In a model with some fixed prices, agents will be subject to rationing and one must specify their behavior in this situation – for example, what are the rationing rules and resulting spillover effects.

With the specification of the agents, their motivation, and the institutional constraints under which they interact, a general equilibrium model is still not completely determined. One must also define "equilibrium conditions" which are

[48]This description draws on Ginsburgh and Robinson (1984).

"system constraints" that must be satisfied, but that are not taken into account by any agent in making his decisions.[49] Formally, an equilibrium can be defined as a set of signals such that the resulting decisions of all agents jointly satisfy the system constraints. The signals represent the equilibrating variables of the model. For example, a market equilibrium in a competitive model is defined as a set of prices and associated quantities such that all excess demands are zero. In a market economy, prices are the equilibrating variables that vary to achieve market clearing.

As discussed earlier, the definition of equilibrium conditions is a fundamental property of a model. The specification of equilibrating variables and of system constraints that characterize an equilibrium can be seen as a simplifying device that provides a way to describe the results of the workings of an actual economy. For example, instead of specifying prices as equilibrating variables to achieve market clearing, one could instead try to model price determination explicitly, specifying "disequilibrium" price adjustment rules to describe how prices change over time. Such a specification is theoretically very difficult to implement – indeed, even to define – and completely unnecessary if one is willing to accept the market-clearing system constraints under flexible prices as a reasonable description of the final result of such a process within the time period described by the model.

There are, however, times when certain market-clearing assumptions are not reasonable. In CGE models of developed countries, for example, it is usually assumed that capital is mobile across sectors and is allocated so as to equate sectoral (after-tax) rental rates – an equilibrium condition that is consistent with an assumption of perfect capital markets.[50] Such a specification obviates the need to describe exactly how the capital market functions – we are only interested in the result. In models of developing countries, the assumption of sectoral capital mobility is rarely if ever reasonable. Instead, modellers have tended to assume that sectoral capital stocks are fixed within a period and, since sectoral rental rates are not equal across sectors, they have had to specify explicitly how the sectoral allocation of investment is determined from period to period.

4.2. *A neoclassical, closed-economy, CGE model*

Table 18.1 presents a stylized neoclassical CGE model of a closed economy and Figure 18.3 presents the associated SAM. Equations (1) to (5) in Table 18.1 describe the behavior of the various actors. There are n sectors, m factors of

[49]The term "system constraint" is due to Ginsburgh and Waelbroeck (1981) who provide a formal definition in the context of optimizing models.
[50]For examples of such models, see Scarf and Shoven (1983).

Table 18.1
A neoclassical closed-economy CGE model

Real flows		*Nominal flows*	
(1) $X_i^S(F_{i\cdot}^D)$	production (n)	(8) $\tilde{Y} = W \cdot F^S$	nominal income
(2) $C_i^D(P, \tilde{C})$	consumption demand (n)	(9) $\tilde{C}(\tilde{Y})$	consumption function
(3) $Z_i^D(P, \tilde{Z})$	investment demand (n)	(10) $\tilde{S} = \tilde{Y} - \tilde{C}$	nominal savings
(4) $F_k^S(W_k, P)$	factor supply (m)		
(5) $F_{ik}^D(W_k, P_i)$	factor demand ($n \cdot m$)		
Real system constraints		*Nominal system constraints*	
(6) $C_i^D + Z_i^D - X_i^S = 0$	products (n)	(11) $\tilde{S} - \tilde{Z} = 0$	savings-investment
(7) $\Sigma_i F_{ik}^D - F_k^S = 0$	factors (m)	(12) $f(P, W) = \bar{P}$	price index (scalar)
Accounting identities			
(13) $\Sigma_i \Sigma_k W_k \cdot F_{ik}^D = P \cdot X^S$	factor payments = total sales		
(14) $P \cdot C^D = \tilde{C}$	consumption demand = expenditure		
(15) $P \cdot Z^D = \tilde{Z}$	investment demand = expenditure		
Equilibrating price variables			
P = vector of product prices (n)			
W = vector of factor prices (m)			

Notes: X^S, C^D, Z^D, and P are all vectors with n elements, using subscript i. F^S and W are vectors with m elements, using subscript k. F^D is a matrix with $m \cdot n$ elements. In equation (1), the F^D with a subscript $i\,\cdot$ is a vector of k factor inputs into sector i. Nominal variables, all scalars, are denoted by a tilde. A dot $(\cdot)$ indicates either an inner product of two vectors or multiplication. The $f(-)$ in equation (12) denotes a function that defines the numeraire price index, which is fixed exogenously. There are $4n + 2m + n \cdot m + 4$ endogenous variables and the same number of independent equations.

Receipts:	Expenditures: Activities	Commodities	Factors	Households	Capital	Total
Activities		$P \cdot X^S$				$P \cdot X^S$
Commodities				$P \cdot C^D$	$P \cdot Z^D$	$\tilde{C} + \tilde{Z}$
Factors	$W \cdot F^D$					$W \cdot F^D$
Households			$\tilde{Y}$			$\tilde{Y}$
Capital acct.				$\tilde{S}$		$\tilde{S}$
Total	$W \cdot F^D$	$P \cdot X^S$	$W \cdot F^S$	$\tilde{Y}$	$\tilde{Z}$	

Figure 18.3. Social accounting matrix for a neoclassical CGE model. *Note*: Variables are defined in Table 18.1.

production, and one household. Equation (1) describes the production possibility frontier for the economy, given the set of sectoral production functions. In this simple model, intermediate goods have been netted out. In almost all applied CGE models, input–output coefficients are used to determine the demand for intermediate goods, while primary factors – capital and various kinds of labor – are assumed to be inputs in a neoclassical production function.[51] Given the production technology, profit-maximizing behavior, and the existence of competitive factor and product markets, equation (5) describes the demand for factors by sectors. Equation (4) describes aggregate factor supplies, which are usually just fixed exogenously in most CGE models applied to developing countries.[52]

Equations (2) and (3) describe the demand for products. Equation (2) is an expenditure function for the single household describing how total consumption expenditure is allocated among goods. Various expenditure systems have been used, usually assuming that some utility function is being maximized.[53] While this model has only one consumer, it is possible to specify any number of households in the model, each with its own sources of income and separate expenditure function.[54]

Equation (3) converts aggregate investment into demands for investment goods by sector of origin. In most applied models in developing countries, the sectoral allocation of aggregate investment is explicitly modelled and equation (3) then serves to translate investment by sector of destination into demand for investment goods by sector of origin. The standard technique follows that used in dynamic input–output models, with fixed capital-share coefficients describing different compositions of capital across sectors. The assumption of heterogeneous sectoral capital is empirically important in developing countries, where the agriculture and service sectors are large and use quite different kinds of capital goods than do the manufacturing sectors.[55]

[51]A variety of functional forms have been used, including, Cobb–Douglas, CES, generalized Leontief, translog, and various multi-level versions of these forms. See Dervis, de Melo and Robinson (1982, ch. 5), for a discussion of different specifications.

[52]CGE models applied to developed countries often have more elaborate factor supply equations incorporating the labor–leisure choice of workers. See, for example, Ballard, Fullerton, Shoven and Whalley (1985).

[53]The linear expenditure system is probably the most popular in models of developing countries, but others have been used. Dervis, de Melo and Robinson (1982) describe some of the choices.

[54]The one-consumer model, of course, is easier to solve. As noted above, it can be solved as a straightforward one-step non-linear programming problem.

[55]Most models of developed countries do not allow for heterogeneous capital across sectors. It is difficult to tell how important is the omission, but it might well be significant, especially in models where investment allocation is computed in some optimal fashion. See Dervis (1975) for an analysis of the importance of heterogeneous capital in a dynamic CGE model which includes intertemporal equilibrium.

Equations (8), (9), and (10) map the distribution of income from the factor accounts in the SAM to institutions. In this case, the SAM shown in Figure 18.3 is very simple, with only one aggregate household and a consolidated capital account. The household receives income, saving some and using the rest for consumption. The capital account serves the function of the financial sector, collecting savings and allocating it to investment, leading to demands for investment goods. Equation (11) specifies that aggregate nominal savings equal investment, or that the model be in macroeconomic equilibrium. Since the model has no independent investment function, the system constraint that investment equals savings [equation (11)] serves to determine aggregate investment. The model is "savings driven" and has no place for any interesting macroeconomic adjustment mechanisms and additional equilibrating variables.

Equations (6) and (7) represent the excess demand equations for the product and factor markets and provide the system constraints defining equilibrium in these markets. The equilibrating variables are product and factor prices, which serve as signals to producers and households in determining supply and demand behavior. Equations (13), (14), and (15) are accounting identities that the model must satisfy. They are not independent equations, but instead are implied from the factor and product demand equations.[56] Given these identities, the excess-demand equations satisfy Walras' Law – the sum of the nominal excess demands across all product and factor markets is zero. In the SAM in Figure 18.3, the identities guarantee that the "total" row and column have the same sum. In this case, the $n + m$ system constraints are not independent and will not suffice to determine $n + m$ product and factor prices. However, the behavioral assumptions are such that typically all the supply and demand functions are homogeneous of degree zero in all prices. Thus, one is free to add an additional equation defining a numeraire price index, equation (12), which defines a unit of account and has no effect on the equilibrium value of any real variable.[57]

Given the definition of the numeraire, the non-linear system has at least one solution endogenously determining relative prices and all real flows.[58] A fair amount of mathematical rigor is being finessed here. The supply and demand

[56]For example, homogeneous production functions yield factor demand equations which satisfy equation (13). If production functions were not homogeneous, then some factor return (such as profits) would have to be defined residually. Any expenditure functions arising from utility maximization will satisfy equation (14). Equation (15) is certainly a reasonable requirement to impose on investment demand.

[57]The "numeraire" is a good, or aggregation of goods, whose price is set to one (or any exogenous value) in order to define the units of all relative prices in the system. I will often use the term "numeraire price index" to refer to the price of this numeraire good.

[58]Problems of existence have been much studied and will not concern us here. See Ginsburgh and Waelbroeck (1981) and Scarf and Hansen (1973) for further discussion in the context of empirical models. Arrow and Hahn (1971) and Mas-Colell (1985) provide excellent textbook treatments of general equilibrium theory.

equations are specified as functions, not correspondences, and the equilibrium conditions as equalities, which is typical of CGE models. All prices will be strictly positive, with correspondingly strong assumptions about the nature of production technology and utility functions. While a CGE model with many consumers potentially might have multiple solutions, no one has ever reported such a problem with an applied model.[59]

It is possible, given the numeraire, to view producers as maximizing nominal profits and consumers as maximizing utility subject to nominal budget constraints. Such an interpretation is not necessary and the system can also be seen as representing a barter economy with relative prices indicating exchange values. For the neoclassical, savings-driven model, the choice of numeraire is purely a matter of convenience, essentially only setting the units in which nominal magnitudes are measured. The nominal variables – the ones with a tilde in Table 18.1 and Figure 18.3 – represent macro aggregates in the national income and product accounts. It is useful to define these macro aggregates for later use, but they could easily be substituted out in this model.[60]

While useful for exposition, the neoclassical CGE model has had very limited application in developing countries. The simplifications are too confining for applied work, and it has usually been used to analyze questions where a stylized model is appropriate. The original CGE model of Norway by Johansen (1960) stays close to the neoclassical paradigm and essentially the same model was also applied to Chile by Taylor and Black (1974).[61] In these cases, the scope of the analysis is carefully restricted, and the authors recognize the limitations of the stylization.[62] The neoclassical model seems to have had a longer life in developed countries; only very recently have models of these countries started to reflect any structuralist features.[63]

Over long time horizons, the assumptions of the neoclassical model are more appropriate. For example, stylized, long-run CGE models have been used fruitfully to examine determinants of long-run urbanization and structural change.

[59]See Mas-Colell (1985) and Kehoe (1980) for discussions of uniqueness of equilibria in general equilibrium models. It is evidently much more of a problem for theorists than for applied models.

[60]In standard textbook treatments of general equilibrium models, the expenditure function [equation (2)] has as arguments product prices, factor prices, and initial endowments. Nominal magnitudes are just side equations.

[61]These models have a different specification of aggregate investment than the neoclassical CGE model in table 18.1, which will be discussed below.

[62]Serra-Puche (1983) and Kehoe and Serra-Puche (1983), on the other hand, have constructed a stylized, neoclassical CGE model of Mexico and attempt to use it for policy analysis. Their use of such a stylized model for policy analysis is criticized by Robinson (1983) on the grounds that the model does not adequately reflect the structure of the Mexican economy, given their policy focus.

[63]For a survey of these models, see Shoven and Whalley (1984). See also the survey by Manne (1985).

These stylized historical models illuminate basic dynamic forces in development and give the economic historian a simulation laboratory for doing controlled experiments. They provide an excellent framework for sorting out historical trends and for doing experiments in counterfactual history. Such models have been constructed by Jeffrey Williamson, with various coauthors, for Japan, England, the United States, and India.[64]

One also might argue that a neoclassical model provides an appropriate framework for doing shadow pricing exercises for project analysis. Shadow prices used for large projects should reflect long-run scarcities, as well as take into account general equilibrium interactions. The work using SAMs to generate shadow prices can easily be extended to the framework provided by the neoclassical CGE model, and there is some work in this vein.[65]

Similarly, CGE models have been used to generate general equilibrium variants of measures such as effective rates of protection (ERPs) which have been developed to measure the impact of the tariff structure on value added, and hence resource allocation, in the economy. Empirical work with CGE models indicates that general equilibrium effects may matter a lot, changing the ranking of sectoral protection measures based on partial equilibrium assumptions. The standard partial equilibrium measures do especially badly when assumptions of imperfect substitutability between domestic and imported goods are introduced, as is done in the model described below.[66]

4.3. *Extending the neoclassical CGE model*

Modellers working on developing countries, however, have not stayed long with the neoclassical model. As discussed above, they have sought to extend the models in a variety of directions in order to capture "structuralist" features of developing countries. Within the framework of the CGE model, one can distinguish three kinds of structuralist models. First, one can stay within the theoretical structure of the neoclassical model, but specify limited substitution elasticities in a variety of important relationships. This type of model might be termed

[64]See Kelley, Williamson and Cheetham (1972), Kelley and Williamson (1974, 1984), Williamson and Lindert (1980).

[65]See, for example, Bell and Devarajan (1983). Bell and Srinivasan (1984) suggest that such an approach should be productive.

[66]Balassa (1982) discusses conditions under which the general equilibrium results from CGE models assuming perfect substitutability will be consistent with partial equilibrium measures. See also de Melo (1980). For comparisons of partial and general equilibrium measures in models assuming imperfect substitutability, see de Melo and Robinson (1981) and Devarajan (1987).

"elasticity structuralist". A second type, which can be called "micro structuralist", assumes that various markets do not work properly or are not present at all. Instead, there are assumed to be restrictions on factor mobility, rigid prices, rationing, and neoclassical disequilibrium in one or more important markets. "Macro structuralist" models represent a third type and focus on questions of achieving equilibrium among various macro aggregates; in particular, savings and investment, exports and imports, and government expenditure and revenue. While there has been some work to extend the macro structuralist models to include asset markets, virtually all of the applied models have incorporated constraints and equilibrium conditions on nominal flows representing macro aggregates.

There are various schools of thought in development economics that argue for models with differing mixes of structuralist features. For example, Hollis Chenery has argued that developing countries are characterized by a mix of elasticity and micro structuralist features. This school, which might be described as "neoclassical structuralist", accepts the neoclassical model of resource allocation and the importance of the operation of markets, but argues that substitution possibilities are more limited in developing countries than is usually assumed in neoclassical models, especially in foreign trade and production. In addition to low response elasticities, neoclassical structuralists also argue that there are important imperfect or incomplete markets, especially for factors of production and foreign exchange, in which prices do not respond properly to market forces. These imperfections may arise either from institutional sources or from policy choices. Another strand of this school's view is that rapid structural changes characteristic of the process of industrialization lead to continuing dynamic micro and macro disequilibria as market adjustments try to catch up with the dynamic processes. Chenery (1975) provides a succinct statement of the major arguments.[67] While there are many disagreements among neoclassical structuralists, they have in common an eclectic theoretical approach and probably share with most development economists the feeling that an uncritical application of the textbook neoclassical model to developing countries will lead to serious errors of analysis and policy advice.

A second school emphasizes the disequilibria that work through macroeconomic mechanisms, but whose roots lie in political and social conflict. The intellectual lineage of this school can be traced from Marx through Cambridge,

[67]See, for example, Chenery and Strout (1966), Chenery (1979), Chenery and Raduchel (1979), and Eckaus (1955). See also Chenery (1971, 1984), Chenery, Robinson and Syrquin (1986), and Adelman and Thorbecke (1966) for further elaboration of the approach and examples of models in this tradition.

England, to Latin America. Lance Taylor and his coauthors are prominent in this tradition.[68] While the term "Latin American structuralists" is sometimes used, it is more descriptive to view these models as examples of "macro structuralist" models in order to emphasize the mechanisms by which the disequilibrium adjustments are assumed to operate. This approach seeks to integrate macro models with multisector models, and so blend Keynes and Walras.

The attempt to force a macro framework onto a multisector model leads to many problems, including the need to add a number of micro structuralist features in order to capture the desired impact of macro adjustment on the economy. While the Latin American structuralists represent one school of thought, there are other macro structuralist approaches that mix macro adjustment and micro structuralist features. A variety of approaches will be discussed below in the context of alternative "macro closures" of a CGE model.

There are difficulties in extending the CGE model to incorporate these different structuralist features. As discussed above, the Walrasian model provides an uneasy host for macro models, and mixes of CGE and macro models all have an ad hoc flavor that arises from the fact that there is as yet no acceptable reconciliation of their different underlying theories. While the macro structuralist models probably place the greatest strain on existing theory, imposing micro structuralist features also has theoretical problems in that the structuralist rigidity often cannot be justified within the structure of the model.

The usual approach is to impose a rigidity on the model from outside, and then examine how the resulting mixed model performs. In many cases, it is possible to view the rigidity as arising from technological or institutional constraints that prevent maximizers from interacting across markets, even if they are not explicitly included in the model. For example, there is now a large body of theoretical literature indicating that there are many circumstances under which it is reasonable to assume that prices will not adjust as needed in the neoclassical model, and such frictions are widely observed in both developed and less developed countries. Models with price rigidities and "fixprice" adjustment mechanisms are now common in the theoretical as well as applied literature.[69]

The extension of a neoclassical CGE model to include micro and macro structuralist features raises two major complications in sorting out equilibrating mechanisms in the resulting hybrid model. First, is the model still homogeneous, i.e. is the real side "neutral" to the choice of numeraire? Many micro structuralist

[68] See Taylor (1979, 1983). Diamand (1978) provides an excellent discussion of the Latin American school.

[69] See, for example, Benassy (1982) for a discussion of fixprice general equilibrium models which exhibit Keynesian features. Waelbroeck (1986) discusses the problems and benefits of incorporating such features into CGE models.

Table 18.2
An elasticity structuralist CGE model

Real flows

(1) $X(L^{\mathrm{D}}, V^{\mathrm{D}}, K^{\mathrm{D}})$ production
(2) $X(E, D^{\mathrm{S}})$ export transformation
(3) $Q^{\mathrm{D}}(M, D^{\mathrm{D}})$ import aggregation
(4) $M/D^{\mathrm{D}} = f_1(P^m, P^d)$ import demand
(5) $E/D^{\mathrm{S}} = f_2(P^e, P^d)$ export supply
(6) $C^{\mathrm{D}}(P^q, \tilde{C})$ consumption demand
(7) $Z^{\mathrm{D}}(P^q, \tilde{Z})$ investment demand
(8) $V^{\mathrm{D}}(R, W, P^q, P^x)$ intermediate demand
(9) $Q^{\mathrm{D}} = C^{\mathrm{D}} + Z^{\mathrm{D}} + V^{\mathrm{D}} + \overline{G}^{\mathrm{D}}$ total
(10) $L^{\mathrm{S}}(W, P^q)$ labor supply
(11) $L^{\mathrm{D}}(R, W, P^q, P^x)$ labor demand
(12) $K^{\mathrm{D}}(R, W, P^q, P^x)$ capital demand

Nominal flows

(16) $\tilde{Y}^L = W \cdot L^{\mathrm{S}} \cdot (1 - \overline{T}^L)$ labor income
(17) $\tilde{Y}^K = R \cdot \overline{K}^{\mathrm{S}} \cdot (1 - \overline{T}^K)$ capital income
(18) $\tilde{Y}^G = \overline{T}^L \cdot W \cdot L^{\mathrm{S}} + \overline{T}^K \cdot R \cdot \overline{K}^{\mathrm{S}}$ government income
(19) $\tilde{C}(\tilde{Y}^L, \tilde{Y}^K)$ consumption function
(20) $\tilde{S}^P = \tilde{Y}^L + \tilde{Y}^K - \tilde{C}$ private saving
(21) $\tilde{M} = \overline{P}^{\$m} \cdot M$ dollar imports
(22) $\tilde{E} = \overline{P}^{\$e} \cdot E$ dollar exports

Price equations

(23) $P^m = r \cdot \overline{P}^{\$m}$ import price
(24) $P^e = r \cdot \overline{P}^{\$e}$ export price
(25) $P^q(P^m, P^d)$ composite price
(26) $P^x(P^e, P^d)$ output price

Real system constraints

(13) $D^{\mathrm{D}} - D^{\mathrm{S}} = 0$ product market
(14) $L^{\mathrm{D}} - L^{\mathrm{S}} = 0$ labor market
(15) $K^{\mathrm{D}} - \overline{K}^{\mathrm{S}} = 0$ capital market

Nominal system constaints

(27) $\tilde{S}^P + \tilde{S}^G + r \cdot \overline{B} - \tilde{Z} = 0$ savings-investment
(28) $\tilde{Y}^G - P^q \cdot \overline{G}^{\mathrm{D}} - \tilde{S}^G = 0$ government balance
(29) $\tilde{M} - \tilde{E} = \overline{B}$ balance of trade
(30) $f_3(P^d, P^m, P^e, W) = \overline{P}$ numeraire

Accounting identities

(31) $P^x \cdot X = P^e \cdot E + P^d \cdot D^{\mathrm{S}}$ value of output = value of sales
(32) $P^q \cdot Q^{\mathrm{D}} = P^m \cdot M + P^d \cdot D^{\mathrm{D}}$ value of composite goods = absorption
(33) $P^x X = W \cdot L^{\mathrm{D}} + R \cdot K^{\mathrm{D}} + p^q \cdot V^{\mathrm{D}}$ value of sales = value of inputs
(34) $P^q \cdot C^{\mathrm{D}} = \tilde{C}$ consumption demand = expenditure
(35) $P^q \cdot Z^{\mathrm{D}} = \tilde{Z}$ investment demand = expenditure

Endogenous variables

X = aggregate output
D^{S} = supply of domestic output
D^{D} = demand for domestic output
E = exports
M = imports
Q^{D} = composite good demand
V^{D} = intermediate demand
L^{S} = labor supply
L^{D} = labor demand
K^{D} = capital demand
C^{D} = real consumption
Z^{D} = real investment
$\tilde{Y}^L$ = nominal income
$\tilde{Y}^K$ = capital income

Endogenous variables, cont.

$\tilde{M}$ = dollar value of imports
$\tilde{E}$ = dollar value of exports
P^m = domestic price of imports
P^e = domestic price of exports
P^x = price of aggregate output
P^d = price of domestic sales
P^q = price of composite good
W = wage of labor
R = rental rate of capital
r = exchange rate
$\tilde{Y}^G$ = government income
$\tilde{S}^P$ = private savings
$\tilde{S}^G$ = government savings
$\tilde{C}$ = nominal consumption
$\tilde{Z}$ = nominal investment

Table 18.2 Continued

Exogenous variables	
$\overline{G}^{\mathrm{D}}$ = real government demand	$\overline{B}$ = balance of trade (in dollars)
$\overline{K}^{\mathrm{S}}$ = aggregate capital supply	$\overline{P}^{\$m}$ = world price of imports
$\overline{T}^{L}$ = tax rate on labor income	$\overline{P}^{\$e}$ = world price of exports
$\overline{T}^{K}$ = tax rate on capital income	$\overline{P}$ = numeraire price index

Notes: Variables with a tilde denote nominal magnitudes. Variables with a bar are exogenous. The superscripts d, m, e, x, and q refer to the domestic good, imports, exports, output, and the composite good, respectively (D, M, E, X, and Q). The superscripts D and S refer to demand and supply. The superscripts L and K refer to labor and capital. Superscripts P and G refer to private and government. A dot denotes multiplication. There are 29 endogenous variables and 30 equations. The equations, however, are functionally dependent and represent 29 independent equations.

The production function and import aggregation function [equations (1) and (3)] are CES functions [equation (1) is often a two-level nested function]. The export transformation function [equation (2)] is a CET function. Equations (4), (5), (8), (11), and (12) are the corresponding demand equations based on first-order conditions for profit maximization or cost minimization. In many models, intermediate demand is assumed to be given by fixed input–output coefficients, in which case equation (8) is a function only of output. Equations (25) and (26) are the cost function duals to the import aggregation and export transformation functions. Equation (30) defines the numeraire price index.

features can be captured by specifying various fixed relative prices, with the resulting model still neutral to the choice of numeraire. If not, however, then the numeraire price normalization must be interpreted as an aggregate price index which serves as an important signal to some actors; an exogenous variable whose changes will affect real behavior.

A second issue concerns the interpretation of the nominal flows, including financial flows (in the capital account) and transfers. Extending the CGE model to include macro flow equilibrium conditions does require that the model be seen as reflecting a monetized economy in which nominal aggregates play an important role. However, the model need not include assets and money explicitly. It is an open question whether macro structuralist models can be truly convincing without explicitly including assets and asset markets, but it is certainly possible to capture a number of interesting macro stories in such models.

While the theoretical difficulties in extending the CGE model are great, the potential payoff in developing useful policy models is also great. But it is important to proceed with caution, adding at each step only as much complication as is needed, and retaining a clear view of the causal mechanisms at work.

4.4. An elasticity structuralist CGE model

Table 18.2 sets out the equations of a simplified version of a stylized elasticity structuralist model of an open economy that also includes a government account. The associated SAM is given in Figure 18.4. The model is representative of a

Receipts:	Expenditures: Activities	Commodities	Factors: Labor	Capital	Households	Government	Capital account	World	Total
Activities		$P^d \cdot D^S$						$p^e \cdot E$	$P^x \cdot X$
Commodities	$P^Q \cdot V^D$				$P^q \cdot C^D$	$P^q \cdot G^D$	$P^q \cdot Z^D$		$P^q \cdot Q^D$
Factors:									
Labor	$W \cdot L^D$								$W \cdot L^D$
Capital	$R \cdot K^D$								$R \cdot K^D$
Households			$\tilde{Y}^L$	$\tilde{Y}^K$					$\tilde{Y}^L + \tilde{Y}^K$
Government			$\bar{T}^L \cdot W \cdot L^S$	$\bar{T}^K \cdot R \cdot \bar{K}^S$					$\tilde{Y}^G$
Capital acct.					$\tilde{S}^P$	$\tilde{S}^G$		$r \cdot \bar{B}$	saving
Rest of world		$P^m \cdot M$							$P^m \cdot M$
Total	$P^x \cdot X$	supply	$W \cdot L^S$	$R \cdot \bar{K}^S$	$\tilde{Y}^K + \tilde{Y}^L$	$\tilde{Y}^G$	$\tilde{Z}$	foreign exchange	

Figure 18.4. Social accounting matrix for an elasticity structuralist CGE model. *Note*: Variables are defined in Table 18.2.

class of CGE models that have been widely used to analyze issues of structural adjustment in developing countries. With some variations, a number of applied models developed over the past ten years are based on this essential structure.[70] Many of the features of the model are described in detail in Dervis, de Melo and Robinson (1982, ch. 6 and 7).[71]

To save on notation, the simplified model has one sector producing a single commodity (X) which is then transformed into an export good (E) and a good for the domestic market (D). Equation (1) is the production function, using labor, an intermediate input, and capital.[72] In this case, the factor demand equations [(11) and (12)] involve no summing over sectors. Expanding to a multisector model involves: (1) adding sectoral subscripts to equations (1)–(9), (13), and (23)–(26); (2) differentiating demand for intermediate inputs by sector of origin and destination; and (3) summing over sectors where required [e.g. equations (11), (12), (21), (22), (28), and (31)–(35)]. In many models, labor is also disaggregated by skill category and/or the labor markets are segmented across broad sectors (agriculture, industry, and services). Thus, average wages may differ between agricultural, industrial, and service sectors. Also, capital is often assumed to be sectorally immobile, so that capital rental rates (R) will differ across sectors.

Equation (2) gives the function for transforming output into different goods for export and domestic sales, which is usually a constant elasticity of transformation (CET) function. In a multisector model, the assumption is that domestic sales and exports with the same sectoral classification represent goods of different qualities or, perhaps, subsector composition. The CET function describes the ease with which it is possible to shift the composition of sectoral production between the domestic and foreign markets.

On the import side, domestic goods sold on the domestic market are assumed to be imperfect substitutes for imports. What demanders want is a composite commodity, which is a CES aggregation of imported and domestic goods. Equation (3) is the CES import aggregation function.[73] Given equation (2) and

[70]For examples of applications in this tradition, see Dervis and Robinson (1978, 1982); Dervis, de Melo, and Robinson (1981); Lewis and Urata (1984); Robinson and Tyson (1985); Grais, de Melo, and Urata (1986); Condon, Corbo, and de Melo (1985a, b); Drud and Grais (1983); Benjamin and Devarajan (1985); and Michel and Noel (1984). Sanderson and Williamson (1985) provide a survey of some of these applications. Decaluwe and Martens (1987) survey over 40 CGE models of 20 countries, of which something over half are applied models. Devarajan, Lewis, and Robinson (1986) list some 40 references describing applied models of around 30 countries.

[71]See also Condon, Robinson, and Urata (1985), who describe an updated version of the core model, including some new features included in the model in Table 2 such as the CET export transformation function.

[72]Often, a two-level CES function is used. One can also work directly with cost functions. Intermediate inputs are usually assumed to be given according to fixed input-output coefficients.

[73]The import aggregation function is sometimes called the Armington function, after Armington (1969) who used this formulation to derive import demand functions. Dervis, de Melo and Robinson (1982) call it the trade aggregation function.

(3), plus standard assumptions about profit maximization and cost minimization, it follows that desired import and export ratios are functions of relative domestic and foreign prices. These functions are given by equations (4) and (5).[74] Equations (25) and (26) define the prices of the two composities, X and Q, and correspond to cost function duals to equations (2) and (3). Homogeneity of the CES and CET functions guarantees the satisfaction of the accounting identities given in equations (31) and (32).

In contrast to the standard trade theory model in which all goods are tradable and all tradables are perfect substitutes, this specification endows the domestic price system with a significant degree of autonomy. There are seven prices associated with the single sector: P^x, P^q, P^d, P^m, P^e, $P^{\$m}$, and $P^{\$E}$. This represents quite a lot of structure for a one-sector model! The model can, however, be seen as a three-sector model, with a domestic non-tradable (D), an exportable (E), and a non-produced import (M). Equation (2) can be viewed as a production possibility frontier, and equation (3) becomes part of a two-level utility function. In a multisector model, the interpretation here of imperfect substitutability and transformability of goods within the same sector classification is more appealing. The model retains the standard "small country" assumption in that the world prices of imports and exports are assumed fixed.[75] However, trade policy, which puts a wedge between the world price and domestic price of imports and exports, will have much less effect on domestic prices than in the standard model.

In the past few years, the properties of models in which there is imperfect substitutability in trade have been analyzed in detail.[76] To summarize the results, the model is still very neoclassical in spirit and presents no problems theoretically. Compared to the neoclassical, closed-economy model in Table 18.1, there are additional system constraints involving the balance of trade, equation (29), and the government account, equation (28). There is also an additional price, the exchange rate, which serves as the equilibrating variable to ensure equilibrium in the balance of trade. Since there are no assets in the model and the amount of the balance of trade in equation (27) is exogenous, the exchange rate will vary to achieve a flow equilibrium. The equilibrating mechanism works through changes

[74] Dervis, de Melo and Robinson (1982, ch. 7), present a model in which equation (5) is a logistic function, while equation (2) is a simple linear aggregation. Empirically, their model behaves almost exactly like the model in Table 18.2.

[75] Some CGE models assume instead that there is a downward-sloping world demand function for the country's exports. Such a specification does not change the essential nature of the model. For example, see Dervis and Robinson (1978).

[76] See, for example, de Melo and Robinson (1981, 1985, 1989), Dervis, de Melo and Robinson (1982, chs. 6 and 7), Bergman (1982), and Whalley and Yeung (1984). In particular, de Melo and Robinson (1989) discuss the role of the exchange rate under different choices of numeraire in a simplified version of the model presented in Table 18.2.

in the real exchange rate, which in this model is the ratio of the price of the domestic non-tradable, D to the prices of tradables, E and M.

If the domestic good is chosen as numeraire (setting P^d to one), then the nominal exchange rate in the model, r, will correspond to the real exchange rate. If some other price index is chosen to define the numeraire, which is common in applied models, then changes in the real exchange rate will be a monotonic function of changes in the nominal exchange rate. In analytic models, it is usually convenient to pick the foreign good as numeraire (setting r to one), which means that P^d then serves the role of the real exchange rate.

There appears to be some confusion about this specification in the literature.[77] One problem seems to lie in the interpretation of the behavior of the rest of the world in this single-country model. One view is that, in effect, we really have a two-country model, and the balance of payments constraint should be seen as the budget constraint of the rest of the world. In this view, the model requires an equilibrating mechanism to ensure that the foreign actor is content to be on his budget constraint. However, such an interpretation really strains the single-country model in which the rest of the world is assumed to supply unlimited imports and demand unlimited exports at fixed world prices. In this case, the behavior of the rest of the world is summarized by a straight-line offer curve.[78] The exchange rate in the model is not a signal that affects the behavior of the rest of the world, which passively buys and sells whatever is supplied or demanded. It is probably better to view these equations as providing an empirical description of the operation of international markets, with no assumptions about optimizing behavior on the part of foreigners.

A second problem concerns the interpretation of the exchange rate variable in the model. What the CGE model determines is a stable relationship between the balance of trade and the real exchange rate. Given this relationship, a macro model is needed to determine any two, but no more than two, of the following variables: the domestic aggregate price level, the balance of trade, and the nominal exchange rate. Given fixed value of two of these variables, the CGE model will determine the equilibrium values of the third, given the flow system constraints. In the model in Table 18.2, and in many applied models, the aggregate price level and the balance of trade are set exogenously, and the model solves for the exchange rate. Fixing the nominal exchange rate, the model will solve for the domestic price level. In both of these cases, the model solves for a single equilibrium real exchange rate. Alternatively, fixing the exchange rate and the aggregate price level, the model will solve endogenously for the balance of

[77]See, for example, Srinivasan (1982) and Whalley and Yeung (1984). They criticize applied CGE models for including the exchange rate as a "financial" variable.

[78]Assuming a downward-sloping world demand curve for exports does not change the essential nature of the model, but only adds some curvature to the foreign offer curve. The foreigner is still assumed to be a price taker. See de Melo and Robinson (1989) for a discussion of this point.

trade. In a more complete macro model, one which includes assets, there are undoubtedly additional relationships among these variables, but they are outside of the CGE model.[79]

There are a few studies which use a CGE model of this type to analyze the impact of various exogenous price and policy shocks on the equilibrium exchange rate. In these studies, the CGE model is used as a laboratory for doing counterfactual experiments to sort out the relative importance of factors such as: (1) the maintenance of a fixed exchange rate in the face of differential domestic and world inflation rates, (2) changes in world prices of goods such as oil, (3) changes in capital inflows and remittance flows, (4) changes in export demand, and (5) changes in the structure of trade. The results from studies of Turkey and Yugoslavia indicate that the calculation of price level deflated exchange rates to measure changes in the equilibrium exchange rate – a common practice in the IMF and World Bank – can be badly off the mark.[80] In a world of changing relative prices and world market conditions, a partial equilibrium analysis appears to do very badly compared to a CGE model.

The open-economy CGE model in Table 18.2 has a set of nominal flows similar to those in the earlier neoclassical model, with some additional macro aggregates. The SAM in Figure 18.4 lays out the various accounts. Factor income is separated into two types, labor and capital, and the capital account has new sources of savings: the balance of trade in domestic currency (foreign savings) and the balance on the government account (government savings). As in the earlier model, investment is assumed to be savings-driven; aggregate consumption is given by equation (19), government saving is determined residually in equation (28), and equation (27) serves to determine aggregate investment. Also, as in the earlier model, the accounting identities [equations (31)–(35)] are implied by the behavioral equations.[81] They ensure that the model satisfies Walras' Law; the sum of the nominal values of equations (13)–(15) and (27)–(29) equals zero.

With the addition of foreign trade and the government, and more substitution possibilities, the elasticity structuralist model can serve as a richer framework for policy analysis. Many of the applications explore the structural impact of changes in the composition of the macro aggregates (balance of trade, government deficit, and savings–investment balance). With both foreign and domestic savings identified, and assuming low substitution elasticities for imports, the model also

[79] Keeping these macro relationships outside of the CGE model assumes a certain separability between the models. For example, one might argue that macro forces affect the parameters of the CES and CET functions determining the real demand for imports and supply of exports in the CGE model.

[80] See, for example, Dervis and Robinson (1982), Lewis and Urata (1984), and Robinson and Tyson (1985). These and other related studies are surveyed in Sanderson and Williamson (1985).

[81] Equation (33) requires an assumption of homogeneity of the production function, or else the rental rate on capital must be defined residually.

captures elements of the Chenery and Strout (1966) two-gap model, which is evident in a number of applications. The basic model structure can also be used to analyze the implications of different choices of development strategy (such applications will be discussed below).

4.5. Micro structuralist models

While a considerable advance, the assumptions of the elasticity structuralist model of an open economy are still quite stylized. All prices are assumed to be flexible and all markets are assumed to clear. The model is still fundamentally neoclassical, with some limitations on the ease with which factors and products are substituted. Relative prices are the equilibrating variables and are the only signals actors need to see.

Most applied models, while largely staying within this framework, have also added some structuralist constraints on the ability of markets to function. First, most models of developing countries assume that capital is sectorally fixed. In equilibrium, rental rates will thus differ across sectors. Two additional common micro structuralist constraints are to assume that wages and/or the exchange rate are fixed. In a general equilibrium model, when an equilibrating variable such as a price is fixed, then some other equilibrating mechanism must be specified that includes a rationing mechanism by which the "excess" supply or demand is allocated in the system. For the labor market, a common assumption is to assume that firms are always on their demand curves for labor and that all unemployment is borne by the suppliers of labor. In this case, the labor supply equation is dropped from the system and the labor market equilibrium equation states that labor demand is always met by supply.[82] A different mechanism would be required if the wage were fixed too low (i.e. excess demand for labor).

Similarly, a model with a fixed exchange rate requires the specification of a rationing rule and equilibrating mechanism. One approach, which was used in many earlier linear programming models, is to assume that the net foreign capital inflow becomes the equilibrating variable. In Table 18.2, with a fixed exchange rate, the balance of trade (B) simply becames endogenous. While perhaps reasonable in models built during the 1960s, such a specification, which implies unlimited borrowing capacity, is clearly inappropriate for models used in the last decade.

[82] This rationing rule assumes that there will be unemployment, or that suppliers will freely supply all labor demanded at the fixed wage. The labor supply function can be used as a side equation to compute involuntary unemployment. The unemployed, however, are assumed to receive no income, do not consume, and effectively disappear from the system.

With a fixed exchange rate and a fixed balance of trade, some new equilibrating mechanism must be specified which involves rationing of imports.[83] Dervis, de Melo and Robinson (1982) explore two mechanisms: a fixprice and a flexprice rationing system. In the fixprice system, the equilibrating variable is an average quantity rationing rate, and all demanders are assumed to be forced off their import demand functions so as to achieve equilibrium in the balance of trade.[84] In the flexprice system, in which there is an open market in import licenses, the average import premium rate becomes the equilibrating variable and serves as a uniform tariff to raise domestic prices of imports and so achieve equilibrium. In the flexprice system, it is necessary to model explicitly who receives the value of the import licenses, which represents the rents generated by import rationing.

A number of stylized and applied models have been built which incorporate one or both of these import rationing mechanisms.[85] One theme of some of these models is to assume that there is rent-seeking behavior arising from the import rationing that leads to waste of resources and, hence, efficiency losses.[86] An important stylized fact coming out of this work is that, in many countries, the value of the "chaseable rents" generated by import rationing is a very large number. Chaseable rents arising from even a relatively mild import rationing scheme can easily amount to 10–15 percent of GDP in a semi-industrial country with a significant trade share.[87]

The existence of rents does not necessarily imply that there will be rent seeking, with concomitant waste of resources. Indeed, in a system in which distortions have long been institutionalized, one would expect that the allocation of the resulting rents would also have been settled, with little scope for further rent-seeking activity. However, in a period in which new distortions are introduced that generate major rents, there would likely be major disruptions in the system as agents adjust to the new situation. An element adding to this disruption is the fact that the chaseable rents are not reflected in standard national income statistics, adding to the difficulties facing policy-makers trying to figure out what is going on in the economy. In addition, since it is usually illegal to

[83]The assumption is that the real exchange rate is set at an overvalued level, given the numeraire, thus requiring import rationing. An excess supply of foreign exchange would require a quite different rationing mechanism.

[84]The question of spillovers in this quantity rationing mechanism is important, and has been dealt with in a variety of ways in existing models. See, for example, Dervis, de Melo and Robinson (1982 ch. 9) and Dewatripont and Robinson (1985).

[85]See, for example, World Bank (1980, 1983), Robinson and Tyson (1985), Kis, Robinson and Tysin (1985), Robinson, Tyson and Dewatripont (1986), Dervis and Robinson (1978); de Melo and Robinson (1980), Drud, Grais and Vujovic (1982), Lewis and Urata (1983, 1984), and Condon, Corbo and de Melo (1985a, 1985b).

[86]The seminal theoretical article is Krueger (1974). See also Bhagwati and Srinivasan (1980).

[87]Condon, Robinson and Urata (1985) present a stylized model of Turkey which explores these costs. The effect on income distribution of different adjustment mechanisms in explored in a stylized model by de Melo and Robinson (1982). See also references to applied models cited earlier.

monetize the value of import rationing, its imposition adds to incentives to cheat and to report data inaccurately.

In an economy with reasonable consumption and factor substitution possibilities, dead-weight efficiency losses arising from price distortions seldom amount to more than 1–2 percent of GDP. During the adjustment period, the potential disruption costs arising from the generation of chaseable rents is a much larger number. In the short to medium run, implementing policies designed to improve allocative efficiency by "getting the prices right" may well be less important than implementing policies designed to reduce chaseable rents or to control rent seeking, although the two goals are probably often interdependent.

While a fixed exchange rate and fixed wages are the most common features of micro structuralist models, there are also some models which specify fixed product prices for various sectors. A common feature of Latin American macro structuralist models is to assume that manufacturing firms set prices by imposing fixed markups over prime costs in order to ensure an acceptable profit. In a CGE model, this pricing rule amounts to fixing some sectoral prices relative to non-capital input costs. In these sectors, a quantity adjustment mechanism, often Keynesian in nature, is specified to clear the product markets, dropping the assumption of profit-maximizing supply behavior and replacing it with an assumption of excess capacity.

Whenever a modeller chooses to fix some prices, it is necessary to explain exactly what is being fixed and to specify the alternative adjustment mechanisms and equilibrating variables. In a CGE model, a fixed price is always a fixed relative price, and the modeller must specify relative to what. For example, fixing the real wage involves fixing the ratio of the nominal wage to an appropriate price index.[88] In this case, the solution values of real variables will still be unaffected by the choice of numeraire. However, some modellers choose to fix the nominal wage.[89] In this case, what is being fixed is the wage relative to the numeraire price index, and the real wage will not be fixed unless the appropriate consumption bundle was chosen as numeraire. Similarly, a fixed exchange rate is usually set in nominal terms, and hence must be interpreted as fixed relative to the numeraire price index. In this case, the real exchange rate – the relative price of tradables to non-tradables – is not fixed unless the appropriate domestic price index is chosen to define the numeraire.

Even though some relative prices are fixed in a micro structuralist CGE model, the system constraint equations are still part of the model. Equilibrium is still well defined but, since prices no longer serve as the equilibrating variables for

[88]In a model with many labor categories and many sectors, the definition of the appropriate real wage is not trivial. For example, is it the sectoral marginal revenue product or the supply price of labor of a given skill category?

[89]See, for example, Lysy and Taylor (1980) and Ahluwalia and Lysy (1979). This specification is common in macro structuralist models.

these markets, some other mechanism must be specified. In addition, since prices no longer serve their proper signalling function, it is necessary to reconsider the behavioral equations of the various actors. What is their new, constrained optimization problem? What are the spillover effects when there is quantity rationing? The gains in realism from extending the neoclassical model are not bought cheaply, but instead impose new theoretical and expositional burdens on the modeller.

The justification for fixing various prices must come from theoretical considerations outside of the Walrasian paradigm. There is now a large and growing literature justifying fixprice assumptions, most of it in the context of macro models. In the development literature, there are models in which the real urban or industrial wage is fixed, with the corresponding labor supply assumed to be infinitely elastic at the exogenous wage.[90] In CGE models, this formulation is easily accommodated, without any need to worry about the choice of numeraire. However, fixed nominal wages or a fixed nominal exchange rate, which are common assumptions in macro models, require justification in macro theory and must, in a CGE model, be viewed as fixed relative to the choice of numeraire. The numeraire defines a price index that is to be set exogenously in the CGE model. In this case, the definition of this index matters, affecting real variables, and must be part of the underlying macro model. While exogenous to the CGE model, it is an active variable in a macro model that is, in a sense, being imposed from outside the CGE model.

For example, in Table 18.2 there are three prices that might be set exogenously, depending on the underlying macro theory: the domestic price, the output price, or the composite price. These correspond to a domestic wholesale price index, a GDP deflator, and a retail price index, respectively. Which of these indices one would wish to assume fixed, along with the nominal wage and/or the exchange rate, depends on one's view about the nature of monetary policy and price level determination in the particular economy.

Macro problems have insidiously crept into the micro structuralist model. Note that, given the aggregate price index defining the numeraire, there are no theoretical problems concerning the functioning of the CGE model. It is now a less well-behaved general equilibrium model with some fixed relative prices.[91] What is at issue is the rationale for the choice of relative prices to fix. In the CGE model, the clear dichotomy between the real and nominal sides is no longer sustainable. Indeed, interaction between the nominal and real sides is a crucial part of any interesting macro model. If money were always neutral and relative

[90] The Lewis model, with its many variants. See Fei and Ranis (1964).

[91] With some relative prices fixed, existence proofs are harder. However, there are existence theorems for some fixprice models, and no one has reported any difficulties finding solutions to empirical models.

prices always free to vary to clear product and factor markets, there would be little for macro economists to do.

4.6. Macro structuralist models

Controversies about the macroeconomic properties of CGE models have been intense since the first such models were constructed for developing countries. The debate started with the distribution-focused models of Korea by Adelman and Robinson (1978) and Brazil by Lysy and Taylor (1980), but quickly moved beyond particular multisector models.[92] The discussion has focused on what has come to be called the macro "closure" of economywide models, be they one-sector or CGE models.

The early work on macro closure was concerned only with how equilibrium was achieved between aggregate savings and investment and largely ignored the macroeconomic impact of both the government and the foreign accounts. A variety of savings–investment closure rules have been specified in CGE models, which illustrate the different macro theories at issue.[93] In comparing alternative macro specifications, it is important to distinguish between the macro equilibrating mechanisms at work and the equilibrating variables in the models.

The two CGE models given in Tables 18.1 and 18.2 both exhibit "neoclassical closure." They are savings-driven, with no special equilibrating variable required to achieve savings–investment equilibrium. In his model of Norway, Johansen (1960) replaces the aggregate savings function – equation (20) in Table 18.2 and equation (10) in Table 18.1 – with an aggregate investment function. In this "Johansen closure," aggregate consumption is determined residually, and again no additional equilibrating variable is required. The macro story, however, is quite different. The Johansen model is investment-driven, which implies that some unspecified macro mechanism outside of the model, presumably involving government expenditure policy, works to make aggregate consumption adjust residually.[94]

[92] The controversy with regard to those two models is discussed in Taylor and Lysy (1979) and Adelman and Robinson (1988). For a review of the early debate, see Bruno (1979) and Dervis, de Melo and Robinson (1982, ch. 12). These two models are also discussed in surveys by Bigsten (1983), Sanderson (1980), and Thorbecke (1985). Distribution models in general are surveyed in Chapter 17 by Adelman and Robinson in this Handbook.

[93] The seminal work on macro closure is Sen (1963). Rattso (1982) and Lysy (1983) provide surveys. See also Dewatripont and Michel (1987) and Robinson and Tyson (1984) for different approaches to the macro closure issue.

[94] Johansen (1960) justifies his specification on the basis of explicit government tax and expenditure policies designed to maintain a target level of aggregate investment. All this is implicit, however, since his model does not include government as an actor.

If one wished to have a model with both an aggregate consumption or savings function and an aggregate investment function, then some new equilibrating variable would be required to achieve macro equilibrium. One approach, which might be termed "Fisherian closure," would be to include a loanable funds market in the model, with both savings and investment depending on a new equilibrating variable, the interest rate.[95] While the model would not need to include any assets explicitly, it certainly begins to strain the Walrasian paradigm.

The three macro closures discussed so far are all similar in that they view the macro problem as one of achieving the proper composition or balance among macro aggregates. Disturbances in nominal macro balances in the model may affect the sectoral composition of demand, and hence production, but will have little or no effect on aggregate output. The models all assume full employment and, with reasonable substitution possibilities, empirical models adjust to compositional changes with little change in aggregate production and real income. Minor variations on these themes have been used in a number of CGE models of developing countries designed to analyze medium-term development strategies. The time horizon is long enough in these models so that exogenous projections of aggregate employment are reasonable.

In contrast to these essentially neoclassical models, structuralist macro models postulate strong links between the real and macro sides of the model. That is, changes in the composition of the nominal macro aggregates affect both the level of aggregate output and employment as well as their sectoral structure. Drawing on Keynes, Kalecki, and Kaldor for intellectual inspiration, Lance Taylor and various associates argue that the macro specification drives the model, determining both aggregate and distributional outcomes.[96] In these Latin American macro structuralist models, relative prices do not work as in the neoclassical paradigm and quite different mechanisms come into play in order to achieve macro equilibrium. Two equilibrating mechanisms common to most such models are: (1) Keynesian multiplier effects by which changes in aggregate demand lead to changes in aggregate supply, and (2) Kaldorian distributional effects by which changes in the distribution of income lead to changes in aggregate savings.

The CGE model of Brazil by Lysy and Taylor (1980) is an early example of models in the Taylor tradition, and its major features can be seen by starting from the neoclassical structuralist model in Table 18.2. First, an aggregate investment function is added to the system, usually by making aggregate real investment an exogenous variable. The model now needs a macro equilibrating variable to balance aggregate savings and investment. Second, the labor supply

[95]One should probably be careful with names. Lance Taylor noted that this closure could be attributed to J.S. Mill.

[96]See Taylor (1979, 1983). An excellent discussion of this literature is provided by Buffie (1984). See de Janvry and Sadoulet (1985) for a survey of macro structuralist CGE models of six countries: India, Peru, Mexico, Egypt, Korea, and Sri Lanka. These models display a wide variety of structuralist features. See also Taylor (1989).

function is dropped from the system and firms are assumed always to be on their demand curves for labor. The wage no longer serves as the equilibrating variable for the labor market, since labor supply is always assumed to meet demand. Third, the nominal wage is chosen as numeraire [equation (30)] and the aggregate output price level is no longer assumed fixed. Finally, the model also specifies different savings rates out of capital and labor income, so changes in the functional distribution will affect aggregate savings.

This model displays what Taylor and Lysy (1979) call "Keynesian closure". Assume an increase in exogenous investment. With fixed savings rates, the levels of income and real output increase through a Keynesian multiplier process, and so generate the increased savings necessary to match the higher level of investment. Since firms are assumed to be on their demand curves for labor, they must be induced to hire the required additional labor. The real wage must therefore fall and provides the driving variable by which the multiplier process operates. Given that the nominal wage is fixed, the macro equilibrating variable is the aggregate price level. An increase in the aggregate price level lowers the real wage, inducing firms to hire more labor and increase output, which leads to higher income and hence savings.

Note that if the aggregate price level were chosen to define the numeraire, then the nominal wage would serve as the equilibrating variable to achieve balance between aggregate savings and investment. The mechanism is exactly the same in the CGE model – changes in the real wage serve to drive the multiplier process. In either case, the underlying macro story justifying the process lies outside of the CGE model. In neither case is it possible to view the equilibrating variable as a signal entering decision functions of actors in the system. Certainly, neither the nominal wage nor the aggregate price level can serve as a signal in the loanable funds market, even if the CGE model had such a market! The price-level adjustment story sounds more plausible, especially in Latin American countries, although either will give the same result for all real variables in the CGE model.[97]

One important feature of the CGE model with Keynesian closure is that any increase in aggregate output is always associated with a decrease in real wages. This property leads to unfortunate distributional effects – any Keynesian expansion cuts wages as it increases employment.[98] In a different version of Keynesian closure, Dewatripont and Robinson (1985) specify a macro structuralist CGE

[97]In fact, in the Brazil model, the story is a bit more complex. Some nominal flows, including categories of government expenditure, are fixed, so changes in the aggregate price level have real effects in addition to driving the multiplier process. There is also a fixed exchange rate, so variations in foreign capital inflows potentially may affect savings–investment equilibrium.

[98]Lysy and Taylor recognize this property of their Brazil model. See Lysy and Taylor (1980, p. 161). In a model with markup pricing, one can potentially break this link since firms are no longer assumed to be on their demand curves for labor.

model with simultaneous rationing in the product and labor markets.[99] In their model, the Keynesian multiplier also drives the macro equilibrating mechanism, but – given spillover effects from the product market to the labor market – increases in demand lead to a relaxation of rationing in the product market and are associated with rises in the real wage. Which of these Keynesian closures better reflects the views of J.M. Keynes is a debate I leave to others.

Given that different actors have different savings rates, macro structuralist models have potentially important links between the functional distribution of income and macro equilibrium.[100] In some CGE models, these distributional effects are enhanced by assuming markup pricing rules for some sectors, usually manufacturing. In this case, as noted above, output prices relative to non-capital input prices are fixed, and the assumption that firms maximize profits is dropped. Output supply is assumed to adjust to demand, with employment linked to output by fixed coefficients. After capacity output is achieved, the regime shifts and the markups adjust. The underlying story is that capitalists attempt to maintain their profit share through the fixed markups, nominal wages are fixed, and the aggregate price level is again the macro equilibrating variable.[101]

In an open economy, the balance of trade provides another potential equilibrating mechanism for achieving savings–investment balance. Even assuming a fixed balance of trade in dollars, changes in the exchange rate will lead to changes in the value of the trade balance in domestic currency, and so affect aggregate savings. If the balance of trade is assumed to adjust, there is an even stronger link. At one extreme, Ahluwalia and Lysy (1981) built a model of Malaysia in which the balance of trade adjusts to achieve equilibrium between savings and investment, with the real exchange rate thus serving as the macro equilibrating variable.[102] Models in which foreign borrowing adjusts to changes in macro variables seem especially important for Latin American countries. There are a number of examples, although none with such extreme behavior as specified in the Malaysia model.[103]

[99] Their model is in the tradition of macro models analyzed by Malinvaud (1977) and Muellbauer and Portes (1978).

[100] Lysy and Taylor (1980) assert that these Kaldorian linkages are very important in their Brazil model, but Adelman and Robinson (1988) find that, in a stylized version of their model, the Keynesian multiplier is empirically far more important. In most of their experiments, distributional effects on aggregate savings are insignificant. For a different approach to capturing macro distributional effects in a CGE model, see Bourguignon, Michel and Miqueu (1983).

[101] See, for example, Taylor, Sarkar and Rattso (1984). In this model, applied to India, there is a mix of fixprice and flexprice sectors. See also Gibson (1985) and Gibson, Lustig and Taylor (1985) for similar CGE models of Nicaragua and Mexico.

[102] In this model, the nominal exchange rate is fixed, so variations in the domestic price level serve as the equilibrating variable. The equilibrating mechanism, however, works entirely through changes in the real exchange rate, which cause changes in the trade balance.

[103] See, for example, Condon, Corbo and de Melo (1985a, 1985b), Feltenstein (1980), and Levy (1987). Adelman and Robinson (1988) consider how the Keynesian multiplier is weakened in models with a fixed exchange rate. See also Devarajan and de Melo (1987).

Macro structuralist CGE models are based on a variety of assumptions that lead to adjustment problems and links between changes in nominal macro aggregates and real aggregate output and employment. These include: (1) markup pricing rules, resulting in rationing in the product markets, (2) working capital financing requirements, (3) segmented credit markets, (4) financial repression leading to low savings levels and investment rationing, (5) fixed exchange rates, leading to import rationing, (6) fixed nominal wages, leading to unemployment, (7) fixed aggregate real investment, (8) non-competitive imports of intermediate inputs, and (8) immobile sectoral capital.

Empirical support for a number of these specifications is weak, and some of them are better suited for a stylized rather than an applied model. For example, assuming that aggregate real investment is fixed is theoretically convenient when tracing out the analytic implications of some structuralist specifications. In an applied model, however, it is empirically untenable to assume that real investment does not change as part of a process of macro structural adjustment. Similarly, it is common in some analytic macro structuralist models to assume all intermediate inputs are imported, which serves to focus attention on the effect of devaluation on costs. In applied models, the assumption would be empirically inappropriate. In evaluating these different specifications, it is important to keep in mind the purpose of the model. Strong assumptions that are reasonable and useful for an analytic or stylized model must be qualified in an applied model and countervailing linkages must be taken into account.

Macro structuralist models strain received theory. Questions of macro closure in a model that incorporates only flow equilibria can take us only so far. Further progress probably requires the explicit inclusion of assets and asset markets in the model. There has been some work in this direction.[104] A good example of such a model is Lewis (1985), who has built a stylized CGE model of Turkey that incorporates money and bonds, as well as a segmented loanable funds market that can capture elements of financial repression.[105] The model is able to incorporate a variety of structuralist features and is used to explore the empirical implications of various combinations of macro specifications, including markup pricing. Lewis finds that dividing sectors into two types, markup and flexprice, leads to unstable dynamic behavior in the flexprice sectors as they are forced to take the residual adjustment burden. He argues that this empirical result brings the basic assumption into question, and should lead to further work on ways to

[104] Dewatripont and Michel (1987) argue persuasively that further progress on macro closure issues must involve explicit incorporation of assets in a dynamic model with expectations. Adelman and Robinson (1978) included money in their model and also had an elaborate specification of the loanable funds market, but no explicit asset markets. Taylor and Rosensweig (1984) present an initial version of a stylized structuralist CGE model of Thailand with asset markets, portfolio choice, and endogenous determination of interest rates. See also Feltenstein (1984).

[105] Along the lines suggested by McKinnon (1973).

incorporate the stylized fact that some prices do not adjust to changes in market conditions as fast as others.

Neoclassical CGE models are best suited for looking at medium-run issues. The longer the time horizon, the more appropriate are the assumptions of the neoclassical paradigm, with prices adjusting to clear markets in an environment of mobile factors and reasonable substitution possibilities in demand and supply. Macro structuralist models often justify some of their structural rigidities (e.g. assuming a fixed nominal wage, markup pricing, or lack of supply constraints) on the basis of short-run considerations, but then are applied to analyze the impact of shocks over the medium run. The view that the medium run is a sequence of short runs is a temporal tautology but a theoretical error. The types of assumptions and equilibrium specifications appropriate for a short-run analytic model are quite different from those appropriate for a medium-run model, and it is difficult to mix the two types of models. While the payoffs from a successful mixing are potentially great, more care and diffidence seem called for than is evident in a number of the macro structuralist models built to date.

5. Structural adjustment and alternative development strategies

Since the initial work on income distribution, macro structuralist models have been mostly used to analyze questions of structural adjustment – how an economy adjusts to some shock emanating from the world economy such as an exogenous decline in foreign capital inflows or an increase in import prices of commodities such as oil or capital goods. Neoclassical and micro structuralist CGE models have also been used for such analysis, and there is an active debate about the appropriateness of different specifications. While it is premature to judge the outcome of these debates, there is wide agreement of the need to use multisectoral models to analyze the issues. Structural adjustment involves shifts in the sectoral structure of demand, trade, resource allocation, and production, as well as in the magnitudes of macro aggregates.

Even given the difficulties in using CGE models for analyzing macro issues, they nonetheless provide the best framework available for analyzing issues of structural adjustment. Unlike any macro model, CGE models incorporate sectoral detail that permits a richer analysis of changes in the structure as well as the volume of production and trade. The CGE framework is all the more important in a situation in which relative world prices have changed, and they have been widely used to analyze the impact on the structure of production and trade arising from changes in the price of oil.[106] Under suitable assumptions, as noted

[106]See, for example, Gelb (1985) and Mitra (1984) for comparative studies of structural adjustment when oil prices change. Many of the applications to individual countries cited earlier also analyze this issue. See also Dick et al. (1983) who look at the impact of changes in the prices of primary commodities in a stylized CGE model.

above, they also provide a better framework for analyzing changes in the equilibrium exchange rate after an external shock than a macro model or computations based on price-level-deflated exchange reates. These specifically trade-focused CGE models have been recently surveyed by de Melo (1988) and Devarajan (1987).

Empirically, the models to date have indicated the importance of considering structural rigidities when analyzing structural adjustment. The neoclassical, full-employment model adjusts to shocks with relative ease and little cost – a result confirmed in many empirical exercises. Actual economies are clearly less flexible, and a model must capture the important rigidities if it is to provide a useful framework for policy analysis. Where on the continuum from elasticity structuralist to macro structuralist one must be is still an open and controversial question, but that one cannot remain at the neoclassical end of the spectrum is widely understood.

Another use of structuralist CGE models has been the analysis of the implications of alternative choices of development strategy. In this use, the models follow in a long tradition of dynamic input–output and LP models. More recent applications have tended to mix questions of structural adjustment with choice of development strategy, which is reasonable given the international environment in the past decade. The concept of development strategy has narrowed in many applications to include only trade strategy, and most of the applications cited earlier also consider issues of the best choice of trade policies.

The debate in the 1960s on the choice of appropriate development strategy asked whether a country should follow an open, outward-looking development strategy based largely on manufacturing exports, or should it pursue an inward-looking strategy in which industrialization is largely based on encouraging import substitution? The recent discussion is more careful, identifying an "open" strategy with neutral trade incentives leading to investment, production, and trade consistent with comparative advantage, with no particular bias toward the industrial sectors.[107] The general consensus, at least in international institutions such as the World Bank and the IMF, is that an open development strategy emphasizing neutral trade incentives is best, even given the uncertainties of the world economy in the last decade. However, analysis with multisector models has turned up some worries that lead one to question the unqualified promotion of policies designed simply to get the prices right.

An open development strategy involving significant expansion of manufacturing exports, if it is to be successful, involves a balancing and a sequencing of

[107] See Balassa (1985) for a consistent statement of this approach. Also see, for example, Adelman (1984) who argues, using a stylized CGE model, that the changes in world conditions now favor an open strategy of what she calls "agricultural development led industrialization", or ADLI, which emphasizes agricultural exports.

three related processes.[108] First, there must evolve an industrial base sufficient to support significant manufacturing exports. The required industrial base involves a level of technology as well as composition of output, including some complexity in interindustry relations as well as productivity of primary inputs. Second, the country must be able to achieve and maintain significant sectoral rates of total factor productivity growth. Third, the country must be able to finance significant balance of trade deficits in the early phase of the process. After the process has succeeded, the export base will be large enough to generate trade surpluses without hindering further growth.

It may be that these processes are causally related, but not a lot is known about some of the linkages. Operating on the assumption that simply adopting a policy of neutral trade incentives would necessarily start up these processes requires a serious leap of faith. There are a number of success stories among the semi-industrial countries, but they all involved activist governments which certainly did a lot more than adopt policies designed to get the prices right.

Furthermore, there are a number of assumptions about the economic environment that appear necessary for the successful working out of these processes. The world economy must be able to absorb the country's exports without major changes in the terms of trade. The domestic economy must be flexible enough so that the required structural changes, which involve major and relatively rapid changes in sectoral resource allocation, can take place. These structural changes, and the underlying trade policies, may involve major shifts in the distribution of income, which may, in turn, have implications for the ease or feasibility of implementing the strategy.[109]

While the benefits of achieving a successful, export-led development strategy are great, the risks are also significant. If, for example, a country borrows heavily on the assumption that export growth will suffice to generate sufficient surpluses in the future, and the export growth aborts for some reason, then the country is left with a debilitating debt overhang. If the required growth of total factor productivity is not achieved – a process about which very little is known – then the strategy will fail. If factor and product markets do not work properly, then there will be strains on the economy's ability to achieve the necessary structural changes. All of these questions are largely assumed away in the standard neoclassical model. Multisectoral models and analysis that focuses on structural issues are required to illuminate such problems.

[108]The analysis on which this paragraph is based is brought together in Chenery, Robinson and Syrquin (1986). Chapter 11 of that book [by Chenery, Lewis, de Melo and Robinson (1986)] uses a dynamic CGE model to analyze issues of choice of trade strategy. See also Kubo, Robinson and Urata (1986) who use a dynamic input–output model to analyze some of the same issues. For related studies, see Westphal (1981) and Nishimizu and Robinson (1984).

[109]See, for example, de Melo and Robinson (1982) for a CGE model analyzing the impact of different trade policies on the distribution of income.

6. Directions for future research

Multisector models have come a long way since the early input–output models. A combination of advances in economic theory, numerical methods, and computer technology have made a reality of Oscar Lange's dream of computing equilibrium quantities and prices for a multi-market economy. Of course, as soon as we can solve a general equilibrium model, we then see a myriad of new problems. The theoretical limitations of general equilibrium simulation models which only capture flow equilibria across markets become evident. Of the many directions in which new theoretical and applied work are needed, four appear to be commanding the most attention: micro–macro interactions, dynamics, uncertainty, and optimization.

6.1. Micro–macro interactions

The problems of incorporating macro features into multisector models have been discussed extensively above. At this point, given the extensive work on macro closure, the behavior of CGE models when different macro models are imposed on them is fairly well understood. The most active research direction is to extend the notion of macro equilibrium beyond that of nominal aggregate flows and to incorporate asset markets explicitly into the CGE model.[110] Just adding asset markets, however, will do little if the assumptions of full employment and neoclassical equilibrium are maintained. In such a model, macro adjustments only involve changes in the composition of aggregate GDP, but have no effect on its magnitude. An interesting micro–macro model must involve micro structuralist features if it is to be at all realistic. The analysis of links between micro markets and macro signals is an area of active research in macroeconomics, drawing heavily on notions of uncertainty and expectations in a dynamic framework. It is challenging to incorporate such theory directly into a multisector model, and research in this direction with analytic and stylized models is clearly worthwhile. It is, however, easier to build stylized and applied multisector models that include asset markets and micro structuralist features, and so reflect the stylized facts emerging from the new macro work.[111]

6.2. Dynamics

The dynamic behavior of multisector models has been a central concern from the time it was realized that the dynamic input–output model tended to be unstable.

[110] Initial work in this direction was discussed above.
[111] Waelbroeck (1986) is a strong proponent of research is this direction.

The general problem with dynamics is that existing theory is inadequate to give the applied modeller much guidance. Theorists tend to analyze dynamics in terms of intertemporal optimality and steady states, and to avoid discussing how long it takes to achieve the steady state, if it is possible at all. Forward-looking models embodying notions of intertemporal equilibrium based on consistent or rational expectations are theoretically interesting and analytically manageable, but do not seem very realistic.

Applied modellers have tended to respond by building adaptive dynamic models which are recursive in time, with current behavior depending only on solutions from previous periods. While it is important to check the model for stability, and it is sometimes reassuring to show that there is a steady state which the model will approach, its behavior in the relevant time period will be dominated by the dynamic adjustment mechanisms specified. The approach is justifiable in theoretical terms as representing a sequence of temporary equilibria, but there is little theoretical guidance about adjustment speeds and the notions of intertemporal equilibrium such models embody seem unsatisfactory.[112]

The issue of dynamics is certainly not confined to multisector models and has long been recognized as a major problem in macroeconometric models as well. There are numerous theoretical issues involved, including questions of micro–macro linkages and short-run versus long-run adjustment mechanisms. Criticizing applied models because they do not reflect what is acknowledged to be unrealistic theory dealing with long-run steady states and expectations is neither illuminating nor helpful.[113] The challenge is as much to theorists as it is to applied modellers.

6.3. Uncertainty

It is a sign of how far multisector models have come in terms of ease of implementation that one can now seriously contemplate trying to incorporate stochastic elements into the models. Certainly, the last decade has demonstrated the importance of uncertainty, especially about price variations, to policy-makers. For example, a variety of schemes have been proposed to dampen international price variations in primary commodities and uncertainties in export markets have often been cited as reasons for avoiding an open development strategy. The theoretical literature has also advanced and it is evident that optimal policy rules in an environment of uncertainty may differ significantly from those derived in a

[112]On the theory of temporary equilibrium, see Grandmont (1977). Richard Day is a strong proponent of adaptive dynamic models. See Day and Cigno (1978).

[113]See, for example, Bell and Srinivasan (1984).

deterministic model.[114] There is some work underway to incorporate uncertainty in CGE models.[115] The results so far are suggestive and indicate that there are potential payoffs to further research.

6.4. Optimization

The decade from about 1965 to 1975 saw a steady stream of multisector optimizing models, mostly based on linear programming. After 1975, the stream slowed to a trickle as simulation models became more popular. The reasons for the decline of optimizing models were discussed above. Essentially, they were difficult to build and tended to generate unrealistic behavior both because of strong linearity assumptions and because of weaknesses in their theoretical underpinnings. They were never able to provide a reasonable representation of an actual market economy, and so had to be used with considerable care and artful interpretation.

The last decade has seen a growing torrent of simulation models. Now, however, it is time to reappraise the role of optimizing models. There have been major advances in computational algorithms so that now it is easy to solve very large LP problems and relatively easy to solve moderately large, non-linear programming problems. As noted earlier, it is feasible to solve CGE models using non-linear programming and such models have been implemented. For the correct choice of maximand, the shadow prices from a properly specified non-linear program are equivalent to the market prices solved in a CGE simulation model. However, one can get more out of optimization than just another solution technique.

One approach that looks fruitful is to extend to multisector models the methods that have been used for some time to explore questions of optimal policy choice in macro models.[116] For example, one could embed a CGE model as the constraint set in an optimizing model in which one sought to maximize a planner's objective function.[117] The objective function might include macro variables such as aggregate employment, the price level, government balance, and the balance of trade. Policy instruments might include variables such as the exchange rate, taxes, subsidies, and government expenditure. The policy question

[114]For a short review of the relevant theoretical issues, see Arrow (1986). See also Newbery and Stiglitz (1981) and Schmitz (1984).

[115]See Adelman and Serris (1982) and Adelman, Roland-Holst and Sarris (1986). These papers propose models incorporating both uncertainty and optimization, and are discussed below.

[116]For surveys, see Chow (1975) and Kendrick (1981).

[117]Existing CGE models that use such an approach are Zonnoor (1983) for Iran and Martin and van Vijnbergen (1986) for Egypt.

is: What is the best choice of policy instruments to achieve various macro goals, given the workings of the market economy as captured by the CGE model?

An optimization model might also be used to explore "second best" policy questions. For example, Dahl, Devarajan and Van Wijnbergen (1986) use a CGE model of Cameroon imbedded within an optimization framework to ask: What is the best choice of sectoral tariff rates, given that the goverment must achieve some target level of revenue? Their results indicate that the common rule of thumb that countries should seek to equalize tariffs across sectors may often be incorrect. With a government revenue constraint, and especially in the face of existing distorting indirect taxes, optimal tariffs vary widely across sectors. In addition, they find that even a movement from the initial differentiated rate structure toward sectoral equality of rates is not necessarily welfare improving. Such a model might also be used to explore the appropriate choice of shadow prices given the existence of various distortions in the economy, either policy induced or institutional. Again, the constraint set includes the CGE simulation model, so the policy-maker takes as given the institutional structure of the economy.

Finally, it is also empirically feasible to combine optimization and uncertainty in the framework of a stochastic control problem. In their preliminary empirical work, Adelman, Roland-Holst and Sarris (1986) use a linearized version of a stylized CGE model in the constraint set and explore the optimal choice of policies in a dynamic setting given uncertainty about world prices of crucial traded goods. Their objective function is to minimize the deviation over time of a number of macro variables from a target path. The model generates policy rules that differ significantly from those that would be optimal in a deterministic or certainty-equivalent model.

7. Conclusion

Lance Taylor, in his 1975 survey of multisector models, concluded with the question that must face a policy-maker contemplating devoting major resources to building any multisector model beyond the simplest input–output model: "Do they provide enough illumination to justify their own construction?"[118] Based on work with applied models in the past decade, the answer is a clear "yes." Of the twenty-five or so countries for which applied CGE models have been built in the past few years, a number have been collaborative efforts with government ministries.[119] Countries for which such collaborative projects have been done, or are currently underway, include: Bangladesh, Bolivia, Cameroon, Colombia,

[118]Taylor (1975, p. 104).
[119]The number of stylized models is, of course, much greater, See Devarajan, Lewis and Robinson (1986) for a bibliography of work on CGE models applied to developing countries. They also list applications separately, arranged by country. See also Decaluwe and Martens (1987).

Egypt, Hungary, India, Indonesia, Ivory Coast, Malaysia, Mexico, Morocco, Thailand, Turkey, and Yugoslavia. In addition, various static and dynamic SAM-based applied models have been built for a number of countries. While not all equally successful, these exercises indicate that the potential usefulness of multisector models is widely recognized.

At this time, the level of resources required to build a CGE model is little more than would be required for a careful SAM-based analysis. The decision about which tool to use is now less constrained by available computing technology. The modeller can concentrate on matching issues with the appropriate methodology, rather than be forced to pick a simpler methodology because available solution algorithms limit his ability to formulate more realistic models. Indeed, the gap between the formulation of new theory and its implementation in empirical models has shortened considerably in the past decade.

Over the past decade, multisectoral models have been used in a variety of settings and have demonstrated that, for a variety of issues, intersectoral linkages and general equilibrium effects matter. In the past few years, the literature has moved away from large, general purpose models and has focused more on smaller stylized numerical models that illustrate a few important linkages. In analyzing issues such as structural adjustment, income distribution, investment allocation, trade policy, tax policy, choice of development strategy, and the structural impact of macro stabilization policies, stylized multisectoral general equilibrium models have been used to test the validity of insights and policy "rules of thumb" arising from partial equilibrium analysis or macro models. The debate in these areas is still active, but it is certainly possible to conclude from the work surveyed here that it is often misleading to ignore general equilibrium linkages. Indirect effects working through both product and factor markets can often vitiate or reverse the impact effects of some policy change.

The science of economics advances through an interplay among new theory, statistical estimation, and empirical modelling. There is a healthy tension among these three strands that is evident in the work with multisector models. In the last decade, empirical implementation has pushed the limits of available theory and has moved significantly ahead of econometric estimation. In the last few years, there has been work to advance the theoretical underpinnings of CGE models, especially in the areas of trade and macro, and also to improve the statistical base for parameter estimation. It is worth emphasizing, however, that no single strand has monopoly on "correct" analysis – it is through an interplay among all three that progress is made.

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