A Conceptual Regional Econometric Model Incorporating Policy Considerations*

by

Ronald A. Oliveira and Gordon C. Rausser**

I

Regional government policy-makers constantly face the necessity of making decisions -- often concerning issues on which information is unavailable. To assist in ascertaining the effects of various decisions a policy model could be formulated. Such a model in order to be useful for government decision-making purposes, should specify the framework in which decisions are made. In other words, the relevant constraints in the model should specify the economic (and social) mechanisms underlying the regional economy in question. Moreover, a policy model should be formulated on the basis of a regional government's authority to facilitate its use as a guide for planning as well as decision purposes.

The purpose of this paper is to formulate such a decision model on a conceptual basis. Ideally, the model would be employed to determine the optimal levels of various policy variables within the context of a specified preference function of the regional policy-makers. The regional model developed is based on an econometric model approximating the presumed causal relationships within the region. Such a procedure allows the formulation of a model which may be utilized to evaluate the effects of various policy proposals as well as structural changes within the region.

After a brief and admittedly cursory review of the literature on regional econometric models, a description of the region and regional

---

*Paper presented at the Western Economic Association meetings, Davis, California, August 27-28, 1970, 54 pp.

decision-making body is provided. Section III contains a treatment of problems of specification and measurement of preference functions for regional decision-makers. In section IV, a conceptual regional econometric model which includes the legal and institutional frameworks which are normally imposed upon county governments is specified. Moreover, controllable (instrument) variables and their presumed causal relationships with uncontrollable variables of the regional economy are specified. Section V provides a discussion of various estimation procedures that could be employed; while section VI isolates those techniques for obtaining the optimal decision rules or strategies for various preference functions. Finally, in section VII procedures which might prove useful in the measurement and empirical application of the proposed decision model are considered.

II

Prior to setting out the formulation of the model presented in this paper a brief review of some previous regional and state econometric models may prove worthwhile. Four models will be discussed: (1) the California model developed by Burton and Dyckman [8], (2) a Massachusetts model developed by Bell [3], (3) a conceptual regional model proposed by Klein [28], and (4) an econometric model for Ohio formulated by L'Esperance, et al., [31].

None of these models are directly concerned with policy variables that are controllable by the regional or state governments. Although the authors of the Ohio model attempted to determine the policy implications of their model, the variables they considered were highly questionable as controllable variables. To illustrate, the authors of the Ohio model list "the interest rate on corporate bonds" and "military prime contracts awarded in Ohio" as two of their policy variables [31, p. 798]. Obviously, these variables are not directly controllable by the state governmental officials.

All the models except the one formulated by Burton and Dyckman are too aggregative to be used for detailed analysis of the effects of various controllable variables. That is, the models do not include labor supply and demand relationships as well as investment schedules for each sector. Such relationships could enable the policy-makers to examine the effects of various policy variables on the economic activity of the region involved.

Though the California model is highly disaggregated, it is excessively dependent upon secondary data.[1/] In order to meet the purposes desired in this paper, many variables will have to be included for which time series data on a regional basis are unavailable in a secondary form. The causal effects of such variables will be uncertain (unless primary data can be obtained), therefore subjective estimates of their parameters will have to be developed. We shall return to this question in section VIII.[2/]

The model for Massachusetts developed by Bell contains a more precise specification of the cause-effect relationships than the other three models. Though Bell's model provides a development of various behavioral relationships, such as the supply and demand of labor, it is principally a forecasting model which renders it of little value for decision-making purposes. That is, no control variables are explicitly incorporated. The difficulty of utilizing forecasting models for policy needs has been noted by Fisher [18]. He states:

> "Although forecasting economists usually abstain from using notions of loss or welfare functions, they frequently express the conviction that their forecasts are to be used <u>somehow</u> for 'policy purposes'." [18, p. 8] (Emphasis on somehow added by the authors.)

The formulations of the models discussed above are of limited use to regional policy-makers. To elaborate, none of the models contained any specification of the policy variables available to the regional decision-makers. In order to prove useful for analyzing the effects of various policy actions, surely the behavioral relationships within the models must be specified to include the variables which are actually controllable. Furthermore, it will be necessary to formulate preference functions for the regional or state policy-makers. This necessity arises since implicitly policy-makers have preferences and goals concerning their region's development. Moreover, such preferences and goals must be specified in order to select some decision from the set of possible decisions.

A further aspect of these models is that they all have at least a remote connection with one or more of the national econometric models developed. For example, Klein's model is based upon his experience with the Wharton Econometric Forecasting model and upon the Brookings model. He strongly emphasizes the incorporation of regional and national models. However, his development appears to be an incomplete attempt at such an integration. A more elaborate discussion of the issue is presented by Fox, et al., [19, Chapter 12]. They describe in detail how regional models based upon "functional economic areas" could be integrated with the Brookings-SSRC econometric model. Furthermore, they develop methods of measuring the impacts of national economic fluctuations upon local economies. They also suggest measuring the feedbacks from area models to the national models -- which Klein felt would overly complicate the models and present data problems. In addition, Klein fails to describe how the nation would be divided into regions which is a major aspect of the development by Fox, et al. It can be argued that an integration of national and regional models would provide an information exchange between regional, state, and national policy-makers. That is, the information flow between these various levels of government could aid developments such as "sequential planning by stages" [19, p. 385] or decentralized decision-making.3/

Finally, each of these four models fails to confront the problems concerning the proper delineation of a region. Three of the models are based on states -- highly questionable as viable regional economies. Klein supposedly develops a regional model but makes no attempts at defining the proper conceptual region. For both policy and forecasting purposes, the delineation of the region is of crucial importance.

Although the proper area for a regional study has often been discussed in the literature [5, 6, 19, 48, 54, 56], the issue is still unresolved. The region considered in this paper is a conceptual multicounty area which is economically delineated from surrounding areas. In other words, it is similar to Fox's concept of "functional economic areas" in that it is relatively self-contained with respect to the majority of consumer economic activities [19, Chapters 1 and 12]. Examples of such a region are the Economic Development Districts specified by the Economic Development Administration (EDA), an agency of the Department of Commerce.

It is assumed that the region to be investigated has a representative central government consisting of a central policy-making board or committee. In addition, the regional policy-makers are assumed to possess the same powers as presently possessed by counties. The various policy variables under their control are listed in the Appendix and discussed in section IV.

The formulation or delineation of a region around existing counties may not properly define a regional economy as emphasized by Fox, et al. [19]; however, the model presented is based on a multicounty region in order to correspond with EDA districts. The feasibility of policy control appears more likely in areas which incorporate complete rather than partial counties. Nevertheless, the model is formulated in such a way that it could be easily applied to a regional designation not in accordance with county boundaries. Further, it should be recognized that the governmental decision-making body assumed in this paper may not be a true representation of the present state of affairs. It seems reasonable, however, to suggest that the possibility and necessity for such a regional government exists with the development of EDA multicounty districts.[4/]

III

One of the underlying assumptions of this paper is that the regional policy-makers base their actions, consciously or unconsciously, on preferences and goals [55, Chapter 1].[5/] That is, in the process of decision-making, government officials evaluate the trade-offs or marginal rate of substitution between various policy objectives. For example, policy-makers implicitly "measure" trade-offs between objectives when they reduce the benefits accruing from certain policy actions in order to increase benefits elsewhere which may arise from still other policy actions.[6/]

To avoid the difficulty of specifying an overall social welfare function, we shall assume that the preference function specified for the regional policy-making group (which may be interpreted as a combination of the preference functions of its individual group members) approximates the actual aggregate social welfare function. As usual, the naive argument is advanced that if this were not the case, the policy-makers would most likely be replaced in the next election [19, Chapter 15]. It follows that the assumed preference functions of the policy-makers will consist of their personal preferences towards regional policy and what they believe to be the preferences of the voters.

The formulation of a preference function for policy purposes is often criticized principally on the basis that the form of the function is unknown and that it is impossible to establish the weights or coefficients for the variables which are included [30, 41]. However, it can be argued that attempting to specify such a surrogate preference function will prove more useful for policy purposes than pretending to ignore its existence.

There are essentially three viable alternatives to be considered for specifying and measuring the preference function proposed in the analysis of this paper. First of all, a method for estimating the coefficients of a preference function for policy-makers has been proposed by van Eijk and Sandee [13]. Their procedure is based upon obtaining the ratios or trade-offs between the various variables entering the preference function. These ratios or "barter terms" indicate the willingness of policy-makers to sacrifice one variable for a certain amount of another variable without changing the value of the preference function (i.e., they attempt to ascertain points of indifference). "The coefficient of each target is then obtained as the (geometric) average of the barter terms of that target against all other targets (and against itself, which terms are obviously unity)" [13, p. 4]. Operationally, van Eijk and Sandee suggest formulating the preference function for a group of individuals who shape government policy on a committee and consulting type basis. In reality such a situation is highly probable since policy actions may be decided by government officials, but influenced by many others such as advisors, pressure groups, labor leaders, and various technical experts. In order to estimate the subjective barter terms underlying the preference function of such a group, the authors propose a method which they refer to as imaginary interviewing.

> In principle, the coefficients of a welfare function can be estimated only by interviewing the policy-makers. They would have to answer a series of questions about the marginal rates of substitution for all target variables and in different situations. For the time being, however, a genuine interviewing of policy-makers is impossible. This means that interviews must be imaginary. All available knowledge of private and public utterances of members of the government or its advisers must be used. Furthermore, one must interpret the political relations in parliament and in the Social Economic Council. In short, the presumable outcome of a real interview must be forecast [13, p. 4].

Both van Eijk and Sandee present their development for only a linear preference function. However, in principal the procedure could be applied to other preference function formulations as well.

A second procedure for formulating the preference functions of policy-makers has been presented by Theil [52]. Following the terminology of Tinbergen, Theil presents the preference function as a quadratic form expressed as the sum of squares of deviations between actual and desired values of the function's arguments. Theil initially assigns a weight of one to each of the squared deviations -- which is obviously unrealistic since some variables will be considered more important than others. To handle this latter problem, Theil suggests a procedure advanced by A. P. Barten which is termed "equivalent deviations." More explicitly, let $y^*_{1t}, \ldots, y^*_{ut}$ denote desired values of the variables in the preference function, and let $y_{1t}, \ldots, y_{ut}$ stand for the actual values. Then, the preference function can be written in the form

$$(3.1) \quad - \sum_{t=1}^{n} \left[\frac{y_{1t} - y^*_{1t}}{y^\circ_1} \right]^2 + \ldots + \left[\frac{y_{ut} - y^*_{ut}}{y^\circ_u} \right]^2 ,$$

where $y_1^\circ, \ldots, y_u^\circ$ denote what Barten terms "equivalent deviations." For example, if y_{1t} deviates from the desired value y_{1t}^* by y_1° it is the same loss in utility as if y_{ut} deviated from y_{ut}^* by y_u°. Hence, the term "equivalent deviations," and it is apparent that they "form a convenient basis for measuring the intensity of desires" [52, p. 262].[7/] Note as well that this method has the convenient property of scaling all target values in the same units.

In quantifying the equivalent deviations only the relative intensities of desires are of importance; therefore, one may choose an arbitrary positive value for one of the y_i°'s. For example, the equivalent deviation for an autonomous change in property taxes may be set equal to one. The policy-makers may then decide that a 1.25 percent deviation in unemployment is as serious as a 1 percent deviation in property taxes; the equivalent deviation for unemployment would, therefore, be 1.25. The equivalent deviations for other variables entering the preference function could be obtained in a similar manner. Moreover, they could be obtained by a procedure similar to that employed by van Eijk and Sandee for estimating the preference function coefficients.[8/]

Still another approach which might prove useful in developing the preference function of a regional policy-making committee could be based on a lexicographic ordering of preferences. Chipman has referred to lexicographic ordering of preferences as being the simplest way of communicating desires [10]. That is, a lexicographic ordering of preferences may be more easily communicated from one committee member to another and from one level of government to another. It is likely that policy-makers will desire that various variables obtain minimum or satisfactory levels or that a certain undesirable condition be kept below a specified level.[9/]

For example, they might require that the amount of recreational areas in the region be greater than or equal to a certain percentage of the total land area in the region. Another satisficing level which may be imposed is that the regional unemployment must be lower than a certain percentage. Operationally, this approach is equivalent to Tinbergen's [55] use of target levels.

For the purposes of this paper each of the above approaches could be employed in ascertaining the preference function of the regional policy-making group. For example, one can combine the method of "equivalent deviations" with the approach of van Eijk and Sandee, or each development may be used separately and then compared for consistency. In addition, one could simplify the problem by specifying a lexicographic ordering of goals where the last goal consists of a few variables. That is, "satisfactory levels" will be specified for all variables except those in the last goal. Therefore, "preference weights" need only be determined for these few variables. The weighted combination of these variables will then be maximized subject to the satisfactory levels of all prior goals. It may also prove useful to develop preference functions by all of the above procedures, and then determine and compare (via sensitivity analysis) the effects of alternative preference functions on the optimal levels of controllable variables.[10/]

IV

The structural form of the conceptual econometric model is presented in this section. The control variables developed in the model are based upon those normally assumed by county governments; however, some of the policy variables incorporated may be beyond the present powers of county governments. For example, counties typically only apply one tax rate to all types of land in the county; whereas, this model presents tax rates for various land types. This extension is included because varying tax rates may provide important implications of policy actions. Moreover, under the present practice of variable assessment rates the effective tax revenues from different property types do in fact vary. (Assuming the regional government levies the tax rate and also assesses the land.)

Another policy variable which is not in accord with existing county powers is regional government expenditures on schools. This function is mostly carried out by special school districts. However, school expenditures appear to be an important element in a local economy and should be determined within the context of a model which attempts to measure both the direct and indirect effects of such expenditures. Moreover, property taxes required for some school expenditures should not be treated in an isolated framework as is typically done.[11/]

In formulating the model it is recognized that ex post observations are likely to be the only data available for situations in which the model is to be applied. Therefore, the model presented eliminates all desired variables (or ex ante values) usually presumed to enter the decision-making processes of individual behavioral units (for example, desired storage) from the system. The resulting "structural form,"[12/] although based on more realistic hypotheses, is consistent with at least potentially observable characteristics of the regional economy.

One of the major characteristics of the model formulation is that the structural equations are block-recursive -- many of which are stepwise recursive.[13/] Since the model is developed for decision-making purposes, this block-recursive feature allows one to delete those equations whose selected dependent variable does not enter the preference function without substantial alteration in the specified model. In addition, one may wish to drop certain equations in order to simplify estimating the model or because they may be found to be unimportant in the context of a particular region.

Another major feature of the model is that it is assumed that equilibrium forces are absent from the region. In other words, the model contains behavioral relations for determining prices and wages which would normally be determined by identities in an equilibrium situation. Further, the specification of Gross National Product, as a link with the "outside world" in the behavioral relation for exports, results from this same lack of equilibrium forces.

The variables included in the model (i.e., the endogenous, controllable and uncontrollable) are listed in the Appendix along with the structural equations. The recursive form of the model is illustrated in Figure 1, where the equations are grouped according to their various activities. In the remainder of this section the major characteristics of the structural form of the model are discussed. For the sake of brevity, many equations are not discussed, most of which are assumed to be self-explanatory. (A more complete discussion of the model may be obtained from the authors upon request.) The disturbances entering each behavioral relationship are deleted for the sake of notational simplicty.

To begin, equation (1), i.e.,

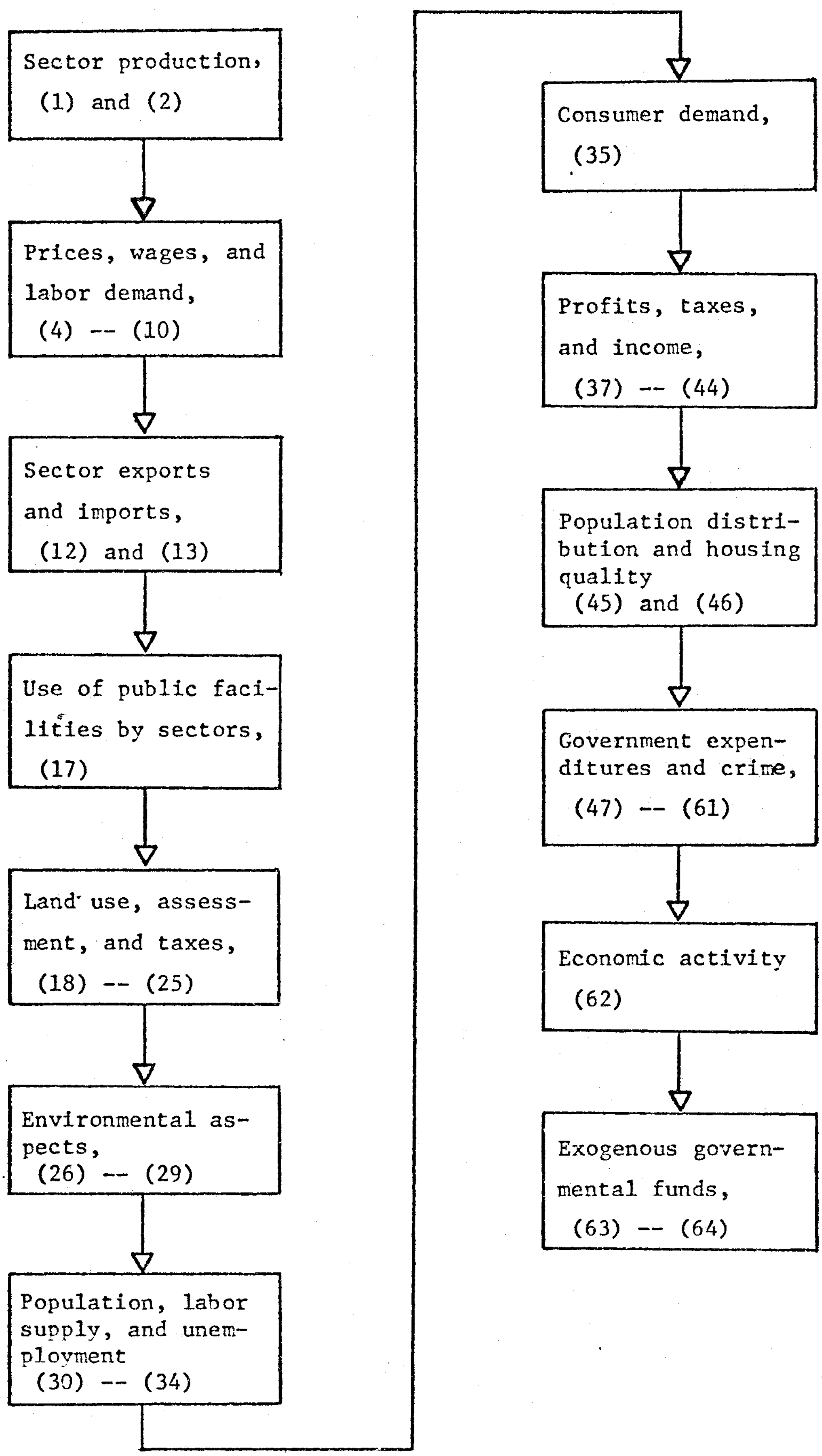
$$X_1 = f_{1i} (X_{if}, K_{it-1}, \pi_{it-1} \overset{-N}{P}_{it-1}, \overset{-S}{P}_{it-1}, S_{it-1}), \qquad (1)$$

$$i = 1, \ldots, n,$$

specifies the behavioral relation for the output of sector i. This equation postulates that the output of the other sectors will influence sector i's production via interindustry relationships. It also states that production in sector i will depend upon sales and profit expectations which are represented by last period's profits and last period's price nationally and in the surrounding regions. It is presumed that the capital

FIGURE 1

Schematic Diagram of Regional Econometric Model



stock last period influences output through capacity limitations. In addition, technological change is assumed to be embodied in the capital stock. The specification also presumes that output decisions in period t will be further influenced by storage in t-1 as well as desired storage, which has been eliminated from the system.

This behavioral relationship may be considered a supply relationship for sector i; however, the model does not consider supply and demand relationships in the usual equilibrium sense (see equation (35)). As noted above the traditional concept of equilibrium (i.e., supply equals demand) is hypothesized to be nonexistent on a regional basis. One may consider supply and demand relationships in equilibrium on a national scale, but such "market clearing" forces need not exist in a region. Thus, the model includes equations for determining prices and wages (see equations (4) and (8)) which would be simultaneously determined by identities in an equilibrium model.

The second equation,

$$X_{if} = f_{2i}(X_f, P_{it-1}, \bar{P}^S_{it-1}), \qquad i, f = 1, \ldots, n, \quad (2)$$

hypothesizes that purchases of sector f from sector i are influenced by the output of sector f (i.e., interindustry relationships) and the price of sector i's output locally and in neighboring regions. The relation between X_{if} and X_f is not intended to be of a strict input-output type; that is, the relationship is conceptually stated to allow for the substitution of imports or other inputs.

The price determining relationship,

$$P_i = f_{4i}(X_i, P_j, \bar{W}_i, \bar{P}^N_{it-1}, \bar{P}^S_{it-1}, F_{it-1}), \quad (4)$$

$$i = 1, \ldots, n,$$

is included in the model due to the lack of equilibrium forces in the region as previously mentioned. Pricing decisions in sector i are hypothesized to depend upon desired sales, represented by X_i, prices last period, and prices of substitutable products. Wages paid in sector i are a proxy for production costs which are assumed to influence prices. In addition, the equation postulates that consumer purchases from last period effect this period's price.

Investments in sector i are specified as

$$I_i = f_{5i}(\bar{W}_i, a_1(L)P_{it-1}, C_{TI}, C_{TC}, C_{TLy}, Y_I^S, Y_C^S, Y_{Ly}^S, \quad (5)$$
$$C_{WAS}, WAS_N, C_{POL}, POL_N, t_I, r_R, \sum_k U_{kt-1}),$$
$$i = 1, \ldots, n.$$

Past prices of i and all other variables appearing in the equation are presumed to influence the desired value of capital stock and, hence, investment. Note that a(L) is some power series in the lag operation, L, where L is defined by $L^\theta X_t = X_{t-\theta}$, for any θ and any sequence $\{X_t\}$. More precisely, it is hypothesized that investment is influenced by present costs of labor, $\bar{W}_i$, and capital, r_R, as well as the expected availability of labor (represented by unemployment last period, which implicitly includes past labor migration). The variables (C_{TI}, C_{TC}, C_{TLy}, t_I, and r_R) are assumed to influence investment decisions via their effect on user cost of capital (i.e., the implicit mental value of capital). Furthermore, it is likely that these variables influence investment when compared to their values in neighboring regions (Y_I^S, Y_C^S, Y_{Ly}^S). It is also presumed that property taxes and waste and pollution control standards in the region (i.e., locational costs) will be compared with those outside the region by sectors considering investments within the region. In an empirical application, one may wish to include locational factors, i.e., closeness to markets and transportation costs, as arguments of the postulated investment function as well as other relations in the model.

The demand for labor type k in sector i, i.e.,

$$L_{ik}^{D} = f_{7ik}(X_i, W_{ik}, K_i, r_R), \qquad i = 1, \ldots, n, \quad k = 1, \ldots, L, \tag{7}$$

is hypothesized to depend upon production needs, labor costs, and possibilities for labor substitution by capital, which are influenced by existing capital stock and the user cost of capital. Due to the absence of equilibrating forces necessary to equate the supply and demand of labor in the region, a wage determining equation is included in the model, which is presented by

$$W_{ik} = f_{8ik}(P_i, \overline{W}^{S}_{kt-1}, \overline{W}^{N}_{kt-1}, W_k^m, W_{ikt-1}, K_i), \quad i = 1, \ldots, n, \quad k = 1, \ldots, L. \tag{8}$$

The wage rate for labor type k in sector i is presumed to be partially dependent upon the productivity of labor type k which is represented by the output price and capital stock. External wages as well as the minimum wage level are also assumed to influence the regional wage rates. It is hypothesized that wage levels will follow those of last period and will most likely not decrease (i.e., "sticky downward"). The relationship with last period's wage rate may be considered to result from a Koyck transformation. Equations (9) through (11) and (14) through (16) are identities which follow from behavioral relationships (7) and (8).

Equation (17),

$$Q_i = f_{17i}(X_i, K_i, C_u, r_R), \qquad i = 1, \ldots, n, \tag{17}$$

is a behavioral relation explaining the use of regional public facilities or services. Though this "use" may be expressed as a flow or a stock, it is assumed in this model that it is measurable as a flow. An example would be the use of public water or sewage treatment. Equation (17) postulates that the use of public facilities is determined by production needs, machine or capital stock utilization, and the associated service charge or tax. The regional interest rate may serve as a proxy for substituting private sector facilities and investments for public facilities or services. In other words, it is assumed that the interest rate is the imputed cost of constructing private facilities such as sewage treatment plants. This formulation does not restrict the use of public facilities to firms; obviously, one of the sectors may be defined as households.

The use of land type j in area d by sector i is represented by

$$N_{ji}^{d} = f_{18jid}(X_i, C_{Tj}, C_{dj}, VN_{jit-1}^{d}), \quad i = 1, \ldots, n, \quad j = A, I, C, R, \quad d = 1, \ldots, G. \qquad (18)$$

Four land types for sector use are assumed in the model: agricultural, industrial, commercial, and residential. Also, the region is assumed to be partitioned into A different locational areas, G of which are uncontrollable endogenous areas (see equation (25) below). The amount of land type j in area d used by sector i is postulated to depend upon the land's assessed valuation last period, how the land is zoned, the property tax rate, and the production needs of the sector. In addition, these variables as well as the interest rate are presumed to influence land use via their effect on the imputed land cost to the sector.

Next is equation (19),

$$VN_{ji}^{d} \equiv \sum_{h=1}^{B} Z_{hj} \cdot N_{ji}^{d} \cdot C_{Vhj}, \quad i = 1, \ldots, n, \quad j = A, I, C, R, \quad d = 1, \ldots, G, \qquad (19)$$

which is an identity defining the assessed value of land type j in area d used by sector i. The assessed value of land used will be endogenous simply because the amount of land use is endogenous. The assessed valuation per acre for land type j (i.e., C_{Vhj}) is a discrete policy variable with B different levels. Z_{hj} determines the level of assessment; i.e., Z_{hj} equals 1 if N^d_{ji} is assessed at level h and equals 0 otherwise (Note: $\sum_h Z_{hj} = 1$). Equations (20) through (24) are identities following from equations (17), (18), and (19).

Total "green belt" type land in the region is represented by equation (25) which is the following identity:

$$NG \equiv N_A + C_{GB} + C_{PR}. \qquad (25)$$

As noted before, there are A areas in the region. G of these are uncontrollable as to type of use (i.e., the regional government only has zoning and assessment power in these areas). C of the areas are classified as green belt areas by the regional government and are, therefore, restricted to agricultural use. In addition, P of the areas consist of regional government parks and recreational areas. Therefore, the various land areas are as follows:

areas:	d = 1, . . . , G,	Uncontrollable endogenous areas
	= G+1, . . . , G+S	Controllable green belt areas
	= G+S+1, . . . , G+S+P,	Government parks and recreational areas,

where G+S+P = A. The regional government may own or use parcels of land in the first G areas, but it is assumed that most of this land is privately owned. Federal and state parks and recreational areas are assumed to be located in the last P areas. Total "green belt" type area in the region is, therefore, defined to be agricultural land in the first G areas, controlled green belt areas, and parks and recreational areas.

Regional government school expenditures ascertained by federal and state regulations are determined by equation (47),

$$G_{SF} \equiv f_{47d}(G_{SFt-1}, POP, FR_S, SR_S), \qquad (47)$$

which is an identity. More precisely, this equation will be specified as a formula prescribed by federal and state agencies. It should be noted, however, that the parameters of this and a number of other identities can, of course, change within the sample or application period. Such changes will be determined by exogenous elements, thus, the parameters of the equation are not included in the model estimation. Equation (47) states that federal and state regulations may require a certain amount of regional expenditures based on last period's expenditures and on the regional population (more explicitly on the number of school-age children). In addition, fixed minimum amounts of regional expenditures may be required; these levels will be determined exogenously by the federal and state governments. External governments will also determine the method of calculating the former expenditures which typically vary with certain endogenous variables. Similarly, the reasoning for this equation applies to equations (49), (51), (53), (57), and (59), which are identities determining required regional government expenditures on unemployment aid, health, housing, judicial and public protection matters, and welfare, respectively. Total regional government expenditures on these categories are established by equations (48), (50), (54), (58), and (60) which are also identities. These last six equations incorporate the regional government expenditures over and above those required by federal and state regulations; i.e., these "extra" expenditures are regional policy variables.

The model as specified above can be written in general notational form as follows:

(4.1) $\Gamma' y_t + B'X_t = U_t$

where

y_t is a column vector of the endogenous variables for the t^{th} observation,

X_t is a column vector of the predetermined variables for the t^{th} observation, which consist of controllable exogenous (policy) variables, lagged endogenous variables, uncontrollable exogenous variables, and lagged exogenous variables,

Γ' is a matrix of coefficients for the endogenous variables,

B' is a matrix of coefficients for the predetermined variables, and

U_t is a vector of disturbance terms for the t^{th} observation.

Assumptions as to the properties of these more general vectors and matrices will be presented in the following section.

V

The econometric model formulated in section V has two possible uses, and the desired use may influence the procedure utilized in estimating the unknown parameters. First of all, the model may be used for deciding on future values of controllable policy variables (with given values of the remaining exogenous variables -- which are uncontrollable) that maximize the preference function for the regional policy-makers. That is, the model can be used for decision making, which is the major theme of this paper. However, one might also wish to use the model for predicting future values of the endogenous variables assuming given values of the exogenous variables, i.e., the model formulated may be utilized as a prediction model.

Although prediction and decision models are employed for different purposes, the unknown parameters of both models are often estimated by the same statistical procedures. Fisher [18] has demonstrated that estimating the unknown parameters of a decision model without reference to the preference function involves a loss of welfare (which results from basing policy decisions on "incorrect" parameter estimates). Thus, he points out that the proper estimating procedures for each case differ, as one would intuitively expect, since the loss functions for each of the two problems on which the estimates are based differ.[14/]

Traditionally, economic models have been estimated by a two-stage procedure. That is, stage 1 involves estimation without reference to a preference or welfare function; while stage 2 involves the application of the estimates for prediction and policy purposes without reference to data or probability (estimation of unknown parameters) problems. This procedure is the typical approach to prediction and decision problems and has been specifically recommended by Marschak [36] and Koopmans and Hood [29].[15/]

One may desire to use the econometric model developed in section V for purposes other than decision making. For example, forecasts of endogenous variables in future time periods may be of use for investment plans. In addition, considerable uncertainty may exist with respect to the preference functions; therefore, parameter estimates may be desired that are not influenced by any specific preference function. In such cases, one may incorporate traditional estimation procedures of models for both prediction and decision purposes with unknown or nonspecified preference functions.

We assume the model specified in section V is linear in the unknown parameter space and the equations are linear in the variables.[16/] To simplify the discussion, the model is again expressed in general notation as in (4.1), i.e.,

(5.1) $\Gamma' y_t + B'X_t = U_t$

where the notation is as defined in section V.[17/] The general form of (5.1) can be simplified once we introduce the *a priori* information contained in the regional econometric model outlined in the last section. More specifically, *a priori* information enters the equational system (5.1) via the matrix of coefficients relating current values of the endogenous variables to one another, i.e., Γ', and the matrix relating contemporaneous disturbances among the different equations, i.e., the covariance matrix Ω. Thus,

$$(5.2)\quad \Gamma' y_t = \begin{bmatrix} \Gamma'_{11} & 0 & \cdots & 0 \\ \Gamma'_{21} & \Gamma'_{22} & \cdots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \Gamma'_{c1} & \Gamma'_{c2} & \cdots & \Gamma'_{cc} \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \\ \cdot \\ \cdot \\ \cdot \\ y_{ct} \end{bmatrix}, \text{ and}$$

$$(5.3)\quad \Omega = \begin{bmatrix} \Omega_{11} & 0 & \cdots & 0 \\ 0 & \Omega_{22} & \cdots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & \cdots & \Omega_{cc} \end{bmatrix};$$

or equivalently Γ' is block-triangular (with square diagonal blocks) and Ω is block-diagonal with conforming blocks. That is, the system is specified as block recursive [17, pp. 99-102] which implies that the equation system (5.1) can be partitioned into c small equation systems or blocks, each of which can be estimated independently of the other blocks in the system. For example, the first block of the system consists of equations (1) and (2) as specified in section V. This block is followed by equation (3) which in turn is followed by the third block consisting of equations (4) through (10). Equations (11) through (65) then follow in a single equation recursive manner, where each equation is an individual block.

Specification (5.3), i.e., that Ω is block diagonal, suggests that the disturbance from one equation in any block is known to be uncorrelated in the probability limit with the disturbances from other equations in the same block. The degree to which this simplifying specification approximates the "true" structure is open to question. Therefore, this assumption may have to be relaxed in an empirical application.

The combination of (5.2) and (5.3) for the system (5.1) and its associated assumptions result in some rather interesting properties. First, the block triangularity of Γ' suggests ". . . that movements in any element U_i lead through effects on the endogenous variables to movements in the elements of y_j if and only if $j \geq i$ [for j, i = 1, . . . , c]" [17, p. 100]. This or any other element of U_i does not, however, affect the elements of $y_1, y_2, \ldots, y_{i-1}$. For example, in the model specified in section V, exports from sector i, E_i, enter explicitly into equations (30) and (36); however, E_i's variability does not affect those equations before equation (12) in the model.

Secondly, the block diagonality of Ω, i.e., (5.3), implies that movements of U_i are not systematically associated with movements in the elements of U_j, for $i \neq j$. Lastly, the two previous properties in combination ". . . allow us to treat endogenous variables from a given block of equations as predetermined with respect to equations of any higher-numbered block" [17, p. 100]. This means, of course, that any j^{th} block may be estimated (assuming each equation with the block is identified) with regard only for the equations it contains and without regard for the existence of the remaining equations, i.e., those of other blocks. That is, in terms of the model presented in section V, the block consisting of equations (4) through (10) may be estimated separately from the other equations. The behavioral relations in equations (11) through (65) may each be independently estimated by single equation methods.

The above properties may be extended to the dynamic representation of system (5.1). That is, by partitioning and rearranging we may rewrite (5.1) as

$$(5.4) \quad y_t = Ay_t + B_1'c_t + B_2'c_{t-1} + B_3'y_{t-1} + B_4'Z_t + U_t$$

where in terms of (5.1) $\Gamma' = I-A$, i.e., A has zeroes everywhere on its principal diagonal and the normalization rule is such that each endogenous variable has a parameter of unity in a single equation, $-B' = (B_1' \; B_2' \; B_3' \; B_4')$ and $X_t = (c_t \; c_{t-1} \; y_{t-1} \; Z_t)'$, i.e., the predetermined variables are partitioned into controllable policy variables, c_t, lagged controllable policy variables, c_{t-1}, lagged endogenous variables, y_{t-1}, and uncontrollable exogenous variables, Z_t.[18/]

Although there is some loss in welfare involved with traditional estimating procedure, we will assume in the following sections that the parameters of the model have been estimated without consideration of a preference function. The principal reason for this is that the model, in most empirical applications, will be associated with a set of preference functions. In this case, Fisher's [18] and Marschak's [38] procedure would require a set of estimates -- the computational costs of which may exceed the benefits.

Therefore, in an empirical estimation of the model the blocks consisting of more than one equation, i.e., the block with equations (1) and (2) and the one with equations (4) through (10), may be estimated by one of the simultaneous equation methods, such as two-stage least squares or three-stage least squares.[19/] Single equation techniques may be employed to estimate the behavioral relations in the single equation blocks, i.e., equation (3) and equations (11) through (65).[20/]

VI

In this section we shall discuss two general procedures for obtaining the optimal decision rules or strategies for the preference functions discussed in section IV. To simplify the presentation, it is assumed that the actions of the regional policy-making can be approximated by a quadratic preference function. In the framework of Tinbergen [55] and Theil [52] those variables that are assumed to enter the preference function are the uncontrolled endogenous variables and the controllable policy instruments. The vectors and matrices of coefficients associated with the endogenous and policy variables are assumed to have been obtained by one (or more) of the procedures outlined in section IV.

More formally, we define subvectors of policy instruments and endogenous variables for each period t:

$$(6.1) \quad c_t = \begin{bmatrix} c_1(t) \\ \cdot \\ \cdot \\ \cdot \\ c_m(t) \end{bmatrix}, \qquad y_t = \begin{bmatrix} y_1(t) \\ \cdot \\ \cdot \\ \cdot \\ y_n(t) \end{bmatrix} \qquad (t = 1, \ldots, T)$$

where $c_h(t)$ and $y_i(t)$ are the values taken by the h^{th} policy instrument and the i^{th} endogenous variable, respectively, in time period t. The complete vectors of policy instruments and endogenous variables may be defined as:

$$(6.2) \quad c = \begin{bmatrix} c_1 \\ \cdot \\ \cdot \\ \cdot \\ c_T \end{bmatrix}, \qquad y = \begin{bmatrix} y_1 \\ \cdot \\ \cdot \\ \cdot \\ y_T \end{bmatrix},$$

where c denotes an mT-vector and y an nT-vector each partitioned according to time periods of the planning horizon. Employing this notation, the quadratic preference function may be represented as:

$$(6.3)\quad w(c,y) = a'c + b'y + 1/2(c'Dc + y'Hy + c'My + y'M'c),$$

where a and b are mT and nT vectors of parameters, respectively, and D, H, and M are mT x mT, nT x nT, and mT x nT matrices of parameters, respectively. A and B are assumed to be symmetric.

The above formulation follows largely from Theil [52]. In this framework the preference function (6.3) is maximized subject to the linear constraints:

$$(6.4)\quad y = Rc + s$$

where s denotes the stochastic (additive) elements.[21/] The set of constraints (6.4), relating uncontrollable to controllable variables within the regional economy, is based upon the econometric model formulated in the previous sections. To illustrate this result, consider the structural form of sections V and VI expressed in the following general form (note that it is assumed without loss of generality that all lags are confined to one year):

$$(6.5)\quad y'\Gamma + c'B_1 + c'_{-1}B_2 + y'_{-1}B_3 + Z'_tB_4 = U'_t$$

where:

y and c are as defined previously, Z_t is a p x 1 vector of uncontrollable exogenous variables for period t, Γ is an n x n matrix of coefficients for the jointly dependent endogenous variables, U'_t is a 1 x n row vector of disturbances for period t, and B_1, B_2, B_3, and B_4 are n x m, n x m, m x m, and p x m matrices of coefficients for the contemporaneous controllable exogenous variables, the lagged controllable variables, the lagged uncontrollable endogenous variables, and the uncontrollable exogenous variables, respectively. Since Γ is assumed nonsingular, we may derive the reduced form of (6.5) as:

$$(6.6)\quad y'_t = -y'_{-1}B_3\Gamma^{-1} - c'B_1\Gamma^{-1} - c'_{-1}B_2\Gamma^{-1} - Z'B_4\Gamma^{-1} + U'\Gamma^{-1}$$

$$= y'_{-1}\pi_3 + c'\pi_1 + c'_{-1}\pi_2 + Z'\pi_4 + V',$$

where

$$-B_3\Gamma^{-1} = \pi_3,\ -B_1\Gamma^{-1} = \pi_1,\ -B_2\Gamma^{-1} = \pi_2,\ -B_4\Gamma^{-1} = \pi_4,$$

and $U'_t\Gamma^{-1} = V'_t$.

By successively substituting in (6.6) for the lagged endogenous variables, we obtain the "final form" of the equation system:[22/]

$$(6.7)\quad y' = y'_{-t-1}\pi_3^{t+1} + c'\pi_1 + \sum_{r=1}^{t} c'_{-r}(\pi_3\pi_1 + \pi_2)\,\pi_3^{r-1}$$

$$+c'_{-t-1}\pi_2\pi_3^t + \sum_{r=0}^{t} Z_{-r}\pi_4\pi_3^r + \sum_{r=0}^{t} U_{-r}\Gamma^{-1}\pi_3^r,$$

where t denotes the period length of the planning horizon. From this final form the multiplicative restraint matrix, R, in (6.4) will be:

$$(6.8)\quad R = \begin{bmatrix} R_1 & 0 & \cdots & & 0 \\ R_2 & R_1 & & & \cdot \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \ddots & \cdot \\ \cdot & \cdot & & R_1 & 0 \\ R_t & & \cdots & R_2 & R_1 \end{bmatrix}$$

where $R_1 = \pi_1'$, $R_2 = (\pi_3\pi_1 + \pi_2)'$, $R_3 = [(\pi_3\pi_1 + \pi_2)\pi_3]'$ . . . .[23/]

Thus R_1 describes the "current" effectiveness of the control variables, R_2 that of one year later, and so on. The additive structure of the constraints (6.4) also follows directly from (6.7). That is, writing s as the sum of two components,

$$(6.9)\quad s = \sigma + FU,$$

it's obvious that $\sigma' = [\sigma_1, \ldots, \sigma_t]$ is based on the aggregate influence of the lagged endogenous variables (for t<0), i.e., $y'_{-t-1}\pi_3^{t+1}$; the noncontrollable exogenous variables, i.e., $\sum_{r=0}^{t} Z_{-r}\pi_3^r$; and the lagged values of the controllable exogenous variables (for t<0). The second component is simply a linear combination of structural disturbances, i.e.,

$$(6.10)\quad F = \begin{bmatrix} F_1 & 0 & \cdots & 0 \\ F_2 & F_1 & & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & U \\ F_t & F_{t-1} & \cdots & F_1 \end{bmatrix} ; \quad U = \begin{bmatrix} U_1 \\ U_2 \\ \cdot \\ \cdot \\ \cdot \\ U_t \end{bmatrix},$$

where $F_1 = \Gamma^{-1'}$, $F_2 = (\Gamma^{-1}\pi_3)'$, $F_3 = (\Gamma^{-1}\pi_3^2)'$ 24/

Thus the matrix F can be determined from the estimated parameters of the econometric model. Note as well that the parameters of the probability distribution of s can be estimated from the estimated residuals of the econometric model (i.e., $\hat{U}$).

Within the above framework, i.e., (a) a quadratic preference function (6.3), (b) linear relations between controllable and uncontrollable variables which are stochastic only by additive disturbances (6.4), and (c) these disturbances are independent of the controllable variables, it follows that the first period vector of control variables that maximizes expected utility is identical with the first period vector of control variables that maximizes the preference function subject to the constraints after s is replaced by its expectation. This result is based on Theil's [52] well-known first period certainty equivalence theorem.25/ Thus, in essence, a stochastic problem is replaced by a deterministic one for obtaining the optimal levels of the instruments in the first period. For subsequent periods within the planning horizon, a similar procedure is followed. In other words, the optimizing problem is reformulated in such a way that the second becomes the first, the third the second, and so on, as information which becomes available about past periods is taken as given for the current period in which decisions must be made. For each reformulated problem, the current (or first-period) decisions of the optimal strategy are determined after the unknown or stochastic variables are replaced by their mathematical expectations.

The above procedure is computationally efficient only if (1) the coefficient vectors and matrices of the constraints have a regular structure (i.e., the corresponding coefficients for different periods are the same), and (2) the planning period is infinite or very large. In most empirical applications a far shorter horizon is of interest than that required by (2). Moreover, in still other situations, the regular structure assumption may not be satisfied. For these cases, an algorithm developed by van de Panne [43] can be employed. This algorithm essentially utilizes a feedback rule in which Theil's optimum decision vector is adjusted by a linear combination of the decision errors as they are perceived in the current period.

In some empirical applications the conditions required (quadratic preference function, linear constraints, etc.) for Theil's certainty equivalence approach (or the van de Panne or Malinvaud generalizations) will not be satisfied. That is, the preference function may be nonquadratic or more importantly for the development of regional decision models one may wish to incorporate discontinuous, inequality, or nonlinear constraints. For example, inequality constraints following from a lexicographic preference ordering may be incorporated in the regional decision model.

General optimizing problems of this type may be conceptualized as control theory problems.[26/] Specifically, the regional policy model formulated under the control theory approach would be as follows:

(6.11) minimize $W = \int_0^T f(y,c,t)dt$ (objective function)

subject to the model

(6.12) $\dot{y} = m(y,c,z,t)dt$ (model)

and the constraints

(6.13) $y(o) = y_o$ (initial conditions)

(6.14) $y(T) \varepsilon R(T)$ (target region)

(6.15) $c \varepsilon G$ (region of controllability or control region)

where m is a functional and y, c, and z are vectors of n state variables, m control variables, and p uncontrollable exogenous variables, respectively.[27/] It is generally assumed that the control variables are piecewise continuous. However, in most empirical applications, discrete representations will be required. For example, problems considered by regional planners are typically periodic.[28/] In this case, general dynamic programming may be employed.[29/]

The dynamic programming approach can, in principle, be used to find an optimum vector of control variables for any decomposable multistage decision systems which allow the inclusion of a set of recursive relationships. A necessary condition for decomposability is that the preference (objective) function be separable [4, 21]. However, when seeking numerical solutions, dynamic programming is usually restricted to problems involving a small number of state variables. Such an approach is hardly applicable to the type of decisions considered in this paper.

The most viable approach in this context may be the application of dynamic programming to a sequence of nonlinear programming problems that have been parameterized in the state vector. Burt [7] has specifically recommended this procedure for problems containing a large number of state and control variables.[30/] Another approach is Wilson's [57] method of conjugate gradients. This method is based on a decomposition principle that partitions the problem in the time dimension and thus eases the computational load.[31/] Lastly, an efficient algorithm which could assist in obtaining solutions to each stage's nonlinear programming problem (that have been parameterized in the state vector) is that developed by Hartley and Hocking [24] for convex programming by tangential approximation.

As the brief account above would indicate, the particular optimization techniques employed for the regional policy model will depend upon the underlying assumption of the model, the preference function, and the mathematical forms involved. To summarize, the constraints on the optimization problem are obtained from the econometric model employed as an approximation to economic mechanisms that exist within the regional economy. In cases where these constraints or others that might be incorporated are nonlinear, discontinuous, or stated as inequalities, general dynamic programming is the suggested approach. For this approach, the only restriction on the objective function for the complete planning horizon is that it be separable. While the Theil procedure (or van de Panne's generalization) does not require separability, quadratic preferences and linear constraints are assumed. Moreover, the incorporation of stochastic disturbances in the certainty equivalence approach is restricted by the assumption that these random elements are serially independent. General dynamic programming does not require this assumption. For the type of models suggested here for regional policy purposes containing large numbers of state and control variables, the Theil approach would appear preferable on grounds of ease and cost of computations while the general dynamic programming approach is preferable on the basis of its generality.

VII

In an empirical application of the regional model problems will no doubt arise due to measurement difficulties for certain variables. Although these problems are of concern, they should not restrict the use of variables for which data is not readily available or which may be difficult to quantify. In addition, in order to be useful for policy purposes, models will most likely be large in scope. Kain and Meyer [27] have recognized the need for such models in stating:

> Actually, large-scale models of this type, which systematically check economic and physical data against one another, can provide an invaluable set of consistency checks on the accuracy and quality of data obtained from diverse sources. Such models also provide useful insights as to where data ignorance is likely to be most penalizing in terms of decision quality. Indeed, the development of such models is almost a necessary prerequisite to better specifying data requirements and information systems for public investment evaluations. [27, pp. 178-179]

Burt [7] has noted that policy models such as the one presented in this paper should be formulated in an adaptive framework which involves periodic modifications as new information becomes available.[32/] Such adaptive models will, also, need to utilize subjective estimates of some parameters due to a lack of data sources. These subjective estimates may be revised in a Bayesian manner similar to the procedure presented for sequential decision problems.[33/] That is, it can be assumed that the policy-making group has prior (subjective) estimates for some of the parameters in the model.[34/] These prior estimates are then combined with sample information (available data) to obtain posterior estimates of the parameters.[35/] The posterior estimates will, then, become the prior estimates in the following period. In addition, the policy-makers will observe their errors in past periods (or obtain subjective estimates of their errors) and incorporate this information into new prior estimates.36/ In addition to allowing for subjective adaptation, the model should contain procedures for incorporating data not now available, for example, information sources on pollution and waste disposal variables. Furthermore, in specifying a dynamic decision nodel one should consider the problem of incorporating information not currently available on future parameter changes.37/

The optimization process involved in solving for decision rules may be simplified by utilizing a "decentralized" policy-making process. More specifically, the model developed could incorporate centralized planning with decentralized policy actions. This procedure would be similar to that discussed by Dantzig [12, Chapter 23] in the context of a decomposition principle.38/ That is, a central planning authority could determine the "correct" information (shadow prices) that should be utilized by each of the individual agencies within the region.39/ The central organization and individual agencies may then exchange information in an iterative procedure to arrive at some "best" outcome. For example, the central planning authority could determine the optimal school expenditures and the optimal tax rates. The local school districts would then incorporate these "shadow prices" in the formulation of budgets which enter their individual decision models; their decisions being transferred back to the central authority and so on. In such a process, the central agency would incorporate into its analysis the interdependencies of the local governments' policy actions. Surely, most policy actions by one community or county in the region will have effects on the other communities and counties. For example, the decision of one community to encourage industrial development in its vicinity by offering location incentives (such as loans) may hinder the possibilities for industrial development in other areas of the region. Similarly, if one county does not establish pollution controls, other counties and communities are likely to be affected (atmospheric pollutants will not "stop" at the county line).[40/] Therefore, due to the conflicting means (controllable variables in a Tinbergen framework [55, p. 175]) of the various local governments within a region, a centralized planning agency seems necessary in order to maximize a regional preference function.[41/] More specifically, due to the interdependencies, diseconomies, and economies arising from localized policy actions, complete decentralization of policy-making is unlikely to be preferred to centralization [37, 55].

The formulation and discussion of the model has assumed that the regional policy-makers behave rationally. However, in an empirical application, considerations could be given to the irrationality of some local governmental decision makers. Such considerations could be incorporated in the control variables as well as the constraints.

APPENDIX

Exogenous--Controllable Variables (Policy Vars.):

C_{TS} = sales tax rate.

Note: certain amount of state rate may be varied within bounds; therefore, assume that rate will always be greater than or equal to state rate. That is, the state rate plus the regional rate which is limited.

C_{Tj} = tax rate for property type j, where j = Agricultural (A), Industrial (I), Commercial (C), and Residential (R).

C_{TLy} = licensing tax or fee for level y, y = 1, . . . , E, (discrete variable).

C_u = service charge or tax rate for public facilities.

C_{WAS} = regional standard on waste purity.

C_{POL} = regional standard on pollutant density.

C_{dj} = zoned classification of land in area d as type j.

Note: different type lands may be in the same area.

C_{Vhj} = discrete level h of assessed valuation for property type j. (i.e., assessment of property type j at level h where J = A, R, J, C and h = 1, . . . , B.

Note: $Z_{hj} = \begin{cases} 1 & \text{if assessed at level k} \\ o & \text{otherwise} \end{cases}$

$$\sum_h Z_{hj} = 1$$

C_{Eo} = regional government expenditures on o which are variable as a policy instrument, where o = S, Uk, H, HO, L, W stand for schools, unemployment aid for labor type k, health, housing, judicial and public protection, and welfare, respectively.

C_{ER} = regional government expenditures on parks and recreation.

C_{EM} = regional government expenditures on maintenance of roads, etc.

$C_{E,Adm}$ = regional government expenditures on administrative and overhead matters.

C_B = bond indebtedness of the regional government.

$C^d_{E,HO}$ = regional government expenditures on housing in area d.

C_{GB} = land classified as green belt areas by the regional government.

C_{PR} = regional parks and recreational areas operated by regional government (assumed federal and state parks are included in this land).

Endogenous Variables:

1. X_i = output of sector i $i = 1, \ldots, n.$
2. X_{if} = output of sector i purchased by sector f (interindustry demand).
3. D_i = capital consumption in sector i (depreciation or replacement).
4. P_i = regional price per unit of output of sector i $i = 1, \ldots, n.$

   Note: P_j $(j \neq i)$ is the price per unit of output of sector j which is a substitute for the output of sector i, $j = 1, \ldots, n$ (there may be more than one substitute for i).
5. I_i = investment in sector i.
6. K_i = capital stock in sector i.
7. L^D_{ik} = demand for labor type k in sector i.
8. W_{ik} = wage rate for labor type k in sector i.
9. L^D_i = total labor demand in sector i.
10. $\bar{W}_i$ = average wage rate (weighted average) paid in sector i.
11. W_i = total wages paid in sector i.
12. E_i = exports from sector i.
13. M_{iq} = imports by sector i of output from exogenous sector q.
14. W_t = total wages paid in region.
15. $\bar{W}_k$ = average wage (weighted average) for labor type k.
16. W_k = total wages paid to labor type k.
17. Q_i = use of regional public facilities by sector i (basis of service charge).
18. N^d_{ji} = land located in area d zoned as land type j used by sector i.
19. VN^d_{ji} = assessed valuation of property type j used in sector i in area d.
20. T_{ji} = property taxes paid on property type j by sector i.
21. T_{ui} = service charges paid by sector i to the regional government.
22. N_j = total land use of land type j.
23. N^d_j = total land use of type j in area d.
24. N_i = total land use by sector i.

Endogenous Variables (Continued):

25. NG = total "green belt" type land in the region.

26. POL_i = pollutant density of atmospheric emissions from sector i.

27. WAS_i = bacterial density of waste emitted by sector i.

28. POL_T = total pollutant density of atmosphere over the region.

29. WAS_T = total bacterial density of total waste emitted by the sectors.

30. L_k^D = total regional demand for labor type k.

31. L_k^M = net migration of labor type k.

32. POP = total regional population.

33. L_k^S = supply of labor type k in the region.

34. U_k = unemployment of labor type k.

35. F_i = regional consumer demand for the output of sector i $i = 1, . . . , n$.

36. S_i = storage of sector i's output.

37. Π_i^b = profits before taxes in sector i.

38. YT_i = federal income taxes paid in sector i.

39. T_{Li} = licensing taxes and fees charged to sector i.

40. T_i = total taxes paid by sector i.

41. Π_i = profits in sector i.

42. GRP_i = gross regional product originating in sector i.

43. Y_{Dy} = percent of regional population in income category y.

44. T_s = regional sales tax revenues.

45. POP_d = population in area d.

46. SLM_d = size of slum area in area d.

47. G_{SF} = required regional government expenditures on schools.

48. G_{ST} = total regional government expenditures on schools.

49. G_{ukF} = required regional government expenditures on unemployment of labor type k.

50. G_{uk}^T = total regional government expenditures on unemployment of labor type k.

Endogenous Variables (Continued):

51. G_{HF} = regional government expenditures on health determined by federal and state regulations.

52. G_{HT} = total regional government expenditures on health.

53. G_{HOF} = regional government expenditures on housing determined by federal and state regulations.

54. G_{HOT} = total regional government expenditures on housing.

55. CR = regional crime rate (or reported crimes).

56. RT = mean police response time to reported crimes.

57. G_{LF} = required regional government expenditures on judicial and public protection matters.

58. G_{LT} = total regional government expenditures on judicial and public protection matters.

59. G_{WF} = required regional government expenditures on welfare aid.

60. G_{WT} = total regional government expenditures on welfare aid.

61. G_T = total regional government expenditures.

62. GRP_T = gross regional product (total).

63. R_F = revenue or aid from federal sources.

64. R_S = state funds channeled through the regional government.

65. R_G = total regional government revenue.

Exogenous--Uncontrollable Variables:

t_y = federal income tax rate function (see function 38).

$\bar{P}_i^N$ = average price nationally of output of sector i.

$\bar{P}_i^S$ = average price of output of sector i in surrounding regions.

WAS_N = national waste disposal regulations or standards.

POL_N = national pollutant emission regulations.

TC_i = transportation cost rate for exports of sector i.

t_I = federal tax rate or credit on corporate investment.

GNP = gross national product.

r_R = regional interest rate.

<u>Exogenous--Uncontrollable Variables</u> (Continued):

$\bar{W}_k^S$ = average wage rate for labor type k in surrounding regions.

$\bar{W}_k^N$ = average wage rate for labor type k nationally.

W_k^m = minimum wage rate for labor type k.

(B-D) = birth rate minus death rate for the region.

FR_o = fixed amount of expenditures required by federal regulations for regional expenditure on o, where o = S, Uk, H, HO, L, W stand for schools, unemployment aid for labor type k, health, housing, judicial and public protection, and welfare, respectively.

SR_o = same as FR_o except for state regulations where o = S, Uk, H, HO, L, and W.

γ_I^S = same as C_{TI} except for surrounding regions.

γ_C^S = same as C_{TC} except for surrounding regions.

γ_{Ly}^S = same as C_{TLy} except for surrounding regions.

Also, lagged endogenous variables and lagged exogenous variables.

<u>Predetermined Parameters</u>:

Ψ = number of nonworking people per worker or labor type.

λ = proportions of sales taxes retained by or returned to the region.

Regional Econometric Model*:

(1) $X_i = f_{1i}(X_{if}, K_{it-1}, \pi_{it-1}, \bar{P}^N_{it-1}, \bar{P}^S_{it-1}, S_{it-1}),$ $\quad i = 1, \ldots, n$

(2) $X_{if} = f_{2i}(X_f, P_{it-1}, \bar{P}^S_{it-1}),$ $\quad i, f = 1, \ldots, n$

(3) $D_i = f_{3i}(X_i, K_{it-1}),$ $\quad i = 1, \ldots, n$

(4) $P_i = f_{4i}(X_i, P_j, \bar{W}_i, \bar{P}^N_{it-1}, \bar{P}^S_{it-1}, F_{it-1}),$ $\quad i = 1, \ldots, n$

(5) $I_i = f_{5i}(\bar{W}_i, a_i(L)P_{it-1}, C_{TI}, C_{TC}, C_{TLy}, \gamma^S_I, \gamma^S_C, \gamma^S_{Ly},$
$C_{WAS}, WAS_N, C_{POL}, POL_N, t_I, r_R, \sum_k U_{kt-1}),$ $\quad i = 1, \ldots, n$

(6) $K_i = I_i - D_i + K_{it-1},$ $\quad i = 1, \ldots, n$

(7) $L^D_{ik} = f_{7ik}(X_i, W_{ik}, K_i, r_R),$ $\quad i = 1, \ldots, n, \; k = 1, \ldots, L$

(8) $W_{ik} = f_{8ik}(P_i, \bar{W}^S_{kt-1}, \bar{W}^N_{kt-1}, W^m_k,$
$W_{ikt-1}, K_i),$ $\quad i = 1, \ldots, n, \; k = 1, \ldots, L$

(9) $L^D_i \equiv \sum_{k=1}^{L} L^D_{ik},$ $\quad i = 1, \ldots, n$

(10) $\bar{W}_i \equiv \sum_{k=1}^{L} \frac{L^D_{ik}}{L^D_i} \cdot W_{ik},$ $\quad i = 1, \ldots, n$

(11) $W_i \equiv \sum_{k=1}^{L} W_{ik} \cdot L_{ik},$ $\quad i = 1, \ldots, n$

(12) $E_i = f_{12i}(P_i, \bar{P}^N_i, \bar{P}^S_{it-1}, \bar{P}^N_{jt-1}, P^S_{jt-1}, GNP, TC_i),$ $\quad i = 1, \ldots, n$

(13) $M_{iq} = f_{13iq}(X_i, P_q, \bar{P}^N_{qt-1}, \bar{P}^S_{qt-1}, GRP_{qt-1}),$ $\quad i, q = 1, \ldots, n$

(14) $W_T \equiv \sum_{i=1}^{n} W_i,$

(15) $\bar{W}_k \equiv \sum_{i=1}^{n} \frac{L^D_{ik}}{L^D_i} \cdot W_{ik},$ $\quad k = 1, \ldots, L$

(16) $W_k \equiv \sum_i W_{ik} \cdot L^D_{ik},$ $\quad k = 1, \ldots, L$

(17) $Q_i = f_{17i}(X_i, K_i, C_u, r_R),$ $\quad i = 1, \ldots, n$

* For the sake of notational simplicity the disturbance terms entering each behavioral relationship are deleted.

(18) $N^{d}_{ji} = f_{18jid}(X_i, C_{Tj}, C_{dj}, VN^{d}_{jit-1})$, $i = 1, \ldots, n$, $j = A, I, C, R$, $d = 1, \ldots, G$

(19) $VN^{d}_{ji} \equiv \sum_{h=1}^{B} Z_{hj} \cdot N^{d}_{ji} \cdot C_{Vhj}$, $i = 1, \ldots, n$, $j = A, I, C, R$, $d = 1, \ldots, G$

(20) $T_{ji} \equiv C_{Tj} \cdot \sum_{d} VN^{d}_{ji}$, $i = 1, \ldots, n$, $j = A, I, C, R$

(21) $T_{ui} \equiv C_u \cdot Q_i$, $i = 1, \ldots, n$

(22) $N_j \equiv \sum_i \sum_d N^{d}_{ji}$, $j = A, I, C, R$

(23) $N^{d}_{j} \equiv \sum_i N^{d}_{ji}$, $d = 1, \ldots, G$, $j = A, I, C, R$

(24) $N_i \equiv \sum_j \sum_d N^{d}_{ji}$, $i = 1, \ldots, n$

(25) $NG \equiv N_A + C_{GB} + C_{PR}$,

(26) $POL_i = f_{26i}(X_i, C_{POL})$, $i = 1, \ldots, n$

(27) $WAS_i = f_{27i}(X_i, Q_i, N_i, C_{WAS})$, $i = 1, \ldots, n$

(28) $POL_T \equiv \sum_i POL_i$,

(29) $WAS_T \equiv \sum_i WAS_i$,

(30) $L^{D}_{k} \equiv \sum_i L^{D}_{ik}$, $k = 1, \ldots, L$

(31) $L^{M}_{k} = f_{31k}(L^{D}_{kt-1}, \bar{W}_k, U_{kt-1}, G_{WTt-1}, a_2(L)G^{T}_{ukt-1}, \bar{W}^{S}_{kt-1},$
$a_3(L)G^{S}_{ut-1}$, $k = 1, \ldots, L$

(32) $POP \equiv POP_{t-1} + POP_{t-1}(B-D) + (1 + \Psi) \sum_k L^{M}_{k}$,

(33) $L^{S}_{k} = f_{33k}(L^{M}_{k}, L^{S}_{kt-1}, POP, a_4(L)G^{T}_{ukt-1})$, $k = 1, \ldots, L$

(34) $U_k \equiv L^{D}_{k} - L^{S}_{k}$, $k = 1, \ldots, L$

(35) $F_i = f_{35i}(W_T, P_i, P_j, GRP_{Tt-1}, G_{WTt-1}, \sum_k G^{T}_{ukt-1},$
$C_{TS}, POP, t_y)$, $i = 1, \ldots, n$

(36) $S_i \equiv X_i - F_i - E_i - \sum_f X_{if} + S_{it-1}$, $\quad i = 1, \ldots, n$

(37) $\pi_i^B \equiv P_i(F_i + \sum_j X_{ij} + E_i) - D_i - W_i - \sum_j P_j X_{ji} -$

$\sum_q P_q^M M_{iq}$, $\quad i = 1, \ldots, n$

(38) $YT_i \equiv t_y(\pi_i^B) \cdot \pi_i^B$, $\quad i = 1, \ldots, n$

(39) $T_{Li} \equiv f_{39i}(I_i, \gamma_{L1}, \ldots, \gamma_{LE})$, $\quad i = 1, \ldots, n$

(40) $T_i \equiv YT_i + IT_i + \sum_j T_{ji} + T_{ui} + T_{Li}$, $\quad i = 1, \ldots, n$

(41) $\pi_i \equiv \pi_i^B - T_i$, $\quad i = 1, \ldots, n$

(42) $GRP_i \equiv \pi_i + W_i$, $\quad i = 1, \ldots, n$

(43) $Y_{Dy} = f_{43y}(W_T, a_5(L)G_{WTt-1}, a_6(L)\sum G^T_{ukt-1}, \sum_i \pi_i)$, $\quad y = 1, \ldots, R$

(44) $T_S \equiv \sum_i C_{TS} \cdot F_i \cdot P_i$,

(45) $POP_d = f_{45d}(POP_{dt-1}, N_R^d, C_{EHO}^d, C_{TR})$, $\quad d = 1, \ldots, G$

(46) $SLM_d = f_{46d}(a_7(L)C^d_{EHOt-1}, G_{WTt-1}, \sum_k U_k)$, $\quad d = 1, \ldots, G$

(47) $G_{SF} \equiv f_{47d}(G_{SFt-1}, POP, FR_S, SR_S)$,

(48) $G_{ST} \equiv G_{SF} + C_{ES}$,

(49) $G_{ukF} \equiv f_{49k}(U_k, POP, FR_u, SR_u)$, $\quad k = 1, \ldots, L$

(50) $G^T_{uk} \equiv G_{ukF} + C_{Euk}$, $\quad k = 1, \ldots, L$

(51) $G_{HF} \equiv f_{51k}(POP, G_{HFt-1}, FR_H, SR_H)$,

(52) $G_{HT} \equiv G_{HF} + C_{EH}$,

(53) $G_{HOF} \equiv f_{53k}(\sum_d SLM_d, \sum_k U_k, POP, FR_{HO}, SR_{HO})$,

(54) $G_{HOT} \equiv G_{HOF} + C_{EHO}$,

(55) $CR = f_{55}(Y_{D1}, \ldots, Y_{DR}, \sum_d SLM_d, \sum_k U_k),$

(56) $RT = f_{56}(CR, a_8(L)G_{LT}),$

(57) $G_{LF} \equiv f_{57}(POP, CR, Y_{D1}, \ldots, Y_{DR}, FR_L, SR_L),$

(58) $G_{LT} \equiv G_{LF} + C_{EL},$

(59) $G_{WF} \equiv f_{59}(POP, \sum_k U_k, Y_{D1}, \ldots, Y_{DR}, \sum_d SLM_d, FR_L, SR_L),$

(60) $G_{WT} \equiv G_{WF} + C_{EW},$

(61) $G_T \equiv G_{ST} + \sum_k G^T_{uk} + G_{HT} + G_{HOT} + G_{LT} + G_{WT} + C_{ER} + C_{EM} + C_{E,Adm},$

(62) $GRP_T \equiv \sum_i GRP_i + G_T,$

(63) $R_F = f_{63}(POP, GRP_T, \sum_k U_k, \sum_d SLM_d, Y_{D1}, \ldots, Y_{DR}, R_{F-1}),$

(64) $R_S = f_{64}(POP, T_S, GRP_T, \sum_k U_k, \sum_d SLM_d, Y_{D1}, \ldots, Y_{DR}, R_{St-1}),$

(65) $R_G \equiv \sum_i \sum_j T_{ji} + \sum_i T_{ui} + \lambda T_S + R_F + R_S + C_B + \sum_i T_{Li}.$

FOOTNOTES

**Ronald A. Oliveira is a graduate student in the Department of Agricultural Economics, University of California, Davis; Gordon C. Rausser is Acting Assistant Professor and Acting Assistant Agricultural Economist on the Experiment Station and on the Giannini Foundation, University of California, Davis.

The authors appreciate the helpful comments provided by S. R. Johnson, Gordon King, Sylvia Lane, and Alvin Sokolow on an earlier version of this paper.

1/ It appears that the authors of the California model were principally concerned with obtaining "good fits" rather than with the causal-effects relationships involved. A more fruitful approach for policy purposes may be to first formulate the econometric model on the basis of presumed causal-effect relationships within the economy and then adjust for the lack of data (i.e., introduce proxy variables, etc.).

2/ To be sure, data collection and information gathering is a decision problem itself. We shall not concern ourselves with this problem, thus implicitly we will assume that the expected benefits exceed expected costs of any data collection efforts. For a discussion of such benefits and costs of this problem, see Modigliani and Cohen [40].

3/ Decentralized decision making within the region is briefly discussed below in section VII.

4/ See Warren [56] for a detailed discussion on multicounty economic development districts as well as a discussion of the present drawbacks of these districts and possibilities for improvement.

5/ For a discussion on conscious choices and the distinction between "choice" and "decision making" see Arrow [2].

6/ The preference function development in this paper ignores the theoretical problems involved with Arrow's impossibility theorem. It is hypothesized that a regional policy-making group is assumed to behave as if such a preference function exists or that preference functions can be approximated by the legislative process (see Maass [32]).

7/ In empirical applications one might wish to include the "carry-over amendment" and the "smoothing amendment" discussed by Theil [52, Chapter 6].

8/ In another paper Theil [51] presents a procedure for combining the individual committee member's preference functions by utilizing individual loss functions. More specifically, for a given vector of policy variables, it is assumed that a unique maximum level of utility for each respective committee member exists (i.e., the maximum of this preference function with respect to the policy variables). This maximum level of utility for any particular committee member will be associated with some "best" policy decision vector from his point of view. Any other decision vector will result in some greater loss of utility for that member. Therefore, the overall committee loss function will be a weighted sum of the individual loss functions. If all committee members are assumed to have "equal" voting power in making policy decisions, of course, the weights are all equal.

FOOTNOTES (Continued)

See Theil [52, Chapter 7] for a discussion of a procedure developed by Van Den Bogaard for obtaining the weights of the committee loss function when the loss matrix is not symmetric. This development assumes that the loss matrix obtained for the individual loss functions is symmetric. For additional features of decision making in committees and the approach of team decision problems, see [37, 45].

9/ For discussions on the problem of measuring "satisfactory levels," see Ferguson [14] and Osborne [42].

10/ In addition to lexicographic orderings, the preference function formulation for a regional policy model may also consider the combination of goals from various levels of government. See Major [34] for such a development.

11/ In addition, it seems reasonable that the regional government could determine the optimal amount of school expenditures and pass this information on to the school districts.

12/ Actually a partial structural form since the true structural form is never actually estimated.

13/ The block-recursiveness of the model is discussed in greater detail in section IV.

14/ The considerations developed by Fisher are presented for a particular model.

> . . . . The case to be considered is that of a quadratic welfare function; a linear reduced form in the endogenous variables that appear in the welfare function, with no overidentifying restrictions on the parameters; nonstochastic exogenous variables; and socially uncorrelated disturbances with a known covariance matrix. [18, p. 2]

In Fisher's development of a special Bayes solution, the investigator or researcher is assumed to postulate a prior personal probability distribution representing his degree of belief in alternative possible values of the parameters for the reduced form; the posterior distribution is based on both the sample and this prior information. In the simple case of one equation and one decision variable Fisher shows the implied optimal estimate for the decision model is an "inflated" least-squares estimate.

The optimal estimates in the decision model involve the constants of the welfare function (except in the simplest special case shown by Fisher); however, in the prediction model they do not. Thus, the researcher estimating a decision model needs to know at least some of the constants of the preference function in order to derive optimal estimates of the unknown parameters.

FOOTNOTES (Continued)

15/ In another article, Marschak explicitly recognizes the inefficiencies of the traditional approach. He states:

> . . . and even though disagreement may exist as to the precise criterion function that the program has to maximize, we have seen that on formal grounds it will be, in general, inefficient to separate the estimation procedure from the determination of optimal rules of action. [38, p. 525]

16/ If the equations are nonlinear in the original variables they are presumed to be intrinsically linear. That is, if the model is intrinsically linear it can be expressed, by suitable transformation of the variables, in the standard linear form.

17/ We shall make the typical assumptions about the model so that it will have all the "nice" properties. First, we assume Γ is nonsingular so the system can be solved uniquely for y_t in terms of X_t and U_t. The structural disturbances are assumed to be generated by a stationary multivariate stochastic process where each disturbance vector has a zero expectation and the contemporaneous covariance matrix of the disturbances in the different equations is the same for all t (i.e., the covariance matrix of the contemporaneous disturbance terms is a symmetric and positive, semi-definite matrix, Ω). Secondly, it is assumed that the disturbance vector is temporally uncorrelated (all covariances between disturbances in the same or different equations which are not contemporaneous vanish). The last three assumptions imply, under general conditions, that the sample variances and covariances of the structural disturbances have as their probability limits the corresponding population parameters [20, p. 300].

Turning to the predetermined variables, we will also assume that they are generated by a stationary multivariate stochastic process with nonsingular contemporaneous covariance matrix Ω_{XX}. Last and perhaps most importantly, we assume that the process generating the predetermined variables is contemporaneously uncorrelated with the process generating the disturbances, such that $E\,X_t'U_t = E\,X_t'E\,U_t = 0$.

18/ To examine the correlations among the disturbance terms and the current and lagged endogenous variables, we solve (5.4) for y_t, obtaining

$$(5.5) \qquad y_t = \Gamma'^{-1}B_3'y_{t-1} + \Gamma'^{-1}B_1'c_t + \Gamma'^{-1}B_2'c_{t-1} + \Gamma'^{-1}B_4'Z_t + \Gamma'^{-1}U_t.$$

Assuming that $\Gamma'^{-1}B_3'$ is stable we may solve the system of difference equations (5.5) as

$$(5.6) \qquad y_t = \sum_{\theta=0}^{\infty} (\Gamma'^{-1}B_3')^{\theta}\,\Gamma'^{-1}(B_1'c_{t-\theta} + B_2'c_{t-\theta-1} + B_4'Z_{t-\theta} + U_{t-\theta})$$

FOOTNOTES (Continued)

denoting the covariance of U_t and $y_{t-\theta}$ by $W_1(\theta)$ and that of U_t and $U_{t-\theta}$, by $W_2(\theta)$ (in each case the columns correspond to U_t and the rows correspond to the elements of $y_{t-\theta}$ and $U_{t-\theta}$, respectively), it follows that

$$(5.7) \qquad W_1(0) = \sum_{\theta=0}^{\infty} (\Gamma'^{-1}B_3')^{\theta} (\Gamma'^{-1}W_2(\theta)). \quad \text{(Note that } W_2(0) = \Omega.\text{)}$$

Since Γ'^{-1} is block-triangular by (5.2), $W_2(0)$ is block-diagonal by (5.3), and $W_2(\theta) = 0$ for all $\theta>0$ by the assumption that the disturbance vector of (5.1) is temporally uncorrelated, it follows that the current endogenous variables of the i^{th} block is uncorrelated in the probability limit with the current disturbances of the i+1, . . . , C blocks. (For a complete development of this proposition in the context of dynamic systems, see Fisher [15].)

19/ The model developed in section IV contained a large number of definitional equations or identities. If these identities are left in the system (5.1), the covariance matrix Ω of disturbances will be singular (which presents problems if one wishes to use such methods as full information-maximum likelihood). In this case, one could eliminate the indentities by substituting into the other equations before estimation procedures are begun (also see Rothenberg and Leenders [47, section 7]). Another viable procedure for most estimation procedures would be to ignore the definitional equations and proceed with the estimation of the behavioral relations, see Christ [11].

20/ The block-recursive structure of the model would permit the elimination of a number of equations in the event that they were irrelevant for the region considered. In particular, the pollution and waste emission relations (if found irrelevant) may be omitted without altering the estimation procedures employed for the rest of the model.

21/ It is assumed, of course, that the conditions required for the expected-utility hypothesis of Von Neumann-Norgenstern are satisfied. The axiomatic basis for this assumption is provided in Marschak [35]. More precisely, the optimizing problem is formulated as one of maximizing the expectation of the preference function (6.3) subject to the constraint (6.4), the latter being interpreted stochastically.

22/ For more details on the derivation of the final form see Theil and Boot [50]. It is assumed, of course, that the system is stable.

23/ This development assumes that the structure in (6.5) does not change, i.e., the coefficients are treated as fixed and given. Although the true coefficients may be constant, the values employed are those estimated from the econometric model. Thus clearly the assumption that they are fixed and given is not satisfied. In principle, however, we can eliminate this difficulty by adopting a Bayesian point of view. That is, the decision-maker fixes all coefficients at certain numerical (estimated) values which measure his "prior beliefs."

24/ This specification is based on the assumption the U_t are serially uncorrelated and distributed independently of the control variables.

FOOTNOTES (Continued)

25/ Malinvaud [33] has generalized Theil's certainty equivalence results. He demonstrates that if the conditions of the certainty equivalence theorem (i.e., quadratic payoff function, linear constraints, etc.) are not satisfied, but the various functions involved are differentiable, an approximate property can be stated. That is, as long as the degree of uncertainty is small the optimal initial decision changes little with the degree of uncertainty. "Decisions taken on the basis of models in which the random disturbances are neglected should be close to optimal as long as these disturbances have zero expected values and the differentiability conditions are satisfied." [33, p. 715]

26/ See Fox, et al., [19] and Pontryagin [44].

27/ Equation (6.12) is a vector differential equation, i.e., it is a concise representation of n scalar differential equations, one for each of the n state variables. M is a scalar function (linear or nonlinear) which consists of n functions, one for each of the n scalar differential equations. It is assumed that the target region, R, and the control region, G, are in an open set in R^n (i.e., the n-dimensional number space) and a closed nonempty set in R^m or the entire space R^m, respectively. A moving-target region is assumed in the general case; i.e., the planning horizon (or end point, T) is not given but determined endogenously. Generally, it is assumed that the equations in (6.12) and their first differentials are continuous and that "f" in (6.11) is continuous [19, Chapter 8].

28/ Of course, such decision problems can be approximated by continuous variational models, however, numerical solutions of these models typically requires discrete approximation methods. Therefore, as Burt [7] points out, it appears advantageous to employ a discrete model initially ". . . since it is more realistic and can be solved directly."

29/ See Bellman and Dreyfus [4] and Burt [7].

30/ The procedure is simply to divide the planning horizon into several segments. The short time horizon problem associated with the last segment is solved in terms of many initial state vectors and a suitable function is fitted to the optimized preference function with this vector as the set of independent variables. The fitted relation is then used as the terminal value of the second problem associated with the next to the last segment of the planning horizon, and so on.

31/ This method as well as the one suggested by Burt [7] is especially appealing for a quadratic preference function since in this case convergence is reasonably rapid.

32/ See Albert and Sittler [1] for further technical considerations.

33/ See Hadley [22] for an exposition of a sequential decision problem in a Bayesian framework.

34/ The prior estimates may be obtained independently by the policy committee or supplied by researchers.

FOOTNOTES (Continued)

35/ For a formal development of such estimates see Tiao and Zellner [53] and Zellner and Chetty [58].

36/ Fisher [16] in a different context has also expressed the idea of incorporating prior (subjective) information in the determination of unknown parameter estimates.

37/ This problem has been recognized by Theil [52]. For similar considerations on an adaptive model within the context of a control system's framework, see Sworder [49].

38/ For a theoretical definition of decentralization see Marschak [37]. He also presents a formal comparison of centralization and decentralization and specifies criteria for evaluating economic decision-making organizations under each case.

39/ See Radner [46] for a discussion on the uses of shadow prices in planning.

40/ In the case of pollution controls, the state or federal government should perhaps be the central control agency. Presently, state governments exert some influence over pollution standards in individual counties.

41/ The authors are planning an empirical application of the conceptual model developed in this paper to a region composed of the North Coast counties of California (Del Norte, Humboldt, Mendocino, and Lake counties). These counties are noted for excessively high unemployment rates and have been declared an economically depressed region by the Economic Development Administration (EDA). In addition, the four counties have expressed a desire to form an Economic Development District under the EDA. Obviously, since the model developed in this paper is of a general framework, it will have to be modified in applying it to a depressed region such as the North Coast. For example, employment and migration relations will be expanded, and water considerations will be specified in some detail.

REFERENCES

[1] Albert, Arthur, and Robert W. Sittler, "A Method For Computing Least Squares Estimators That Keep Up With the Data," J. SIAM Control, Series A, Vol. 3, No. 3, 1965, pp. 384-417.

[2] Arrow, K. J., "Utilities, Attitudes, Choices: A Review Note," Econometrica, Vol. 26, No. 1, January 1958, pp. 1-23.

[3] Bell, Frederick W., "An Econometric Forecasting Model for A Region," Journal of Regional Science, Vol. 7, No. 2, 1967, pp. 109-128.

[4] Bellman, R., and S. Dreyfus, Applied Dynamic Programming, Princeton, New Jersey: Princeton University Press, 1962.

[5] Berry, Brian J. L., Strategies, Models, and Economic Theories of Development in Rural Regions, Agricultural Economic Report No. 127, Economic Research Service, USDA, December 1967.

[6] Bird, Alan R., "The Challenges and Rewards of Regional and Multi-county Planning," Economic Development Division, Economic Research Service, USDA, presented at the First Regional Planning Conference, New York Central Schools, Gouverneur, New York, September 25, 1969.

[7] Burt, Oscar R., "Control Theory for Agricultural Policy: Methods and Problems in Operational Models," American Journal of Agricultural Economics, Vol. 51, No. 2, May 1969, pp. 394-404.

[8] Burton, Richard P., and John W. Dyckman, "A Quarterly Economic Forecasting Model for the State of California," Center for Planning and Development Research: Institute of Urban and Regional Development, University of California, Berkeley, December 1965.

[9] Chakravarty, S., "Alternative Preference Functions in Problems of Investment Planning on the National Level," in Activity Analysis in the Theory of Growth and Planning, E. Malinvaud and M. O. L. Backarach (eds.), London: Macmillan, 1967, pp. 150-169.

[10] Chipman, John S., "The Foundations of Utility," Econometrica, Vol. 28, No. 2, April 1960, pp. 193-224.

[11] Christ, C. F., Econometric Models and Methods, New York: John Wiley & Sons, Inc., 1966.

[12] Dantzig, G. B., Linear Programming and Extensions, Princeton University Press, Princeton, New Jersey, 1963.

[13] Eijk, van, C. J., and J. Sandee, "Quantitative Determination of an Optimum Economic Policy," Econometrica, Vol. 27, No. 1, January 1959, pp. 1-13.

[14] Ferguson, C. E., "The Theory of Multidimensional Utility Analysis in Relation to Multiple-Goal Business Behavior: A Synthesis," Southern Economic Journal, October 1965, pp. 169-175.

REFERENCES (Continued)

[15] Fisher, F. M., "Dynamic Structure and Estimation in Economy-Wide Econometric Models," Brookings Quarterly Economic Model, Duesenberry, et al.,(eds.), Chicago: Rand-McNally, 1965, Chapter 5.

[16] __________, A Priori Information and Time Series Analysis, Amsterdam: North-Holland, 1966.

[17] __________, The Identification Problem in Econometrics, New York: McGraw-Hill, 1966.

[18] Fisher, Walter D., "Estimation in the Linear Decision Model," International Economic Review, Vol. 3, No. 1, January 1962, pp. 1-29.

[19] Fox, Karl A., Jati K. Sengupta, and Erik Thorbecke, The Theory of Quantitative Economic Policy With Applications to Economic Growth and Stabilization, Amsterdam: North-Holland, 1966.

[20] Goldberger, Arthur S., Econometric Theory, New York: John Wiley & Sons, Inc., 1964.

[21] Hadley, G., Nonlinear and Dynamic Programming, Reading, Massachusetts: Addison-Wesley, 1964.

[22] __________, Introduction to Probability and Statistical Decision Theory, San Francisco: Holden-Day, 1967.

[23] Hartley, H. O., "Nonlinear Programming by the Simplex Method," Econometrica, Vol. 29, No. 2, April 1961, pp. 223-237.

[24] Hartley, H. O., and R. R. Hocking, "Convex Programming by Tangential Approximation," Management Science, Vol. 9, No. 4, July 1963, pp. 600-612.

[25] Hermansen, Tormod, "Information Systems for Regional Development Control," Regional Science Association: Papers, Vol. 22, Budapest Conference, 1969, pp. 107-139.

[26] Judge, George G., and Thomas A. Yancey, "The Use of Prior Information in Estimating the Parameters of Economic Relationships," Quantitative Economics Workshop Paper, University of Illinois, Urbana-Champaign, May 1968.

[27] Kain, John F., and John R. Meyer, "Computer Simulations, Physio-economic Systems, and Intraregional Models," American Economic Review, Vol. 58, No. 2, May 1968, pp. 171-181.

[28] Klein, Lawrence R., "The Specification of Regional Econometric Models," Papers -- The Regional Science Association, Vol. 23, 1969, The Cambridge Meeting, November 1968, pp. 105-115.

REFERENCES (Continued)

[29] Koopmans, T. C., and William C. Hood, "The Estimation of Simultaneous Linear Economic Relationships," Studies in Econometric Method, William C. Hood, and T. C. Koopmans (eds.), New York: John Wiley, 1953, Chapter 6.

[30] Kornai, Janos, Mathematical Planning of Structural Decisions, Amsterdam: North-Holland, 1967.

[31] L'Esperance, W. L., G. Nestel, and D. Fromm, "Gross State Product and an Econometric Model of a State," American Statistical Association Journal, Vol. 64, No. 327, September 1969, pp. 787-807.

[32] Maass, Arthur, "Benefit-Cost Analysis: Its Relevance to Public Investment Decisions," Quarterly Journal of Economics, Vol. 80, 1966, pp. 208-226.

[33] Malinvaud, E., "First Order Certainty Equivalence," Econometrica, Vol. 37, No. 4, October 1969, pp. 706-718.

[34] Major, David C., "Benefit-Cost Ratios for Projects in Multiple Objective Investment Programs," Water Resources Research, Vol. 5, No. 6, December 1969, pp. 1174-1178.

[35] Marschak, J., "Rational Behavior, Uncertain Prospects, and Measurable Utility," Econometrica, Vol. 18, 1950, pp. 111-141.

[36] __________, "Economic Measurements for Policy and Prediction," Studies in Econometric Method," William C. Hood and T. C. Koopmans (eds.), New York: John Wiley, 1953, Chapter 1.

[37] __________, "Elements for a Theory of Teams," Management Science, Vol. 1, 1955, pp. 127-137.

[38] __________, "On Adaptive Programming," Management Science, Vol. 9, No. 4, July 1963, pp. 517-526.

[39] Marschak, Thomas, "Centralization and Decentralization in Economic Organizations," Econometrica, Vol. 27, No. 3, July 1959, pp. 399-430.

[40] Modigliani, Franco, and Kalman J. Cohen, The Role of Anticipations and Plans in Economic Behavior and Their Use in Economic Analysis and Forecasting, Studies in Business Expectations and Planning Number 4, Bureau of Economic and Business Research, University of Illinois Bulletin, Vol. 58, No. 38, January 1961.

[41] Naylor, Thomas H., "Policy Simulation Experiments With Macroeconometric Models: The State of the Art," American Journal of Agricultural Economics, Vol. 52, No. 2, May 1970, pp. 263-271.

[42] Osborne, Dale K., "On the Goals of the Firm," Quarterly Journal of Economics, Vol. 78, 1964, pp. 592-603.

REFERENCES (Continued)

[43] Panne, van de, C., "Optimal Strategy Decisions for Dynamic Linear Decision Rules in Feedback Form," Econometrica, Vol. 33, No. 2, April 1965, pp. 307-320.

[44] Pontryagin, L. S., et al., The Mathematical Theory of Optimal Processes, New York: Interscience, 1962.

[45] Radner, R., "Team Decision Problems," The Annals of Mathematical Statistics, Vol. 33, 1962, pp. 857-881.

[46] __________, Notes on the Theory of Economics Planning, Center of Economic Research, Athens, 1963.

[47] Rothenberg, T. J., and C. T. Leenders, "Efficient Estimation of Simultaneous Equation Systems," Econometrica, Vol. 32, No. 1-2, January-April, 1964, pp. 57-76.

[48] Spiegelman, Robert G., Analysis of Urban Agglomeration and Its Meaning for Rural People, Agricultural Economic Report No. 96, Economic Research Service, USDA, June 1966.

[49] Sworder, David, Optimal Adaptive Control Systems, New York: Academic Press, 1966.

[50] Theil, H., and J. C. G. Boot, "The Final Form of Econometric Equation Systems," Review of the International Statistical Institute, Vol. 30, No. 2, 1962, pp. 136-152.

[51] __________, "On the Symmetry Approach to the Committee Decision Problem," Management Science, Vol. 9, 1963, pp. 380-393.

[52] __________, Optimal Decision Rules for Government and Industry, Amsterdam: North-Holland, 1968.

[53] Tiao, George C., and Arnold Zellner, "Bayes' Theorem and the Use of Prior Knowledge in Regression Analysis," Biometrika, Vol. 51, No. 1 and 2, 1964, pp. 219-230.

[54] Tiebout, Charles M., The Community Economic Base Study, Supplementary Paper No. 16, Committee for Economic Development, New York, December 1962.

[55] Tinbergen, J., Economic Policy: Principles and Design, Amsterdam: North-Holland, 1967.

van de Panne, C., (see Reference #43).

van Eijk, C. J., (see Reference #13).

[56] Warren, Robert O., The Organization of Multicounty Economic Development Programs, Department of Political Science, University of Washington, Seattle, September 1968.

REFERENCES (Continued)

[57] Wilson, Robert, "Computation of Optimal Controls," Journal of Mathematical Analysis and Applications, Vol. 14, 1966, pp. 77-82.

[58] Zellner, Arnold, and V. Karuppan Chetty, "Prediction and Decision Problems in Regression Models From the Bayesian Point of View," Journal of the American Statistical Association, Vol. 60, No. 310, June 1965, pp. 608-616.