natives—can be quickly tested by specifying those individual links and stations to be included in the new alternative. It may also be necessary to add more potential links and stations to the initial field inventory; this can be an important contribution to the thoroughness with which later system planning is conducted. Finally, the related between-cluster impacts on community and environmental factors that can be attributed to the many supply-and-demand variations of the system can be quickly examined.

The limitations of the indirect impact-analysis methodology suggested here should also be clearly understood; these are essentially the limitations attached to sketch-planning in general.

1. Sketch-planning results are generalized in nature. Specific impact estimates for individual links or station areas, such as areas of land to be acquired and numbers of dwelling units to be displaced, should not be expected, and procedures for their calculation are not included.

2. Care must consequently be exercised in using these generalized results in community and public-agency interactions. Because specific alignments, centerlines, and station locations are not investigated, it is possible that subsequent system and corridor planning will, for any individual link or station, significantly alter the initial assessment of consequences.

3. In the area of community and environmental factors, particularly at the corridor-planning level, considerable and major additional efforts are necessary to adequately specify the indirect effects that will actually be generated.

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Comparison of the Usefulness of Two Multiregional Economic Models in Evaluating Transportation Policies

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This report describes and compares two large-scale economic-forecasting models—the multiregional input-output model developed by Polenske and the multrieginal, multi-industry forecasting model developed by Harris—to examine their usefulness for transportation planning at national, state, and local levels. The models use fundamentally different methods of economic forecasting, and thus have different appropriate applications. Both the Polenske and the Harris models are currently used in analyzing regional economic activity by industrial sectors. A basic difference is that the Polenske model is used mainly for analyzing the effects of changes in interindustry trade flows between regions, whereas the Harris model is used mainly in forecasting regional growth and evaluating effects of alternative highway and other transportation systems. The Polenske model provides a framework for describing and analyzing the sales and purchases of all industries in every region of the economy and has been used to analyze the role of trade in the economic growth of particular regions, such as the California-Oregon-Washington region, as compared to the rest of the United States. The Harris model is designed to make both short-run and long-run forecasts of economic growth. Because it provides a framework for analyzing interindustry purchases, it has been used to evaluate the regional economic and environmental effects of alternative highway systems.

The assessment of regional effects is increasingly important in the development of transportation programs because of changing patterns of regional growth in the United States and because transportation investments and programs can significantly affect the economic growth of a region. To predict the regional economic effects of major capital investments, such as highways and other transportation facilities, a number of economic-forecasting models have been developed and are being used in transportation planning and policy evaluation at national, state, and local levels. These models have been developed as tools for transportation planning and policy evaluation and should be used with good judgment and other methods of social and economic analysis.

This paper describes and compares two large-scale economic-forecasting models—the multiregional multi-industry forecasting (MRMI) model developed by Harris at the University of Maryland and the multiregional input-output (MRIO) model developed by Polenske at the Massachusetts Institute of Technology and Harvard University—to examine their usefulness for transportation planning at national, state, and local levels. These models use fundamentally different methods of economic forecasting and thus have different appropriate applications.

Their similarities and differences are discussed under the headings of: (a) description, (b) uses, (c) major assumptions, (d) strengths and limitations, and (e) conclusions concerning their usefulness in transportation planning.

DESCRIPTION OF MODELS

Harris Model

The MRMI model is an econometric model composed of three major components, as shown in Table 1—a set of forecasting equations, a transportation-cost linear-programming algorithm, and a regional highway-congestion index—and uses national forecasts obtained from the interindustry forecasting model of the University of Maryland (INFORUM), developed by Almon (1). (INFORUM is not a component of the MRMI model, but rather is an independent model that has been used in a variety of applications, including the application described here.)

The basis of the Harris model is a set of forecasting equations that explain industrial location choices by the relative prices that industry faces at different locations. These prices include land, labor, and capital costs and the transportation costs that are incurred in shipping the raw and finished goods into and out of the region.

Through the use of a transportation-cost linear-programming algorithm for each of 71 commodity industries, transportation-rate data are converted to marginal transportation costs, which are the costs of transporting a marginal unit of a commodity either into or out of a region. These marginal transportation costs vary considerably by region.

Transportation-rate data include national and regional data on shipments by size, weight, type of goods, distance, and mode of transportation and use Interstate Commerce Commission formulas that consist of line-haul costs and terminal costs. The transportation rate of shipping a good between two regions is calculated according to the minimum cost by mode of transport, for each weight class, aggregated over all weight classifications.

The regional highway-congestion index, the third major component of the Harris model, is an index that measures the amount of traffic congestion on principal roads within each region. It was computed for each of the 173 Bureau of Economic Analysis (BEA) economic areas from Federal Highway Administration data for urbanized areas (aggregated or adjusted to the BEA areas) on vehicle distances traveled, lengths of freeways and arterials, and capacity of freeways and arterials.

INFORUM, which is a national input-output model, makes forecasts of the final-demand spending (consumer expenditures, investment, governmental expenditures, and exports minus imports) of the national economy for each year and generates a set of national output levels for each industry that is consistent with the final demand. Historical trends of technological changes and expected rates of adoption of new technologies are incorporated into its forecasts.

The Harris model makes regional economic forecasts under alternative transportation assumptions, such as changes in the transportation system, with the regional forecasts controlled to sum to the INFORUM national forecasts, which ensures consistent and reasonable regional forecasts. The Harris model forecasts regional shares and then applies the national values to obtain the regional values. In different applications, the regions used have been either individual counties or the BEA economic areas, which are multicounty areas considerably larger than metropolitan areas.

Improvements in highways or other transportation systems affect the cost of shipping goods between regions and thus have an effect on the marginal transportation costs or shadow prices. For example, if construction or the improvement of a highway results in a reduction in truck travel time between two regions, then the total transportation costs between the two regions will be reduced. These changes in marginal transportation costs have an important influence on industrial location decisions. In addition, highway improvements affect industrial location by reducing congestion within a region and by construction spending, which stimulates employment and income during the construction period.

For each of the 173 economic areas, the model makes year-by-year (from 1970 to 1990) forecasts of output, earnings, personal consumer expenditures, exports, and imports for each industrial sector; equipment purchases for each equipment-purchasing sector; construction expenditures for each construction sector; and government spending for each government sector. Figure 1 (2) shows how each year's forecasts are developed from the previous year's forecasts.

To test the accuracy of the model, forecasts for 1966 to 1970 were made, and the 1970 forecasts were compared with the actual 1970 regional data by using regression equations. Forecast accuracy was very high for total population, total employment, and total personal income. For employment, it was high in 83 of the 103 industrial and labor sectors, fair in 19, and poor in 1 (agriculture, which depends upon many noneconomic factors).

Polenske Model

The MRIO model requires three component sets of data for implementation as indicated in Table 1—base-year input-output tables for each state or region, interregional trade-flow tables for each commodity, and final demands for each state or region—and uses these data sets to make forecasts of interregional trade and interindustry outputs for future years. The model has three versions—column coefficient, row coefficient, and gravity coefficient. The column-coefficient version has been developed in the greatest depth and is used most often in implementation; thus it will be the only version described here. It can be implemented with differing degrees of aggregation. The most disaggregated version, which is discussed here,

uses the 50 states plus the District of Columbia and 80 industries. For any level of aggregation, the process of implementation is similar.

The first component is a set of input-output tables for each state, which is prepared from base-year (1963) data by using state and national sources (3, 4). These tables show, for each state, all the interindustry purchases and final-demand purchases (by private and public consumers) made in that state in 1963. An example of such a table is given in Figure 2a [modified from Polenske's figure (5)], in which the entry in the motor-vehicles row under the machine-shop-products column shows the total purchases of motor vehicles by the machine-shop-products industry in Michigan in 1963. The sum of each industry column in that diagram shows the total production of that industry in Michigan, and the sum of each industry row shows the total consumption of the output of that industry in Michigan regardless of where that output was produced.

To show the interstate trade that accounts for where the output was produced, the second component of the model—interregional trade flows for each commodity—was developed. Interregional trade-flow tables for the base year 1963 were prepared for each industrial commodity. For example, in Figure 2b, the trade-flow table for motor vehicles shows the amount of motor vehicles shipped into and out of each state in 1963, which equals the column sum in the input-output table in Figure 2a. Trade-flow tables were prepared by using state and national data sources, with checking and adjustments to ensure a set of consistent data.

The third component for implementation—a set of final demands for each state—was prepared for the base year 1963 and projected for the forecast years 1970 and 1980 (3, 4). Final demand includes consumer expenditures, private investment, governmental expenditures, and net foreign exports. By using national and state data, each category of final demand was estimated for each state for the base year 1963 and for the forecast years 1970 and 1980.

Table 1. Basic characteristics of models.

Characteristic	MRMI (Harris) Model	MRIO (Polenske) Model
No. of regions	173 BEA economic areas; can also analyze counties and standard metropolitan statistical areas	51 (50 states plus District of Columbia); can also analyze census divisions
No. of sectors	216 (99 industrial, 28 construction, 8 governmental, 69 equipment-purchasing, 2 extra import, 6 population, and 4 extra labor)	86 (80 industrial and 6 final demand)
Years	1965-1966 and 1970 (base); 1970 to 1990 (forecast); to be updated to 1972 base	1963 (base); 1970 and 1980 (forecast); to be updated to 1972 base
Components	Set of forecasting equations; transportation-cost linear-programming algorithm; regional highway-congestion index; national forecasts from INFORUM	1963 base-year input-output tables for each state; interregional trade-flow tables for each commodity that is shipped; set of final demands, such as consumption, investment, and government expenditures for each state for each year to be forecast

Figure 1. Development of year-by-year forecasts in multiregional multiindustry forecasting model.

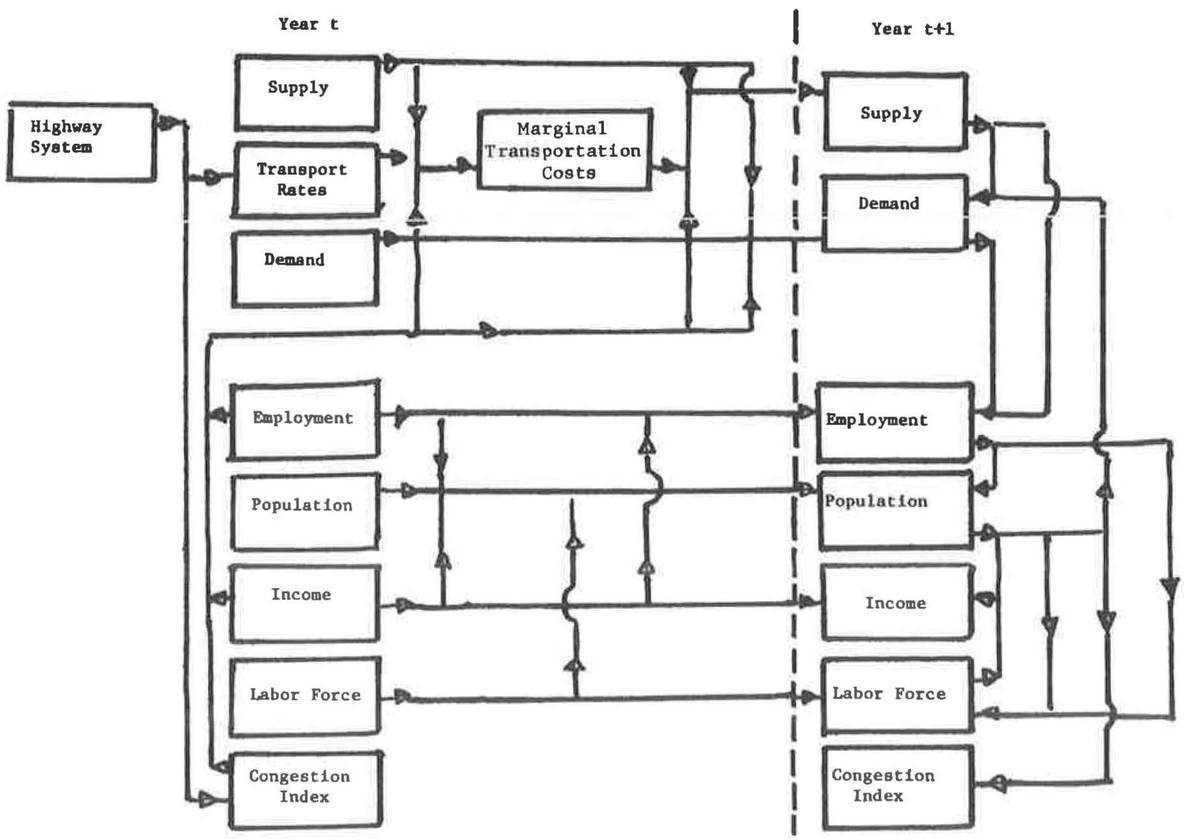
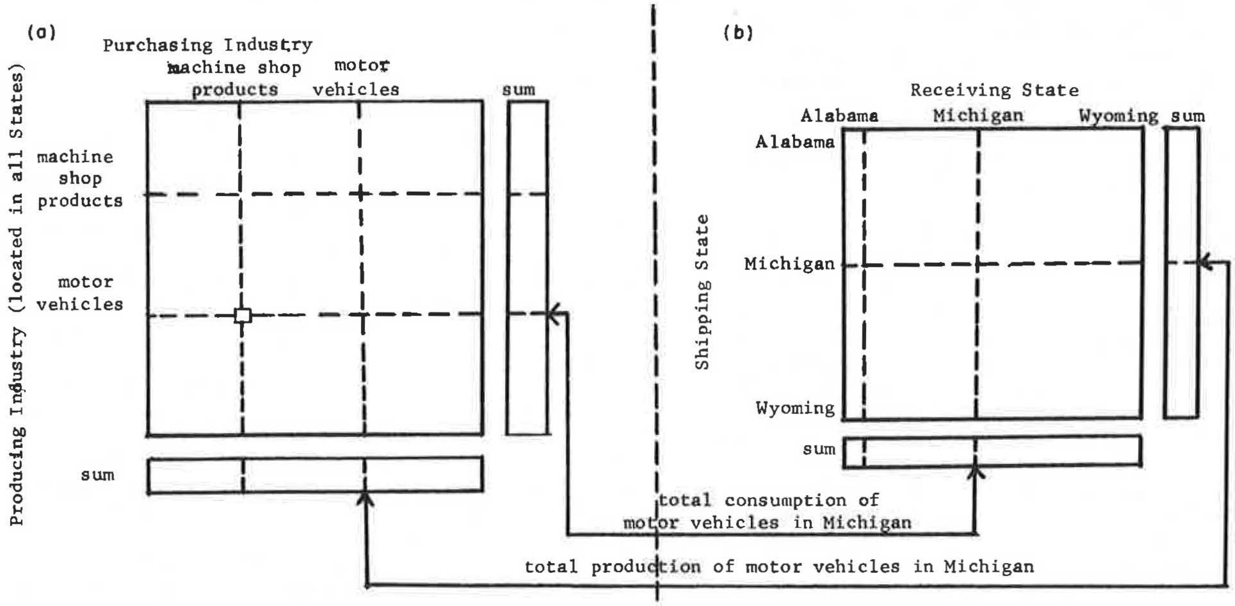


Figure 2. Relation between interregional trade flows and regional input-output table in the multiregional input-output model.



After assembly of the three components, the Polenske model uses computerized input-output techniques of matrix transformation and successive iterations to forecast interindustry purchases and interregional trade flows for the years 1970 and 1980. These forecasts show the levels of output of each industry in each state and the shipments of each commodity from state to state that would be generated by the levels of final demand that are projected for 1970 and 1980.

This information is useful to transportation planners and others because it can be used to analyze the changes in state outputs and trade between base and forecast years and provides an analytical framework for analyzing other changes. For example, in making decisions about highway and other transportation investments, it is important to predict the demands that will be placed on the proposed transportation system. Forecasts of industrial outputs and commodity shipments between states are an important element in predicting such demands and can also be used to analyze projected income and employment changes. However, because forecasts from the Polenske model are based on assumptions of unchanged technologies and structures of trade between states, it is more useful for short-run than for long-run analyses.

The accuracy of the model was tested by running it for 1947, 1958, and 1963 and comparing the resulting forecasts with actual data from those years. The results were very accurate for 1963 (the year on which it is based), moderately accurate for 1958, and less accurate for 1947. For example, forecast output for 1958 was within 10 percent of actual output in two-thirds of the sectors tested.

By modifying the model, for example, by updating or disaggregating the data in sectors that are of particular importance to transportation, planners can use the model to analyze the impacts of recent or projected changes in those sectors on other industries and commodity shipments.

USES

Both the MRMI and the MRIO models are currently being used to analyze regional economic activity by industrial sectors. A basic difference is that the major use of the Harris model is in forecasting regional economic and environmental impacts of alternative investments and programs, including highways and other transportation systems, whereas the Polenske model is used mainly for projecting the short-term effects of changes in interindustry purchases and trade between regions. The Harris model is designed for both short-run and long-run forecasting and for measuring the impacts of external changes in economic variables and can make economic forecasts at the county and functional-economic-area levels. The Polenske model provides a framework for describing and analyzing sales and purchases between industries in different regions and can be used to measure the short-run direct and indirect effects of changes in industrial purchases throughout the country.

Harris Model

Current Uses

1. The regional economic and environmental effects of hypothetical alternative U.S. highway systems were analyzed for the Federal Highway Administration (6). Six alternatives were studied—a base year system (if Interstate construction were stopped in 1970), a completed Interstate system (if construction were completed in 1976), an extended primary system, an economic-development system, an urban system, and a piggybacking (trailer-on-flatcar) system. These systems affect regional growth because improved highways lower transportation costs between regions and congestion within regions, and highway construction expenditures stimulate employment and income.

The model was also used to forecast 1990 regional resource and energy requirements for each alternative highway system. Data on national energy use, resource requirements, and pollutant emissions were converted to national coefficients for each industry (indicating the amount of energy used or pollutant emitted per unit of output), by using the INFORUM national input-output model (1). These coefficients were applied to the regional forecasts of industrial outputs to determine regional forecasts of energy use, resource use, and pollutant emissions for each alternative highway system.

The results of these applications showed that the

benefits of a completed Interstate system by population size of the areas were mixed; i.e., some high-population areas would benefit, but others would not; and some low-population areas would benefit, but others would not. Both low-income and small BEA areas would benefit by extended primary or economic-development systems, with relatively more areas benefiting from the economic-development system. An urban system would stimulate growth in the largest urban areas, but the percentage gains are not large.

Energy, resource, and pollution forecasts generally reflect the impacts of the alternative highway systems. For example, if a large urban area gains in output by the construction of an urban highway system, its energy use, resource use, and pollution levels also increase.

2. A Canadian version of the Harris model was developed for the Ministry of State of Urban Affairs (7). This application involves the analysis of the interregional, multi-industry structure of the Canadian economy and the development of a model that uses Canadian national and regional data. The resulting Canadian version can be used to evaluate alternative transportation investments in Canada.

3. The model was applied at the county and metropolitan-area levels to forecast the economic and population impacts of proposed highway or other transportation investments (7). For example, the effects of a proposed 32-km (20-mile) segment of Interstate 190 were forecast for Worcester County, Massachusetts. Forecasts from the model have also been used to provide control totals for county and metropolitan-area transportation-planning models. The control totals can be used with national technical coefficients (inputs per unit of output for each industry) to generate county-level, input-output tables for use in transportation and other regional planning.

4. The effects of possible cutbacks in natural gas supplies in different areas of the United States were analyzed at the county level (7). In Maryland, the Harris model was used to evaluate two alternative allocation formulas for the distribution of the anticipated reduction of natural gas to users and the regional economic impacts of these formulas. In Texas, Arizona, New Mexico, and California, the model was used to evaluate the impacts of possible reduced agricultural production because of the decreased supply of natural gas, which is used as the source of power for irrigation.

Studies Under Way

1. The model is being used to analyze the regional economic effects of changes in personal travel costs and expenditures by modifying the national input-output model and the multiregional forecasting model to forecast the regional effects of personal travel-related expenditures (8).

2. The Harris model is being used for national and regional-level transportation-policy analysis and as an input in the urban transportation planning process (8). It is also being extended to analyze the economic and environmental effects of alternative transportation policies at all regional levels (national, state, metropolitan area, and county) for all major modes (highway, rail, air, and water). An important part of the study will be to modify the INFORUM model to predict the growth effects on the gross national product that would result from alternative investment levels in various transportation modes.

3. The model is being used in a project sponsored by the Federal Highway Administration to analyze the economic impacts of alternate levels of national highway performance, i.e., conditions of highways (taking into account operating characteristics such as average speeds and traffic levels and necessary maintenance), to obtain information for use in planning national highway policies.

Polenske Model

Current Uses

1. The economic interaction between electricity, coal, and freight transportation created by changes in regional technologies for generating electricity and in the interregional shipments of coal was analyzed (9). The 1963 base-year table of technical coefficients was updated to include 1970 data on coal and electricity production and the 1963 trade-flow table was updated to include 1970 coal-shipment data. The model was then rerun to forecast the effects of these changes on production and interregional trade.

For example, the eastern states were forecast to have decreased input requirements for nearly all industries (not just those directly related to coal) and the mountain and Pacific states were forecast to have increased industrial requirements, when compared to the nonupdated version of the model. The updated results are generally more reliable because they include more recent changes in technology and trade. Similar updating can be done for other industries and for years later than 1970.

2. Trade in the California-Oregon-Washington region and differences in economic growth between this region (a fast-growing region) and the rest of the United States were analyzed (10). The results showed that from 1963 to 1970 the California-Oregon-Washington region was growing fastest in those industries that were also growing fastest nationally. Also, growth in final demand in the California-Oregon-Washington region helped to generate increased production in other regions to supply those demands. This type of study can serve as a basis for analyzing the role of transportation in interregional trade and can be extended to other regions.

3. The impacts of expenditures for the proposed Consolidated Rail Corporation (Conrail) on employment and income in the Conrail region and in the remainder of the United States were analyzed (11). The Conrail region includes the northeastern and middle Atlantic states, Virginia, West Virginia, and some Great Lakes states. The Polenske model was used to calculate three major indirect effects of Conrail expenditures—increased industrial outputs, induced spending, and induced investment. The results showed that the greatest amount of jobs and income would be generated in 1985, the final year of investment expenditures.

Studies Under Way

1. Changes in technology and trade flows and investments are being incorporated into the Polenske model to extend it into a dynamic framework; i.e., regional technical coefficients and interregional trade coefficients would be predicted to change over time, according to past trends, and the dynamic model would be used to make more realistic long-run forecasts (9).

2. The regional and industrial interrelationships between the transportation and energy sectors are being analyzed. This has been done already for coal, electricity, and freight transportation and can be extended to other sectors and other years by modifying the model to include regional pollution and energy-use data by source industry, including transportation-related industries. This modification will enable the model to analyze alternative energy and transportation policies in general (9).

3. The economics of the automobile industry in Michigan are being analyzed by the Michigan Department of Commerce.

MAJOR ASSUMPTIONS

Harris Model

The equations for forecasting output, employment, income, consumer expenditures, and other variables were fitted by using 1965-1966 cross-section data and partial 1970 data. For example, 1965-1966 and 1970 regional data on income, industrial output, and other factors were used to fit equations for each industry to predict its output in each region. As 1972-1973 data become available, the equations will be reestimated, and this reestimation will be used to update the coefficients of the equations. The equations have been used to make year-by-year forecasts from 1970 to 1990.

Firms attempt to maximize profits and minimize costs. This is a standard assumption of most econometric forecasting models.

The 1965-1966 data on demand by industry used in fitting the equations include direct county data on personal consumer expenditures, federal defense expenditures, and gross foreign exports (aggregated to BEA areas). But, for all other industrial-demand data (interindustry purchases by each industry, other federal purchases, and state and local government purchases), direct county data were not available, and so national technical coefficients (inputs per unit of output calculated from national data) were applied to county totals (12).

Firms attempt to minimize transportation costs. Except for rate differentials, firms are indifferent to the mode of transportation used in shipping goods.

By using a linear-programming method of computation, national and regional transportation data (shipments by size, weight, type of goods, distance, and mode of transportation) are converted to marginal transportation costs for each industry in each region. Truck and rail are the only modes considered because it is assumed that industry location will be influenced primarily by the availability of those two modes.

Linear programming is the framework for the calculation of the marginal transportation costs associated with a given level of shipments out of and into a region, which are important factors influencing industrial location and thus are important in the Harris model.

Polenske Model

The trade-flow table, which indicates interregional shipments of goods, and the table of interindustry technology, which indicates amounts of inputs per unit of output of each industry, are constructed by using 1963 data. As 1972 data become available, these tables will be reestimated to reflect the 1972 structure of trade and technology. The 1963 structure of trade and technology has been used to make predictions (assuming different levels of final demand) of 1970 and 1980 levels of output in each industry in each region and of interindustry trade flows between regions. However, neither the structure of trade between regions nor the structure of technology is generally stable over time, and thus long-run forecosts of trade flows are generally not very reliable. More work on trade-flow forecasts is necessary, and as new data become available, the model can be modified to allow prediction of changes in technology and trade structures over time.

The column-coefficient version of the Polenske model, which is the version discussed here, assumes that, for each region, the fraction of total consumption of a good in that region that is important from another region is the same for each industry in the consuming region. For example, if 10 percent of the steel used in Michigan is imported from Indiana, then this percentage is assumed to be the same for every industry in Michigan that uses steel. This is equivalent to holding each supplier's share in each region's consumption constant over time. As a result, the net transfer (outflow minus inflow) out of a region may be progressively overestimated (or underestimated) in each time period following the base year, if production and outflow are growing (or declining), but the percentage of a region's consumption of a good coming from each remaining region is held constant (13).

The regional trade data used in constructing the interregional trade-flow table include the value of crosshauls (shipments of the same good in opposite directions, e.g., the value of oranges grown in California and shipped to Florida and the value of oranges grown in Florida and shipped to California). Crosshauls are somewhat important because aggregation of several commodities into a single commodity class can obscure the differences in the composition of traded commodities. For example, if crosshauls of oranges and other fruit between Florida and California were not counted in the trade-flow table, but rather only the net transfer of fruit from one state to the other were counted, then important data on trade patterns would be obscured (13).

STRENGTHS AND LIMITATIONS

Harris Model

Regional supply and demand are interrelated because of the use of forecasting equations, which allows changes in the location of output and resources to take place between regions. This avoids the problem of many input-output models in which the use of predetermined levels of final demand does not permit the production of goods in a region to influence demand (14).

The model is deliberately designed to predict industrial changes over time. Changes in technological relations are also included by using the INFORUM model to generate national totals, which incorporates estimates of technological changes into its technical coefficients.

Transportation information including costs and the effects of alternative systems (at present only highway systems are included, but the model can be generalized to other modes) is developed in considerable detail, and thus the model is capable of evaluating the regional effects of alternative highway (and later, other modal) systems.

Forecasts are generated from equations that were fitted by using 1965-1966 and partial 1970 data. Forecasts of the industrial output of regions that had unusually good or bad production in 1965-1966 will be over or underestimated relative to other regions. (However, updating of the model to a 1972 data base is planned.)

The model forecasts the distribution of highway benefits between regions, but has not been used to forecast total national net benefits of alternative highway systems.

Polenske Model

The data base of the model is comprehensive as a result of extensive data gathering and analysis. Interregional trade-flow data include trade between regions in both directions (crosshauls) rather than only net transfers (9).

The regional input-output and trade-flow data are internally consistent with each other and with the Department of Commerce national input-output model and the Bureau of Labor Statistics final-demand projections. Thus the results of the model can be linked to subregional and subindustry studies and to national input-output studies that use Department of Commerce or Bureau of Labor Statistics data.

Regional supply and demand are not interrelated; they are estimated in separate steps. First, future levels of final demand are estimated, and then fixed technical coefficients (inputs per unit of output, estimated from base-year data and assumed unchanged) are applied to obtain output levels (supply) for each industry.

The model, as currently developed, does not allow trade coefficients, which indicate flows of goods into and out of each region, or technical coefficients to change over time, and thus is not generally reliable in providing long-range forecasts.

There is no explicit development of transportation costs or the effects of alternative transportation systems; the only transportation data are the interregional trade flows, which do not include data by cost of transportation.

CONCLUSIONS

This report has described and compared two multiregional economic-forecasting models to examine their usefulness in transportation planning. The Harris model is an econometric model that is designed for short-run and long-run forecasting of regional economic and population impacts of alternative transportation and other investments. It has been used to make year-by-year forecasts to 1990. It uses a set of forecasting equations that explain industrial location on the basis of the costs (including transportation costs) that firms face at alternative locations. The Polenske model is an input-output model that is designed for projecting interindustry purchases and trade between regions for selected years by constructing and using multiregional input-output tables. It is useful in forecasting short-run impacts of changes in trade patterns and industrial production.

An important question for transportation planners and policymakers is whether these multiregional forecasting models can be used at the state level, or with state-level (15, 16) and metropolitan models that have been developed.

The Harris model has been applied at the county and metropolitan-area levels to develop forecasts that can be used as control totals for country and metropolitan planning models. In a study to be conducted for the Federal Highway Administration, outputs of the Harris model will be extended to the level of detail commonly used as transportation-planning inputs in land-use models and trip-generation analysis; e.g., employment by categories and population by households. Also, outputs at the regional and county levels from the Harris model can be used with national technical coefficients to generate county-level input-output tables for use in regional transportation planning.

The Polenske model can be used at the state level by using its state input-output tables in statewide economic planning and forecasting. Thus, a state could use the Polenske model either as its principal planning model or in conjunction with other state or substate models. For example, the state of Michigan is using the Polenske model to study the economics of the automobile industry, which is an important component of the Michigan economy.

Both the Harris and Polenske models have several uses in transportation and other related areas and thus are practical and important methods of economic analysis. Both models are examples of the growing usefulness of large-scale economic modeling in the transportation planning and policymaking process at the national, state, and regional levels.

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