Volume Title: Annals of Economic and Social Measurement, Volume 4, number 4

Volume Author/Editor: NBER

Volume Publisher: NBER

Volume URL: http://www.nber.org/books/aesm75-4

Publication Date: October 1975

Chapter Title: Policy-Oriented Macroeconometric Models for Development and Planning

Chapter Author: Jeffrey Nugent

Chapter URL: http://www.nber.org/chapters/c10416

Chapter pages in book: (p. 509 - 529)

*Annals of Economic and Social Measurement*, 4/4, 1975

# POLICY-ORIENTED MACROECONOMETRIC MODELS FOR DEVELOPMENT AND PLANNING

BY JEFFREY B. NUGENT

*This paper presents a method for applying macroeconometric models to policy planning through the use of linear programming techniques. A small-scale econometric model is specified and then estimated separately for each of the five countries of Central America. The models are fitted together to form one large econometric model for the region. Linear programming is then applied to solve the optimal set of macroeconomic policies under two institutional setups—one without coordination among countries and the other one with complete coordination. The results obtained in these alternative situations indicate that the potential benefits of policy coordination among Central American countries range from 2 to 7 percent of the region's GNP.*

The last fifteen years have witnessed dramatic breakthroughs in the development of long-term planning models and of practical criteria for allocating resources in the imperfect market settings characteristic of most less developed countries (LDCs). In contrast, the construction and use of short-term macroeconometric models for policy planning in the LDC context remains a relatively primitive and underdeveloped art form patterned on the earlier econometric models developed in the more developed countries (MDCs).

In the following section I call attention to recent developments which are beginning to improve the fit between the models utilized and both the characteristics of LDCs being modelled and the needs of their policy planners. At the same time I shall speculate on the nature of further improvements that will be necessary before the LDCs can have fully satisfactory macroeconometric models.

The second section presents a method for applying macroeconometric models to policy planning with the use of linear programming techniques. The use of the linear programming approach to policy planning is demonstrated in the context of regional (multinational) policy coordination among Central American countries. A small-scale econometric model is specified and then estimated separately for each of the five countries of Central America. The models are fitted together to form one large econometric model for the region. Linear programming is then applied to the model to solve the optimal set of macroeconomic policies under the two alternative institutional setups—once without coordination among countries and once with complete coordination. A comparison of these solutions provides a measure for the potential benefits of greater policy coordination. The paper is concluded with some suggestions for institutionalizing research on macroeconometric modelling of LDCs.

## PAST AND FUTURE TRENDS IN MACROECONOMETRIC MODELS

What kind of models should be employed for LDCs? This question, posed by Lawrence Klein some ten years ago (Klein, 1965), is still an open one despite some serious attempts during this decade on the part of Klein himself, several of his students and colleagues, and others to suggest some answers.[1]

As Klein noted, the earliest macroeconometric models for LDCs, (e.g., Narasimham, 1956; Suits, 1964) were patterned rather closely to the simple Keynesian model that had been prevalent in the United States and other MDCs in the 1940's and 1950's. Slowly the kinds of models proposed for LDCs have begun to change. Some of the more recent LDC models have paralleled the recent trend of MDC models toward more neoclassical formulations by giving special emphasis to the role of relative prices and to profit maximation (Zarembka, 1967, 1972; Marwah, 1963, 1970) and in making greater use of expectational variables based on distributed lag formulations (Evans, 1970). Other changes in LDC models reflect changes in emphasis of different sectors. While the earlier models were inspired by the closed economy models of Harrod-Domar and Keynes, the large role that foreign trade plays in most LDCs has become increasingly reflected in the more recent models.

Some of the recent innovations in LDC models, however, represent more fundamental breaks with the tradition of MDC models. While the earlier models were (in the Keynesian tradition) demand-determined, several of the more recent LDC models have emphasized supply considerations (Marwah, 1970; Beltran del Rio and Klein, 1973). In others disaggregation has permitted the specification of different production and consumption functions for different sectors (Islam, 1965; Agarwala, 1970; Zarembka, 1972; Kelley, Williamson and Cheetham, 1972), thereby accommodating the Nurkse–Lewis–Fei–Ranis notions of agricultural surplus, and, by admitting various kinds of market imperfections, some models allow various forms of dualism to persist. By way of giving more attention to detail, the more recent LDC models are generally better able than their predecessors to reflect the special conditions and institutions of the particular countries for which they are designed.[2]

In my opinion, these trends toward greater differentiation both between MDC models, as a whole, and LDC models, as a whole, and between and among different LDC models, individually, are desirable. Moreover, it is my expectation that these changes will continue and even accelerate. I believe that in the next several years macroeconometric models of LDCs will succeed to a much greater degree in explaining and utilizing as determinants variables that have heretofore been largely excluded, such as the demographic factors, structural factors, and the determinants as well as effects of changes in income distribution. Even for any given LDC I would expect to find an increasing degree of individuality and differentiation among macroeconometric models to reflect the increasingly differentiated uses to which the different models may be put as well as the different "visions" of different model builders.

Most of these expected changes are essentially those of scope, level of aggregation and emphasis, and most of these changes are already well on the way to being accomplished. My concern in this paper is, rather, with several other areas in which improvements are necessary but which are, as yet, not as clearly fixed on the

[1] See, especially, del Rio and Klein, 1973.

[2] From this point of view, note the rather detailed models of Mexico by Beltran del Rio and Klein, 1973; of India, by Agarwala, 1970; of Argentina, by Nugent, 1967; of Indonesia, by Fukuchi, 1973.

horizon. These are: (1) the need for developing more completely and explicitly the disequilibrium nature of development processes and structures, (2) the need for integrating short-, medium-, and long-range time perspectives, and (3) the need to relate these models more closely to the requirements of development planning and policy decisions.

*Disequilibrium*

We begin with disequilibrium. More and more economists are coming to recognize that we live in a world which is less than perfect and in which often the optimal, "first-best," and even "second-best" adjustment mechanisms cannot be utilized on grounds of political or administrative infeasibility. With optimal adjustment mechanisms ruled out or impeded by political constraints, and others rejected on economic or social grounds, the many dualistic differences which are observed between one sector and another tend to remain in effect and in some cases even to become more exaggerated as time goes on and as development takes place.[3] Partly, this may be the result of faulty policy and, therefore, suggests the need (to be spelled out presently) for macroeconometric models of LDCs capable of yielding more useful policy implications. However, partly the dualisms also seem to be due to the relative strength of various disequilibrating forces that seem to appear rather naturally in the process of economic development.

The failure of prices, technology, savings behavior, and human capital stocks and sectors to come into equilibrium is an important fact of life in LDCs and suggests that very careful consideration must be given to the nature and magnitude of the factors preventing the attainment of equilibrium, and the range within which any particular constraint is binding. For example, with respect to the market for an individual commodity characterized by excess supply or excess demand, the failure of prices to adjust to a level at which the excess supply or demand would be eliminated constitutes a genuine case of disequilibrium. To analyze the situation and to propose policies to deal with it, one must, first, be certain whether the disequilibrium is of the excess demand or the excess supply variety and, then, be in a position to understand the reasons for continued disequilibrium and for the failure of the adjustment mechanisms to restore equilibrium.

The existence of disequilibrium poses prodigious problems, not only for model building but also for estimation. Attempts to trace out supply and demand curves simultaneously by carefully following the ordinary rules for model identification will, in general, be insufficient. Even if this were done, participants in the market under consideration would still generally be "off" one of the relevant curves, not just in the ordinary stochastic sense but consistently in a particular direction. The estimation problems are, of course, not insurmountable and, indeed, some fairly satisfactory models for overcoming them are already with us.[4] Most such methods are based on identifying whether one is in a position of excess demand or of excess supply on the basis of price behavior. But, if price behavior is also stochastic and subject to other variables (as in a price expectations model to the observed price changes of previous periods), such an identification may not

[3] This theme is developed thoroughly in Yotopoulos and Nugent, forthcoming.
[4] See Fair and Jaffee, 1972; Fair and Kelejian, 1974; and Maddala and Nelson, 1974.

be easy to make, particularly if, as in most LDCs, the price data series are weak in quality and limited in quantity.

A second problem that is raised by the admission of disequilibrium in any particular market or sector of one's macroeconometric model is the possibility of secondary or spillover effects to other market sectors. Suppose that the disequilibrium condition in sector A is one of excess demand. What will be the reaction of the consumers of A whose notional demands are frustrated? Will it be to accumulate assets—and if so, what kinds of assets—or will it be to buy more in other sectors? If the latter, in which other sector(s) will the demand spillover effects be the largest? How large will they be? What policy instruments affect the direction as well as magnitude of these spillovers?

Similarly, if there is excess supply, as with respect to labor or even agricultural output in the rural sector, how do frustrated suppliers react? Do they cut purchases from other sectors, and if so, which ones? What happens to the excess supplies? Are they consumed at the farm? Are they thrown away? Are they stored for future use? Do the suppliers migrate? Who are the ones who migrate? Where do migrants go and what do they do there? Although these questions have been addressed frequently in the literature of development economics, clear answers have not yet been obtained. The dogged adherence to equilibrium formulations in models of all kinds has, in my opinion, done much to delay the achievement of greater understanding in this respect.

The spillover effects of disequilibrium can be extremely important and very powerful, and yet are entirely ignored in equilibrium models. What happens when there are several different markets out of equilibrium, e.g., excess supply of labor in urban areas, excess supply of agricultural commodities in rural sectors, excess demand for foreign exchange and capital in the modern sectors? How do the various spillover and linkage effects arising from these factors interact? Do they offset or reinforce each other? Do their effects multiply? Answers to these questions can come only from macroeconometric models possessing a general *dis*equilibrium framework. The need to deal with interdependencies among markets further accentuates the aforementioned problem of estimation, as simultaneous equation estimation techniques must be employed.

The existence of disequilibrium also poses questions of dynamics. By definition, the existence of disequilibrium implies that price adjustments are not instantaneous. But how rapidly do they adjust? Do quantities adjust more than prices? How fast do the quantity adjustments occur? What institutional, policy, and other variables influence the relative as well as absolute speeds of these two types of adjustment? Given that the equilibrium prices are seldom known, to what information do the suppliers and demanders in the different sectors react? Are the reactions linear or are they nonlinear with respect to the gaps between demand and supply?

Moreover, the scope of disequilibrium analysis in LDCs is not limited to strict cases of excess demand or supply in the (usually) relatively few markets where prices are set arbitrarily by government agencies. Any market or sector in which adjustments are either incomplete or less than instantaneous is characterized by disequilibrium. Disequilibrium is reflected in such diverse phenomena as high birth rates in rural areas coupled with outward migration to urban areas, an imported technology which does not fit the factor prices prevailing in LDCs, and a distribution of income which becomes less equal as development proceeds. Indeed, such phenomena are sufficiently pervasive in most LDCs to suggest that disequilibrium formulations should be central to LDC models rather than peripheral to them as at present.

*Integration of Short, Medium-, and Long-Term Perspectives*

Typically, there have been, on the one hand, long-term econometric models, essentially, growth models, based on productivity indexes of full-fledged production functions and changes therein over time,[5] and then, in a completely separate literature, short-term econometric models emphasizing the determination of the level and composition of aggregate demand. Attempts to integrate both aspects into a single macroeconometric model have been rare and superficial. A notable exception is the study of the Economic Planning Agency, Government of Japan (1965), which contains the following interrelated models: an aggregate long-term model focusing on saving, net capital formation, and potential output through the production function; a sectoral long-term model, which focuses on the differences in production functions and labor productivity between sectors, introduces foreign trade, and explains the allocation of labor and capital resources among sectors; a medium-term model, which treats the factors determined in the long-term models as exogenous variables (particularly since they were estimated from a longer data series), determines effective demands, prices, wages and income distribution, and traces the effects of government policy instruments throughout the system; and finally, the short-term interindustry model, which disaggregates the components of aggregate final demand determined in the medium-term model into the demands on individual sectors—foreign and domestic—and computes the labor and capital requirements implied by these demands. The individual models, as integrated, are used for making short- and medium-term forecasts. The forecasts from each model are then compared and revised, iteratively, until convergence and consistency are achieved.

Generalizing on the Japanese model, one might suggest that the long-term models might also be used to identify parameter shifts that will, in turn, identify various "epochs" within which the parameters of the medium and short-term models would be constant but between which they would all change.[6] Conversely, the short- and medium-term models might help to identify situations of excess supply or demand which might feed back into the factor accumulation and other features of the long-term models. In principle, the individual observations of the long-term models could be three, five, or even ten-year averages, whereas the observations for the medium-term models might well be annual observations, and those of short-run models, semi-annual or quarterly observations.

As already noted, the relative importance of demographic factors, structural and technological changes in the case of long-term growth of LDCs, and the persistence of dualistic differences between sectors further increases the potential benefits and importance of integrating the short-, medium-, and long-term considerations in macroeconometric models of LDCs. Without such an integration

[5] The most well-known examples of such models are those of Solow, 1957; Denison, 1962, 1968; and Jorgenson and Griliches.

[6] For an application of this technique in a long-term model see Brown, 1966.

it will generally be impossible to indicate the implications of alternative macroeconomic policy packages on the various developmental targets.

*Policy Planning*

In MDCs the primary use made of macroeconometric models has been for forecasting. Indeed, it is on the basis of selling subscriptions to their forecasts that MDC model builders have been able to finance at least part of the building and then continuous revision and updating of their models. The hypothesis-testing and policy-implications uses of such models have not been fully exploited.

In LDCs the uses of macroeconometric models in hypothesis testing and in drawing policy implications would seem to be potentially of considerably greater importance. Thus far, however, the previously mentioned tendency on the part of LDC model builders to follow in the footsteps of their MDC predecessors, and the understandable desire of LDC model builders to show that their models provide adequate descriptions of the economies for which they were designed, have combined to limit the usefulness of LDC models in these respects.

These shortcomings are traceable to the following procedures with respect to the inclusion of policy instruments and the way in which they are treated. First, perhaps because the government has traditionally played a much smaller role in resource allocation and accumulation in MDCs than in LDCs, the tendency to replicate MDC models has resulted in an unfortunate underrepresentation of the role of macroeconomic policy instruments. Second, in those relatively few models in which the policy instruments have been introduced sufficiently, the details are either excessively abundant so that, for lack of an apparatus for integrating them, few overall conclusions can be drawn, or too insufficient to be of practical relevance to policy makers who must make quantitative decisions with respect to rather specific taxes and kinds of expenditures. Third, frequently the policy instruments included have been treated as endogenous variables, for example, as functions of time or income.[7] Fourth, the short-term perspective of most LDC models may have dissuaded model builders from including in their models some important policy instruments merely because the values of these instruments have changed only very slowly or at very infrequent intervals, thereby making it difficult to obtain quantitative assessments of their impact.

Naturally, when the policy instruments are either excluded altogether, or included but only on an *ad hoc* basis (e.g., when convenient for forecasting purposes) or as endogenous variables, valid implications for policy cannot be drawn.

*The Use of International Cross-Section Models*

Actually all of the shortcomings indicated in existing macroeconometric models of LDCs are interrelated, and most of them are traceable in the final analysis

[7] Our quarrel is not with endogenization of policy variables, *per se*. Indeed, one can but applaud serious excursion into political economy such as that by Marzouk, 1970 wherein policy variables are explained in terms of the relative power of different socio-economic-political groups. However, the specification of policy instruments as functions of time would seem to provide little in the way of benefits as far as explanatory power, specification error, etc. are concerned at the expense of weakening the ability to draw policy conclusions from the model.

to data limitations—in particular, the brevity of the period for which comparable time series data are available for any individual country. The lack of data explains why the most interesting development models are often simulation models.[8] However, not being subject to the formal rules of parameter estimation, and lacking any objective means for evaluating the adequacy of the formulation, simulation models—no matter how interesting they might be—are hardly likely to be sufficiently convincing to influence policy.

Our excessive reliance on equilibrium assumptions and processes is to a large extent attributable to the fact that such assumptions permit one to avoid the interdependencies and linkages of spillover effects and the complexities of partial adjustment processes that arise in situations in which markets and processes are out of equilibrium. The existence of disequilibrium, as pointed out above, raises numerous questions that can be answered only if more and better data are available.

So, too, the preoccupation in macroeconometric models of LDCs with short-term considerations and their failure to integrate long-term ones and to derive the policy implications that could be used by development planners stem, to a large extent, from the relatively few annual observations available and the lack of perceptible change in some important policy instruments within the period of the sample observations.

Supplementary econometric models estimated on the basis of international cross-section data for LDCs alone, or for MDCs and LDCs together, could constitute a valuable means of obtaining estimates of some of the longer-term relationships, of some of the more elusive elements of disequilibrium, and of the impacts of policy instruments which may not have been exercised actively in many LDCs in the short time period for which data are available. Naturally, such efforts are only supplementary; the reasons for the failure of cross-section estimates to hold necessarily for time series situations, or of "average" relationships obtained from a collection of country experiences to hold for individual countries, are well known.

Nevertheless, the use of estimates obtained from international cross-section analysis is already commonplace in a number of different aspects of development, most of which are relevant as far as macroeconometric models of development are concerned. For example, structural changes are usually estimated from international cross-section data and are generally found to be valid over time (Chenery and Taylor, 1968). Similarly, the determinants of aggregate exports, the composition of exports, and the relative benefits of trade and aid have all been very profitably studied from international cross-section data (Cohen and Sisler, 1971; Chenery and Strout, 1966; Naya, 1965; De Vries, 1967; Ooms, 1966; Nugent, 1974). Several studies have estimated aggregate and even sectoral production functions and measured the impact of capital formation, population growth, human capital, and trade in a growth accounting framework on the basis of international cross-section data (Hagen and Hawrylyshyn, 1969; Sommers and Suits, 1971; Kuznets, 1966; Krueger, 1968).[9]

[8] For some interesting applications of simulation models see Holland with Gillespie, 1963, and Shubik, 1966.

[9] Adelman and Morris, 1968, have gone so far as to estimate the parameters of a socio-political-economic model of development from international cross section data.

Indeed, all that needs to be done is to specify a somewhat more complete model that would integrate these various phenomena that have heretofore been looked at separately and often in an *ad hoc* manner.

Individual efforts at macroeconometric model building generate externalities which can at least partially be captured by cooperation among teams of researchers in different countries and teams of researchers working on international cross sections of time series.

## Application of Macroeconometric Models to Policy Planning and Coordination: The Case of Central America

Another justification for supplementing national econometric models with international efforts or even international models is economic interdependence—among major trading partners, or countries among which resources flow relatively freely. If economies are interdependent, indirectly each country is affected by the

TABLE 1

Specification of Individual Country Models for Central America

$$\mathrm{GDP} = C + \mathrm{I} + G + Ex + Ei - Nx - Ni \tag{1}$$

$$\mathrm{GNP} = \mathrm{GDP} + TT + NFY \tag{2}$$

$$Yd = \mathrm{GNP} - Te - Tn - To \tag{3}$$

$$C = a_{10} + a_{11}Yd + a_{12}\mathrm{MS} - a_{13}\mathrm{TIME} \tag{4}$$

$$K_t^* = VS_t^e \tag{5a}$$

$$S_t^e = (1 + W)\mathrm{GNP}_{t-1} \tag{5b}$$

$$Ip_t = Z\left[K_t^* - \left(\frac{1}{1-d}\right)K_{t-1}\right] = ZV(1 + W)\mathrm{GNP}_{t-1} - \frac{Z}{1+d}K_{t-1} \tag{5c}$$

$$Ip = a_{20} + a_{21}\mathrm{GNP}_{t-1} + a_{22}K_{t-1} + a_{23}\mathrm{TIME} + a_{24}Zcm + a_{25}CR \tag{5}$$

$$Ip = a_{20} + a_{21}\mathrm{GNP}_{t-1} + a_{22}K_{t-1} + a_{23}Zcm + a_{24}CR + a_{25}\mathrm{TIME} + a_{26}Ip_{t-1} \tag{5'}$$

$$Ex = a_{30} + a_{31}Nus + a_{32}Te/Ex + a_{33}CR + a_{34}\mathrm{TIME} + a_{35}Zcm \tag{6}$$

$$Ei^i = a_{40} + a_{41}\sum_{j=1}^{4} Ni^j_{j\neq i} + a_{42}CR^i + a_{43}R^i + a_{44}\mathrm{TIME} \tag{7}$$

$$Nx = a_{50} + a_{51}\mathrm{GNP} + a_{52}Tn/Nx + a_{53}Zcm + a_{54}CR + a_{55}R + a_{56}\mathrm{TIME} \tag{8}$$

$$Ni = a_{60} + a_{61}\mathrm{GNP} + a_{62}Zcm + a_{63}CR + a_{64}R + a_{65}\mathrm{TIME} \tag{9}$$

$$K_t = \left(\frac{1}{1+d}\right)K_{t-1} + 1p_t + 1g_t \tag{10}$$

$$Tn = Nx \cdot Tn \cdot Nx \cdot \text{by definition} \tag{11a}$$

$$Tn = a_{70} + a_{71}Nx + a_{72}Tn/Nx \tag{11}$$

$$Te = a_{80} + a_{81}Ex + a_{82}Te/Ex \tag{12}$$

$$To = a_{90} + a_{91}\mathrm{GDP} + a_{92}To/\mathrm{GDP} \tag{13}$$

$$CR = b_{10} + b_{11}\mathrm{MS} + b_{12}\mathrm{TIME} \tag{14}$$

$$\mathrm{MS} = b_{20} + b_{21}\mathrm{RM} + b_{22}\mathrm{TIME} \tag{15}$$

$$\mathrm{BP} = Ex + Ei - Nx - Ni + TT + NFY \tag{16}$$

$$\mathrm{SG} = Tn + Te + To - G - Ig \tag{17}$$

A. Endogenous Variables

| *Symbol* | *Variable* | *Symbol* | *Variable* |
|---|---|---|---|
| GDP | Gross Domestic Product | *Ni* | Intraregional Imports |
| GNP | Gross National Product | *K* | Capital Stock |
| *Yd* | Disposable Income | *Tn* | Import Tax Receipts |
| *C* | Private Consumption | *Te* | Export Tax Receipts |
| *I* | Total Investment ($Ip + Ig$) | *To* | Other Tax Receipts net of Transfers from Government to the Private Sector |
| *Ip* | Gross Private Investment | *CR* | Stock of Credit to the Private Sector |
| *E* | Total Exports | MS | Money Supply (stock) |
| *Ex* | Extraregional Exports | BP | Balance of Payments |
| *Ei* | Intraregional Exports | SG | Government Savings |
| *N* | Total Imports | *TNET* | Total Tax Receipts net of Transfers to the Private Sector |
| *Nx* | Imports from outside the Region | | |

B. Exogenous Variables

| *Symbol* | *Variable* | *Symbol* | *Variable* |
|---|---|---|---|
| *G* | Government Consumption | $R^*$ | Dummy Variable for Completion of Integration Highways |
| *Ig* | Government Investment | | |
| RM | Reserve Money | TIME | Time (in years) |
| *Tn/Nx* | Tax Rate on Imports | *TT* | Terms of Trade Adjustment |
| *Te/Ex* | Tax Rate on Exports | *NFY* | Net Factor Income from Abroad |
| *To*/GDP | "Other" Tax Rate | *Nus* | Index of United States Imports |
| $Zcm^*$ | Dummy Variable for Membership in Customs Union | POP | Population |
| | | *P* | Index of Domestic Prices |

C. Other Symbols

| *Symbol* | *Definition* | *Symbol* | *Definition* |
|---|---|---|---|
| ^ | Over a variable indicates estimate of that variable derived from another equation | Subscript | $t$, $t-1$, indicates time period |
| | | * | indicates desired |
| | | *e* | indicates expected |
| Superscript | indicates country | *D* | before a variable (as in DRM, DMS, DCR) indicates first difference e.g., $(RM_t - RM_{t-1})$, etc. |
| C or CR | Costa Rica | | |
| E or ES | El Salvador | | |
| G or GU | Guatemala | *LPI* | Individual Country Linear Programming Model (without coordination) |
| H or HO | Honduras | | |
| N or NI | Nicaragua | | |
| CM or CACM | Central America | *LPC* | Collective Central America Linear Programming Model (with coordination) |

other country's exogenous variables, including its policy instruments. Such interdependencies have provided the motivation for large-scale cooperative efforts in macroeconometric model building at the international level, especially in Project LINK. If the effects of one country's economic policies on another and vice versa can be assessed quantitatively, the interdependent countries may be induced to coordinate their policies and thereby better achieve their development goals.

In this section I will describe a small-scale effort to estimate these interdependencies in Central America, which, as the result of the establishment of the customs union known as the Central American Common Market, has achieved a considerable degree of economic interdependence. The potential use of macroeconometric models in policy planning is illustrated with respect to the optimal policy choices for the Central American countries, first in the absence of policy coordination among countries, and then again with complete coordination of policies. By comparing the results obtained in these two cases with respect to the maximum income attainable for the region as a whole (and for the individual countries of the region), an estimate of the potential benefits of policy coordination among countries of the region is obtained.

Since our purpose here is strictly to illustrate the possible use of econometric models for policy planning and coordination, the model itself and the presentation of the model and methods utilized are as simple and concise as possible. The interested reader is referred elsewhere (Nugent, 1974) for details. As the reader can see by referring to Table 1, the model utilized is of the relatively naive Keynesian type, and therefore its usefulness is entirely limited to the short run. The models utilized consist of separate macroeconometric models of each Central American country composed of 17 equations in 17 endogenous variables specified uniformly for all countries.[10] The five models are interrelated by the intraregional export variables of each country *i*, $Ei^i$, which are influenced by the level of intraregional imports in each other country *j* of the region, $Ni^j$. There are six policy instruments in each country: government consumption *G*, government investment *Ig*, reserve money RM, and the tax rates on imports $Tn/Nx$, on exports $Te/Ex$ and on income $To$/GDP.

Estimates of the structural equations for each country were obtained by two stage least squares. The results obtained for Costa Rica and El Salvador are presented as examples in Tables 2A and 2B.

Because of the fact that investment is directly affected by lagged endogenous variables, and that thereby almost all the endogenous variables are *indirectly* affected by such variables, the model allows one to analyze the effects of the policy instruments not only on the variables of the current period but also on those of future periods. Since, in the formation of the model, no lags of greater length than one year were employed, most of these dynamic interconnections between policy instruments and other variables will have begun to be felt within two years. For this reason, and in order to keep the model as simple as possible and not to extend it beyond its admittedly short-run capabilities, we have expanded the model so as to include only two periods (years). This doubles the number of equations to 34 per country (except for Costa Rica and Honduras, which lack credit equations). These systems of 34 equations per country can alternatively be treated as separate models or can be fitted together to make one big model for Central America, consisting of 34 × 5 or 170 equations. Adding the following identities for each of the two periods yields for Central America as a whole a complete system consisting of 178 equations.

$$\text{GDP}^{\text{CACM}} = \text{GDP}^{\text{CR}} + \text{GDP}^{\text{ES}} + \text{GDP}^{\text{GU}} + \text{GDP}^{\text{HO}} + \text{GDP}^{\text{NI}} \qquad (171\text{-}2)$$

$$C^{\text{CACM}} = C^{\text{CR}} + C^{\text{ES}} + C^{\text{GU}} + C^{\text{HO}} + C^{\text{NI}} \qquad (173\text{-}4)$$

$$I^{\text{CACM}} = I^{\text{CR}} + I^{\text{ES}} + I^{\text{GU}} + I^{\text{HO}} + I^{\text{NI}} \qquad (175\text{-}6)$$

$$\sum_{j=1}^{5} Ni^j = \sum_{i=1}^{5} Ei^i + \text{transport costs between countries for each year } t \text{ and } t+1. \qquad (177\text{-}8)$$

[10] By multiplying the values of these other predetermined variables by the relevant reduced form coefficients, these effects can be accounted for separately and consolidated into the constant term.

TABLE 2A

Estimates of Model 1 for Costa Rica

| Equation no. | Equation | $R^2$ | $DW$ |
|---|---|---|---|
| (15) | $MS = 3.3850 + \underset{(0.2727)}{1.3931}\ RM + \underset{(0.00039)}{0.00076}\ TIME$ | 0.9793 | 0.60 |
| (14) | A credit equation for Costa Rica was not estimated because a consistent series on credit to the private sector could not be obtained. MS was used in place of *CR* elsewhere in the model | | |
| (5) | $Ip = -5.6292 + \underset{(0.1712)}{0.2285}\ GNP_{t-1} - \underset{(0.0620)}{0.0373}\ K_{t-1} + \underset{(0.00760)}{0.00085}\ Zcm + \underset{(0.7128)}{0.1282}\ \widehat{MS}$ | 0.8066 | 2.77 |
| (6) | $Ex = 60.8291 + \underset{(0.6016)}{0.4482}\ \widehat{MS} + \underset{(0.00162)}{0.00419}\ TIME - \underset{(231.9681)}{942.4532}\ Te/Ex$ | 0.9347 | 2.89 |
| (7) | $Ei = -8.5048 + \underset{(0.1760)}{0.2187}\ \widehat{MS} + \underset{(0.0196)}{0.2276} \sum_{j=1}^{4} Ni^{j}_{j \neq CR} - \underset{(0.00050)}{0.00123}\ TIME$ | 0.9514 | 1.44 |
| (12) | $Te = -3.2133 + \underset{(0.039)}{0.0394}\ \widehat{Ex} + \underset{(10.4210)}{83.1108}\ Te/Ex$ | 0.9452 | 1.83 |
| (4) | $C = 2.5152 + \underset{(0.0158)}{0.8783}\ \widehat{Yd}$ | 0.9978 | 1.98 |
| (8) | $Nx = 26.9702 + \underset{(0.1254)}{0.1502}\ \widehat{GNP} - \underset{(42.8029)}{148.4491}\ Tn/Nx + \underset{(0.8408)}{1.2018}\ \widehat{MS} - \underset{(0.0058)}{0.0087}\ R^{CR} - \underset{(0.00742)}{0.00376}\ Zcm$ | 0.9361 | 2.23 |
| (9) | $Ni = -53.7455 + \underset{(0.0929)}{0.2056}\ \widehat{GNP} + \underset{(0.0038)}{0.0007}\ Zcm - \underset{(0.0019)}{0.0035}\ TIME$ | 0.7158 | 1.25 |
| (11) | $Tn = -28.8671 + \underset{(0.0161)}{0.2655}\ \widehat{Nx} + \underset{(6.1096)}{111.3581}\ Tn/Nx$ | 0.9852 | 2.17 |
| (13) | $To = -31.23 + \underset{(0.0027)}{0.0700}\ GDP + \underset{(45.3244)}{446.9741}\ To/GDP$ | 0.9847 | 1.13 |

TABLE 2B

ESTIMATES OF MODEL 1 FOR EL SALVADOR

| Equation no. | Equation | $\bar{R}^2$ | DW |
|---|---|---|---|
| (15) | $MS = 32.2528 + 0.8167\ RM$ <br> (0.1155) | 0.7656 | 0.56 |
| (14) | $CR = -242.5528 + 4.2036\ \widehat{MS}$ <br> (0.8688) | 0.6000 | 0.40 |
| (5) | $Ip = -18.7532 + 0.08424\ GNP_{t-1} + 0.2398\ \widehat{CR}$ | 0.8260 | 2.62 |
| (6) | $Ex = 60.1061 + 0.00388\ TIME - 120.7129\ Te/Ex + 0.2086\ \widehat{CR}$ <br> (0.00109) (44.8092) (0.1035) | 0.9517 | 1.82 |
| (7) | $Ei = -6.0016 + 0.2393 \sum_{j=1}^{4} Ni^{j}_{j \neq ES} + 0.00323\ R^{ES} + 0.0952\ \widehat{CR}$ <br> (0.0589) (0.00095) (0.0456) | 0.9893 | 1.87 |
| (12) | $Te = -8.7862 + 0.1041\ \widehat{Ex} + 75.5921\ Te/Ex$ <br> (0.0191) (8.2004) | 0.8806 | 1.42 |
| (4) | $C = -24.5543 + 0.9482\ \widehat{Yd}$ <br> (0.0292) | 0.9859 | 2.28 |
| (8) | $Nx = 42.5555 + 0.2253\ \widehat{GNP} - 362.1296\ Tn/Nx + 0.00355\ TIME - 0.00712\ R^{ES} - 0.0156\ Zcm$ <br> (0.0699) (82.3796) (0.0018) (0.0036) (0.0062) | 0.9704 | 2.90 |
| (9) | $N^{i} = -35.0259 + 0.04241\ \widehat{GNP} + 0.00456\ Zcm + 0.23203\ \widehat{CR}$ <br> (0.0290) (0.0035) (0.0760) | 0.9362 | 2.23 |
| (11) | $Tn = -18.1019 + 0.13585\ \widehat{Nx} + 130.3632\ Tn/Nx$ <br> (0.0084) (8.2242) | 0.9518 | 2.58 |
| (13) | $To = -30.3851 + 0.0528\ \widehat{GDP} + 586.6096\ To/GDP$ <br> (0.0016) (35.8836) | 0.9944 | 2.00 |

This system of 178 equations is of the form:

$$\text{(a)} \quad IY = AY + BX$$

where $Y$ is the vector of 178 endogenous variables and $X$ is a vector of 98 predetermined variables and a constant term. $A$ and $B$ are matrices of dimensions 178 × 178 and 178 × 99, respectively. The solution to this system is given by:

$$\text{(b)} \quad Y = (I - A)^{-1}BX.$$

This system of equations may be called the reduced form of the model because each of the 178 endogenous variables contained in $Y$ is expressed as a linear function of the 99 predetermined variables *only*. (The constant term is treated as a "variable" whose value is fixed at 1.0.)

When the necessary calculations are carried out on the $A$ and $B$ matrices from any of the three models whose results were reported above, a 176 × 99 set of reduced-form coefficients is obtained. Such a matrix of coefficients expresses in quantitative terms the impacts of each of the 99 predetermined variables on each of the 178 endogenous variables. Since many of the endogenous variables are of only secondary interest, and since a number of the predetermined variables are not policy instruments, there is no need for us to be concerned with the entire matrix of reduced-form coefficients.

We concentrate instead on the reduced form coefficients of each of the six policy instruments—*G*, *Ig*, RM, *Tn*/*Nx*, *Te*/*Ex*, and *To*/GDP—on five of the more important target variables, i.e., GNP, private consumption (*C*), investment (*I*), government savings (SG), and the balance of payments (BP). As an example of these results, in Table 3 we present the set of reduced-form coefficients representing the impact of a one percent change in the income and sales (referred to in the model as "other" taxes) tax rates on three of the target variables (GNP, SG, and BP) in each country, for each of the two time periods, $t$ and $t + 1$.

Although the primary impact of changes in the policy instruments is felt in the country in which the action is taken, it should be clear from these results that the policy changes do have very substantial effects in the other countries of the CACM. It is not surprising to find out that the spreading effects on the other countries tend to be greater in the case of Honduras and Nicaragua, the countries with the greatest intraregional trade deficits. Another characteristic revealed in the results of Table 3 is that the impact of these policy changes is not confined to a single time period. Indeed, in many instances the lagged effects of the policy changes are as great or even greater than the immediate effects.

With these estimates of the effects of the policy instruments and other predetermined variables on the target variables over time (year $t$ and $t + 1$) and over space (on each of the Central American countries), the job of economic analysis has been completed. This analysis yields a matrix $M$ of country, variable, and date—specific multipliers of the vector of policy instruments, $X_A$, on the vector of endogenous variables $Y$ in which we are interested, $Y_A$, namely the five target variables GNP, $C$, $I$, SG and BP. $M$ is thus the relevant partitioned portion of the complete reduced form matrix $[I - A]^{-1}B$.

We may now move to policy analysis, wherein we reverse the direction of the analysis, i.e., solving for the optimal policy instruments in terms of the (given)

TABLE 3

THE EFFECTS IN MILLIONS OF CA PESOS AT 1962 PRICES OF A 1% INCREASE IN "OTHER" TAX RATES (*To*/GDP)

| Country and Variable Affected \ Country in Which Action is Taken | Costa Rica | El Salvador | Guatemala | Honduras | Nicaragua |
|---|---|---|---|---|---|
| **Central America** | | | | | |
| GNP*t* | −10.10 | −15.21 | −23.14 | −12.19 | −7.42 |
| GNP*t* + 1 | −5.31 | −3.82 | −11.46 | −5.31 | −2.41 |
| **Costa Rica** | | | | | |
| GNP*t* | −6.96 | −0.28 | −0.84 | −2.96 | −0.41 |
| SG*t* | 3.71 | −0.03 | −0.09 | −0.71 | −0.05 |
| BP*t* | 2.41 | −0.06 | −0.18 | −0.41 | −0.09 |
| GNP*t* + 1 | −2.87 | −0.19 | −0.58 | −0.98 | −0.27 |
| SG*t* + 1 | −0.31 | −0.02 | −0.08 | −0.21 | −0.03 |
| BP*t* + 1 | 0.96 | 0.02 | 0.03 | −0.46 | 0.03 |
| **El Salvador** | | | | | |
| GNP*t* | −1.22 | −14.08 | −1.62 | −1.42 | −0.79 |
| SG*t* | −0.10 | 4.69 | −0.14 | −0.10 | −0.07 |
| BP*t* | −0.16 | 3.72 | −0.21 | −0.18 | −0.10 |
| GNP*t* + 1 | −0.83 | −3.06 | −1.17 | −1.05 | −0.40 |
| SG*t* + 1 | −0.07 | — | −0.10 | −0.09 | 0.03 |
| BP*t* + 1 | −0.01 | — | −0.02 | −0.02 | 0.01 |
| **Guatemala** | | | | | |
| GNP*t* | −1.45 | 0.64 | −20.06 | −2.42 | −0.94 |
| SG*t* | −0.14 | 0.06 | 7.85 | −0.33 | −0.09 |
| BP*t* | −0.24 | 0.11 | 5.54 | −0.55 | −0.16 |
| GNP*t* + 1 | −1.28 | −0.46 | −9.08 | −1.46 | −0.67 |
| SG*t* + 1 | −0.12 | −0.04 | −0.85 | −0.18 | −0.06 |
| BP*t* + 1 | −0.07 | 0.05 | 2.45 | −0.09 | −0.08 |
| **Honduras** | | | | | |
| GNP*t* | −0.18 | 0.08 | −0.24 | −5.14 | −0.12 |
| SG*t* | −0.02 | 0.01 | −0.03 | −0.42 | −0.01 |
| BP*t* | −0.04 | 0.02 | −0.06 | −0.33 | −0.03 |
| GNP*t* + 1 | −0.14 | −0.05 | −0.20 | −1.64 | −0.07 |
| SG*t* + 1 | −0.02 | −0.01 | −0.02 | −0.22 | −0.01 |
| BT*t* + 1 | 0.02 | 0.01 | 0.03 | −0.19 | 0.02 |
| **Nicaragua** | | | | | |
| GNP*t* | −0.29 | −0.13 | −0.38 | −0.25 | −5.17 |
| SG*t* | −0.04 | 0.02 | −0.05 | −0.03 | 4.04 |
| BP*t* | −0.06 | 0.03 | −0.08 | −0.06 | 3.07 |
| GNP*t* + 1 | −0.19 | −0.06 | −0.27 | −0.18 | −1.01 |
| SG*t* + 1 | −0.02 | −0.01 | −0.74 | −0.02 | −0.13 |
| BP*t* + 1 | | 0.01 | −0.66 | | 0.39 |

targets. Instead of fixed targets, we shall assume that the targets are flexible and can be stated in terms of maximization and inequality constraints.

Specifically, we first arbitrarily choose one of the goals in $Y_4$, e.g., GNP, as the single fle..ible target to be maximized:

$$\text{(1)} \qquad GNP_t + GNP_{t+1} = \text{Maximum.}$$

Second, for each year, $t$ and $t + 1$, set appropriate constraints on each of the other target variables: consumption ($C$), investment ($I$), the balance of payments

(BP), and government savings (SG). Specifically, the values chosen for the constraints were actual values of these variables for consecutive recent years for which the data were available, 1967 and 1968.

$$C \geq C_{\min} \tag{2}$$

$$I \geq I_{\min} \tag{3}$$

$$\text{BP} \geq \text{BP}_{\min} \tag{4}$$

$$\text{SG} \geq \text{SG}_{\min} \tag{5}$$

Third, we include the trade-offs ($M$) between the instruments ($X_A$) and the five target variables $Y_A$, thereby constituting another 5 equations, equations (6) to (10) for each of the two years.

Fourth, we impose upper and lower bounds on each of the policy instruments so as to represent political constraints on extreme policy changes. The particular upper and lower bounds chosen reflect maximum positive and negative changes from year to year or deviations from the historical trends—whichever seemed most appropriate in the particular country under consideration. (Nugent, 1974, Tables 5-1 and 5-2.)

$$\frac{Te}{Ex} \geq \frac{Te}{Ex}\text{Min} \tag{11}$$

$$\frac{Tn}{Nx} \geq \frac{Tn}{Nx}\text{Min} \tag{12}$$

$$\frac{To}{\text{GDP}} \geq \frac{To}{\text{GDP}}\text{Min} \tag{13}$$

$$\text{RM} \geq \text{RM Min} \tag{14}$$

$$G \geq G\text{ Min} \tag{15}$$

$$Ig \geq Ig\text{ Min} \tag{16}$$

$$\frac{Te}{Ex} \leq \frac{Te}{Ex}\text{Max} \tag{17}$$

$$\frac{Tn}{Nx} \leq \frac{Tn}{Nx}\text{Max} \tag{18}$$

$$\frac{To}{\text{GDP}} \leq \frac{To}{\text{GDP}}\text{Max} \tag{19}$$

$$\text{RM} \leq \text{RM Max} \tag{20}$$

$$G \leq G\text{ Max} \tag{21}$$

$$Ig \leq Ig\text{ Max} \tag{22}$$

Since all of the variables can be scaled (and the constraints and equations changed accordingly), one can add nonnegativity constraints on each of the target and instrument variables. This gives to the system of equations and inequalities (1) to (22) the form of a linear programming model.

$$\begin{aligned} \text{Max} \quad & \cdot CX \\ [I - A] \quad & X \leq B \\ & X \geq O \end{aligned}$$

The "dual" of the above "primal" linear programming formulation has the following form:

$$\begin{aligned} \text{Min} \quad & PB' \\ P[I - A]' & \geq C' \\ P & \geq O \end{aligned}$$

The linear programming form offers the great advantage that solutions to both the primal and the dual can be obtained easily and quickly. If there exists a feasible solution to either the primal or the dual problem, there generally exists an infinite number of solutions from which an optimal solution can be chosen. From the primal solution we can obtain the optimal policy package ($X_A^*$), as well as the maximum welfare attainable ($CX_A^*$), given the constraints. From the dual solution we obtain the optimal shadow prices ($P^*$) representing the cost in terms of welfare of tightening each particular constraint by one unit. In this case the shadow prices provide both (1) the trade-offs between each limitation on every policy instrument and the welfare criterion (GNP) and (2) the trade-offs between each of the other welfare goals ($C$, $I$, BP, and SG) and GNP. Since all the shadow prices are relative prices, and since all are relative to the same standard (in this case GNP), ratios of the different shadow prices of the different constraints can also be calculated. Thereby, a whole matrix of all the possible trade-offs between each policy instrument and welfare goal can easily be obtained. These trade-offs are the *possibility*-trade-offs. With knowledge about the *possibility*-trade-offs, the policy-maker can choose the optimal policy mix by matching the possibility-trade-offs with his *desirability*-trade-offs.[11]

Our present objective concerns only the primal solution. Specifically, we wish to compare the welfare obtainable when complete coordination of policies is possible among countries of the region (utilizing the full Central America model) with that obtainable when no coordination of policy among CACM members is possible (utilizing the separate national models). Therefore, we shall confine our attention to the primal problem solutions—the optimal values of the policy instruments and especially of the target variables.

Using the model in the way we have just described for Central America as a whole, we obtain the values for 1967 and 1968 given in the first two columns (i.e., the columns indicated "*LPC* unadjusted") of Table 4 from the optimal primal solution to the linear programming model. The optimal solutions for the individual country models are given in the second pair of columns (i.e., the columns indicated "*LPI* unadjusted"). Note that in all cases the values of GNP and most of the other

[11] This method was developed and applied in a somewhat different context in Nugent and DePrano, 1966. A general problem that arises is that this procedure is based on the incremental analysis and pertains to discrete periods of time. This limits the model's ability to achieve much in the way of "fine-tuning" of policy choices. Many analysts are for this reason using control theory approaches to policy choices [Intriligator, 1971].

TABLE 4

OPTIMAL SOLUTIONS

| | Comparison 1 | | | | | | Comparison 2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *LPC* Unadjusted | | *LPI* Adjusted | | *LPI* (adjusted and perfect information) | | *LPI* Unadjusted | | *LPC* Adjusted | |
| | 1967 | 1968 | 1967 | 1968 | 1967 | 1968 | 1967 | 1968 | 1967 | 1968 |
| GNP*CR* | 795.0 | 853.2 | 709.7 | 763.8 | 686.0 | 779.5 | 725.3 | 780.2 | 811.3 | 871.2 |
| *CCR* | 594.2 | 615.0 | 508.7 | 547.2 | 491.7 | 559.4 | 524.3 | 557.9 | 595.6 | 627.4 |
| *IPCR* | 100.1 | 175.2 | 100.1 | 124.8 | 100.1 | 119.6 | 100.1 | 128.3 | 100.1 | 178.9 |
| SG*CR* | −32.9 | 8.5 | −20.9 | −1.3 | −18.8 | 3.1 | −23.1 | 0.5 | −35.0 | 10.2 |
| BP*CR* | −43.4 | −43.4 | −43.4 | −43.4 | −43.4 | −43.4 | −43.4 | −43.4 | −43.4 | −43.4 |
| GNP*E* | 1089.9 | 1169.4 | 976.3 | 1007.0 | 985.0 | 1049.5 | 1025.5 | 1067.3 | 1144.0 | 1184.0 |
| *CE* | 899.1 | 961.0 | 805.3 | 820.7 | 824.7 | 847.8 | 854.5 | 872.8 | 953.3 | 1012.3 |
| *IPE* | 119.0 | 155.3 | 119.0 | 135.3 | 119.0 | 141.3 | 119.0 | 143.6 | 119.0 | 157.1 |
| SG*E* | 5.6 | 38.5 | 11.7 | 26.1 | 10.7 | 30.1 | 8.0 | 31.5 | 1.5 | 40.2 |
| BP*E* | −38.5 | −38.5 | −38.5 | −38.5 | −38.5 | −38.5 | −38.5 | −38.5 | −38.5 | −38.5 |
| GNP*G* | 1667.6 | 1917.6 | 1551.9 | 1742.6 | 1585.8 | 1759.6 | 1594.1 | 1808.3 | 1714.6 | 1985.8 |
| *CG* | 1366.3 | 1548.3 | 1260.0 | 1441.0 | 1290.2 | 1455.1 | 1298.8 | 1494.8 | 1409.4 | 1607.2 |
| *IPG* | 141.1 | 193.3 | 141.1 | 170.4 | 141.1 | 177.1 | 141.1 | 178.8 | 141.1 | 195.9 |
| SG*G* | −36.7 | −13.9 | −36.7 | −27.1 | −36.7 | −21.7 | −36.7 | −23.6 | −36.7 | −9.9 |
| BP*G* | −52.8 | −65.8 | −62.4 | −65.8 | −59.6 | −65.8 | −58.9 | −65.8 | −49.0 | −65.8 |
| GNP*H* | 654.2 | 701.2 | 627.6 | 665.9 | 630.0 | 669.8 | 647.4 | 689.0 | 673.9 | 724.8 |
| *CH* | 486.9 | 521.8 | 466.9 | 496.2 | 467.7 | 499.2 | 481.1 | 512.6 | 504.0 | 538.8 |
| *IPH* | 65.1 | 101.6 | 65.1 | 83.2 | 65.1 | 84.0 | 65.1 | 89.7 | 65.1 | 108.0 |
| SG*H* | −17.3 | −9.2 | −17.3 | −13.8 | −17.3 | −13.5 | −17.3 | −10.0 | −17.3 | −5.5 |
| BP*H* | −3.3 | −16.4 | −6.5 | −16.4 | −6.2 | −16.4 | −4.2 | −16.4 | −0.5 | −16.4 |
| GNP*N* | 624.5 | 709.5 | 603.7 | 677.4 | 614.2 | 690.4 | 606.5 | 681.4 | 629.0 | 713.9 |
| *CN* | 460.9 | 526.5 | 437.8 | 497.8 | 447.1 | 508.7 | 440.3 | 501.4 | 460.4 | 530.4 |
| *IPN* | 92.3 | 126.0 | 92.3 | 127.8 | 92.3 | 129.4 | 92.3 | 116.5 | 92.3 | 141.2 |
| SG*N* | −25.2 | −25.2 | −25.2 | −25.2 | −25.2 | −25.2 | −25.2 | −25.2 | −25.2 | −25.2 |
| BP*N* | −35.7 | −45.4 | −38.4 | −45.0 | −37.3 | −45.3 | −38.1 | −45.0 | −35.7 | −45.1 |
| GNP*CM* | 4831.2 | 5351.0 | 4469.2 | 4856.7 | 4595.2 | 4948.8 | 4598.8 | 5026.2 | 4972.9 | 5524.2 |
| *CCM* | 3807.4 | 4172.6 | 3478.7 | 3802.9 | 3596.7 | 3901.5 | 3599.0 | 3939.5 | 3922.6 | 4315.8 |

target variables are larger in the Central America model (in which the policies of all countries are determined simultaneously) than in the single-country models (in which the policies of each country are determined separately).

However, the difference in these two sets of optimal solution values is not only attributable to different approaches to policy determination but also to the estimation errors in the intraregional import equations $(Ni)$—the only equations treated differently in the aggregate Central America model and in the individual-country models. This stems from the fact that $Ni$ variables of the other countries are treated as exogenous variables in the individual-country models but are, of course, endogenous in the aggregate Central America model. In the former set of models no estimation error is involved, whereas in the latter model estimation error is introduced. In order to account for this difference in treatment we have computed the difference in the values of the constant terms in the consolidated and abbreviated reduced-form equations attributable to this source. We have then adjusted the original constant terms in the individual country models upward by the extent to which the Central America model was overestimating each endogenous variable and downward by the extent to which the model was underestimating each endogenous variable. Conversely, the opposite set of adjustments can be made in the constant terms of the Central America model to make the results comparable to the unadjusted individual-country solutions. The optimal solutions obtained from the adjusted individual-country models are now given in the second pair of columns (those indicated by "*LPI* Adjusted") in each of the tables. Similarly, the optimal solutions obtained from the adjusted Central America model are now given in the fifth pair of columns (those indicated by "*LPC* Adjusted") in each of these tables.

The solution values for the target variables from the first and second pairs of columns are now comparable, inasmuch as the effect of estimation error in the $Ni$ equations has now been accounted for. Similarly, and for the same reasons, the fourth and fifth pairs of columns are comparable. As the reader can easily see, without exception, when full coordination of policies among countries is possible (as in the Central America model), higher targets are achievable than when no such coordination is possible.

However, it is still possible that our comparisons yield an overestimate of the true benefit from regional coordination of macroeconomic policies in Central America. This is because the individual-country optimizations were computed without the benefit of knowledge about the optimal policy decisions in the other countries, whereas complete coordination of policy in the Central America model was sufficient to provide perfect information. One might wonder how much better the individual countries might have been able to perform with respect to their goals if they had had perfect information about what the other countries were doing at the optimum. We have recalculated the individual-country model maximizations under conditions where each individual country knows the optimal solutions of the other individual countries by plugging optimal values of $\sum_{j=1}^{4} Ni_j^i \neq 1$ (instead of *actual* values) into the reduced-form coefficients in arriving at the values of the constant terms in the consolidated and abbreviated reduced forms. The resulting constant terms can either be left alone (unadjusted) or can be adjusted to account for estimation error in the $Ni$ terms as before. The sets of optimal solutions for the individual-country models resulting from the latter operation are shown in the third pair of columns (indicated "*LPI* Adjusted and Perfect Information").

The reader can easily see that the provision of perfect information generally brings the values of the target variables from the noncoordinated policy models (the individual-country models) somewhat closer to those obtained from "*LPC* unadjusted," the complete Central American model with complete coordination of policy. However, the effect of perfect information is not generally very large—accounting for only a small fraction of the differences between the comparable solutions obtained under complete coordination of policy and in the absence of such coordination.

To test for the sensitivity of the results to changes in assumptions, parameter values, and the political constraints, we have repeated the same procedures for two different specifications of the macroeconometric models and also for alternative sets of bounds on the flexibility of the policy instruments and secondary targets. The results obtained in these alternative situations, as reported in full in Nugent 1974, indicate that the potential benefits of policy coordination among Central American countries range from 2 to 7 percent of the region's GNP. The fact that the results were generally fairly insensitive to any and all of these changes and that the underlying models seemed to perform fairly satisfactorily in making forecasts and "backcasts" give reason to believe that the findings of quite substantial potential benefits of policy coordination may be fairly representative. As to the distribution of the potential gains among countries, the results indicate that the smaller countries like Costa Rica and El Salvador would generally benefit more than the large ones, and the richer ones more than the poorer ones like Honduras.

The higher incomes are attributable to the fact that, with coordination, each individual country is able to pursue more expansionary monetary and fiscal policies than in the absence of coordination. For example, coordination makes it possible for Costa Rica to follow more expansionary spending policies (higher *G* and *Ig*) and to lower its export and "other tax" rates (*Te*/*Ex* and *To*/GDP, respectively) in return for a slightly less expansionary monetary policy (RM). El Salvador is able to increase government spending in the current period ($t$) and money supply in year $t + 1$ at the cost of a slightly higher "other tax" rate *To*/GDP. Similarly, Guatemala is able to trade off an increase in the "other tax" rate in year $t + 1$ for a reduction in the "other tax" rate in year $t$ and an increase in government spending in year $t + 1$. Honduras is able to reduce its "other tax" rate in year $t$ and to raise government spending in year $t + 1$. Finally, Nicaragua is able to reduce its "other tax" rate in year $t$ and lower its export tax rate in year $t + 1$.

What these solutions reflect is that the greater flexibility derived from a simultaneous solution for all countries allows the countries to trade off slack in some of the less binding resources or constraints for additional flexibility in some of the more binding ones.

Naturally, however, all of the above conclusions must still be regarded as tentative until they can be corroborated by other researchers with a stronger data base and more satisfactory models.

### Some Suggestions for Institutionalizing Research on Macroeconometric Modeling of LDCs

My own experience in building some admittedly primitive macroeconometric models for policy planning purposes has led me to the following suggestions for how research of this sort should be organized if it is to be successful. First, macroeconometric model building must be an ongoing process. Presumably because of lack of financing, most efforts at model building in LDCs have thus far been sporadic and discontinuous. It is heartening to find that one model for a Latin American country (Beltran del Rio and Klein, 1973) has already gone through at least five versions over a period of at least five years, and it should not be surprising that the result has been quantitatively and qualitatively superior to most other models of LDCs. More funding should be made available for research of this kind at the national, regional, and international levels.

Second, it is very difficult for any one model builder—or even team of model builders—to be completely "objective" in model formulation and thereby to do justice to all possible policy positions. Therefore, in demonstrating the benefits and costs of alternative policy packages and development strategies, a strong effort should be made to foster competition between different teams of researchers, each with its own model and "vision" of the economy but all with the same data and probably the same estimation procedures.

Finally, a consortium of researchers in different countries should be fostered whereby the different national experiences in macroeconometric model building could be shared and exchanged and the various national efforts could be assisted with regional and international attempts to look at the same processes from the perspective of international cross sections of time series data. Some of the research efforts might investigate the interdependencies between countries and develop policy models capable of pointing out the benefits of international cooperation, perhaps utilizing the methods demonstrated with respect to the Central American countries.

*University of Southern California,*
*Los Angeles*

### Bibliography

I. Adelman and C. T. Morris, 1968, "An Econometric Model of Development," *American Economic Review*, 58, 5, Pt. 1, (December), 1184–1218.

D. Agarwala, 1970, *An Econometric Model of India, 1948–61*, London: Frank Cass.

M. Brown, 1966, *On the Theory and Measurement of Technical Change*, Cambridge: Cambridge University Press, Ch. 10.

H. B. Chenery and A. M. Strout, 1966, "Foreign Assistance and Economic Development," *American Economic Review*, 56, (September), 679–733.

——— and L. J. Taylor, 1968, "Development Patterns: Among Countries and over Time," *Review of Economics and Statistics*, 50, (November), 391–416.

B. I. Cohen and D. G. Sisler, 1971, "Exports of Developing Countries in the 1960s," *Review of Economics and Statistics*, 53, n. 4, (November), 354–361.

A. B. del Rio and L. R. Klein, 1973, "Macroeconometric Model Building in Latin America: The Mexican Case" N. Ruggles, ed.

B. A. De Vries, 1967, *The Export Experience of Developing Countries*, Washington, D.C. I.B.R.D.

Economic Planning Agency, Government of Japan 1965, *Econometric Models for Medium-term Economic Plan*, 1964–68, Tokyo.

M. Evans, 1970, "An Econometric Model of the Israeli Economy, 1952–1953," *Econometrica* 38, no. 5 (September), 624–660.
R. C. Fair and D. H. Jaffee, 1972, "Methods of Estimation for Markets in Disequilibrium," *Econometrica* 40, 497–514.
——— and H. H. Kelejian, 1974, "Methods of Estimation for Markets in Disequilibrium: A Further Study," *Econometrica* 42, no. 1 (January), 177–190.
T. Fukuchi, 1973, "An Econometric Model for the Indonesian Economy," mimeo.
E. E. Hagen and O. Hawrylyshyn, 1969, "Analysis of World Income and Growth, 1955–1965," *Economic Development and Cultural Change*, 18, no. 1, Part II, (October), 1–96.
E. P. Holland with R. W. Gillespie, 1963, *Experiments in a Simulated Underdeveloped Economy: Development Plans and Balance of Payments Policies*, Cambridge: M.I.T. Press.
M. Intriligator, 1971, *Mathematical Optimization and Economic Theory*, Englewood Cliffs, N.J.: Prentice-Hall.
N. Islam, 1965, *A Short-term Model for Pakistan Economy*, Labori, Karachi, Dacca: Oxford University Press, Pakistan Branch.
A. C. Kelley, J. G. Williamson, and R. J. Cheetham, 1972, *Dualistic Economic Development*, Chicago and London: University of Chicago Press.
L. R. Klein, 1965, "What Kind of Macroeconometric Model for Developing Economies?," *Econometric Annual of the Indian Economic Journal*, 13, No. 3, 313–324 reprinted in A. Zellner, ed., *Readings in Economic Statistics and Econometrics*, Boston: Little, Brown and Co. 1968, 559–570.
A. O. Krueger, 1968, "Factor Endowments and Per Capita Income Differences among Countries," *Economic Journal*, (September).
S. Kuznets, 1966, *Modern Economic Growth*, New Haven: Yale University Press.
G. S. Maddola and F. D. Nelson, 1974, "Maximum Likelihood Methods for Models of Markets in Disequilibrium," *Econometrica*, 42, no. 6, (November), 1013–1030.
K. Marwah, 1963, "An Econometric Model of Price Behaviour in India," Unpublished Ph.D. Dissertation, University of Pennsylvania.
———, 1970, "An Econometric Model of Colombia: A Prototype Devaluation View," *Econometrica*, 37, no. 2, (April), 228–251.
M. Marzouk, 1969, "The Predictability of Predetermined Variables in Macro-econometric Models for Developing Economies," Unpublished Ph.D. Dissertation, University of Pennsylvania.
N. V. A. Narashimham, 1956, *A Short-term Planning Model for India*, Amsterdam: North-Holland.
S. Naya, 1968, "Variations in Export Growth among Developing Asian Countries," *Economic Record*, (December), 480–495.
J. B. Nugent, 1967, Country Study—Argentina, Summer Research Report, Office of Program Coordination, Agency for International Development.
———, 1974, *Economic Integration in Central America: Empirical Investigations*, Baltimore: Johns Hopkins University Press.
——— and M. E. DePrano, 1966, "The Effects of Long-run and Short-run Planning Goals in Economic Policy Instruments," Paper presented to the Econometric Society, Washington, D.C.
V. D. Ooms, 1966, "Regionalization and Export Performance: A Study of Primary Commodities," New Haven: Yale University. Unpublished Ph.D. dissertation.
M. Shubik, 1966, "Simulation of Socio-economic Systems: An Aggregate Socio-economic Simulation of a Latin American Country," Yale University, Cowles Foundation Discussion Paper No. 203 Part II. Mimeo.
R. M. Solow, 1957, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39 (August), 312–320.
P. M. Sommers and D. B. Suits, 1971, "A Cross-Section Model of Economic Growth," *Review of Economics and Statistics*, 53, no. 2, (May), 121–128.
D. B. Suits, 1964, *An Econometric Model of the Greek Economy*, Athens: Center of Economic Research.
P. A. Yotopoulos and J. B. Nugent, forthcoming. *Economics of Development: Empirical Investigations*, New York: Harper and Row.
P. Zarembka, 1967, "A Long-run Economic Growth Model for Underdeveloped Countries," Unpublished Ph.D. Dissertation, University of Wisconsin.
P. Zarembka, 1972, "A Long-run Economic Growth Model for Developing Countries," in L. E. DeMarco, ed. *International Economics and Development: Essays in Honor of Raúl Prebisch*, New York: Academic Press.