THE NORTH DAKOTA INPUT-OUTPUT MODEL: A TOOL FOR MEASURING ECONOMIC LINKAGES

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The North Dakota economy has historically been based primarily on agriculture. Crop production is still its largest single component, although the state's economic base is becoming more diversified. (See "Changing Composition of North Dakota's Economic Base" in this issue for a more detailed discussion of trends in North Dakota's economic base during the past 25 years.) With increasing economic diversification has come a growing interest in estimating the effect of changes in one component (or sector) of the state's economy on the level of sales, employment, and income in other sectors. For instance, the effect of increased crop receipts on retail sales, personal income, and tax revenues is a question of considerable interest to many of the state's decision makers.

The first technique used to address such questions was economic base (or export base) analysis. More recently, an alternative method called input-output analysis has come into widespread use for analyzing economic change and developing economic projections for the state and its substate regions. The basic logic of these two methods is quite similar, but input-output analysis provides more detail about the structure of an economy and the impacts associated with changes in its economic base.

Economic Base Analysis

Economic base analysis involves the ratio of derivative employment to basic employment. Basic employment is employment in those industries that comprise the economic base and consists of such industries as agriculture, mining, and manufacturing. Derivative (or residentiary) industries are those whose existence derives from the fact that basic industries are present in the economy. Derivative industries exist to provide trade and service (as well as local government) functions for the basic industries in the economy.

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The basic assumption of economic base analysis is that derivative employment is some constant multiple of basic employment. Although this multiple depends on the structure of the particular economy, this ratio is often in the neighborhood of 1.5 to 1 (meaning that each job in a basic industry generates about 1.5 jobs elsewhere in the economy so that total employment in the economy is about 2.5 times the employment in the basic sectors). Annual data on employment in each industry are available at the county level so that calculation of derivative to basic employment ratios at the county, sub-state region, or state level is an easy task.

Economic base analysis can be used to estimate employment changes that occur in an economy as a consequence of historical trends in basic employment or because of changes in the economic base (either the entry or exit of basic industries). The only critical assumption for the analysis is that the ratio of derivative to basic employment remains relatively constant.

Input-Output Analysis

Input-output analysis can be used to describe the state's economy (or that of its sub-state regions) or to evaluate the economic impacts of changes in the structure of that economy (such as growth or decline of some of its industries). Initially, input-output analysis in North Dakota was designed to estimate the economic impacts of irrigation development associated with the Garrison Diversion Project. The technique has been used extensively to estimate the economic impacts of new plants for agricultural processing and other kinds of manufacturing, changes in the level of agricultural output, and recreation development. It also has been used for state tax revenue projections and, since 1975, has been used extensively as a part of a model to estimate the economic impacts of North Dakota's energy development.

The logic of input-output analysis is simple. The economy (national, state, or a sub-state region) is divided into sectors, or industrial groupings that consist of firms engaged in the same general type of economic activity. Examples of these sectors include: crop production, retail trade, firms engaged in finance, insurance, and real estate, etc. (See Table 1 for a listing of sectors in the North Dakota input-output model.)

Computations are based on the dollar volume of trade that each sector has with every other sector of the economy and with the rest of the world (rather than on employment ratios as in economic base analysis). Input-output analysis consists of three basic tables: the transactions table, the technical intput-output coefficients (or direct requirements) table, and the interdependence coefficients table. The interdependence coefficients table is often called the multiplier table because it indicates the total (direct, indirect, and induced) requirements per dollar of output for final demand. Final demand in an export-based economy, such as North Dakota, is output exported from the state.

The interdependence coefficients table is derived from the other two tables. (For a description of the way in which the interdependence table is derived see Miernyk, 1965, and Hertsgaard et al., 1984.) The interdependence coefficients table for North Dakota is presented in Table 1.

Each number in the interdependence coefficients table indicates the total output that is required by the row sector per dollar of output for export from North Dakota by the column sector. For example, Table 1 indicates that each dollar of livestock production for export from the state will generate a gross income in the livestock sector of $1.21 (the $1.00 of livestock production for export from the state plus $0.21 of output by the livestock sector for replacement of breeding stock as well as for the livestock products that are produced within the state and consumed by anyone in the state who is involved, directly or indirectly, in the production of livestock for export from the state). Similarly, each dollar of livestock production will generate a gross income of $0.39 to the crops producing sector, $0.57 to the agricultural processing and miscellaneous manufacturing sector, $0.71 to the retail trade sector, $1.05 to the household sector (including any profits of the livestock producer but consisting mostly of personal income in the form of wages and salaries, rents, and profits of others in the state who are involved, directly or indirectly, in the production of livestock), and a total gross income of all sectors in the state of $4.49. Thus, each dollar of income received from the export of livestock from the state "turns over" about four and a half times within the state. Likewise, it can be said that each dollar of income from the export of crops from North Dakota "turns over" about 3.7 times in the state or that the crops "multiplier" is 3.7.

Table 1. Input-Output Interdependence Coefficients for North Dakota.

Sector	(1) Ag, Lvstk	(2) Ag, Crops	(3) Nonmetallic Mining	(4) Const	(4) Trans	(6) Comm & Pub Util	(7) Ag Proc & Misc Mfg	(8) Retail Trade	(9) FIRE
(1) Ag, Livestock	1.21	0.08	0.04	0.03	0.05	0.04	0.19	0.09	0.06
(2) Ag, Crops	0.39	1.09	0.02	0.01	0.02	0.02	0.65	0.03	0.04
(3) Nonmetallic Mining	0.01	0.01	1.04	0.03	0.01	0.00	0.01	0.00	0.00
(4) Construction	0.07	0.08	0.05	1.05	0.05	0.07	0.06	0.03	0.07
(5) Transportation	0.02	0.01	0.03	0.01	1.01	0.01	0.01	0.01	0.01
(6) Comm & Public Util	0.09	0.08	0.16	0 06	0.08	1.10	0.08	0.05	0.13
(7) Ag Proc & Misc Mfg	0.57	0.16	0.03	0.02	0.03	0.02	1.74	0.05	0.07
(8) Retail Trade	0.71	0.81	0.52	0.41	0.55	0.43	0.61	1.27	0.68
(9) Fin, Ins, Real Estate	0.15	0.17	0.11	0.08	0.12	0.11	0.13	0.06	1.14
(10) Bus & Pers Services	0.06	0.07	0.04	0.03	0.05	0.04	0.05	0.02	0.08
(11) Prof & Soc Services	0.07	0.06	0.06	0.04	0.05	0.05	0.05	0.03	0.08
(12) Households	1.05	0.96	0.84	0.61	0.79	0.80	0.79	0.40	1.20
(13) Government	0.10	0.10	0.09	0.05	0.26	0.10	0.08	0.04	0.11
(14) Coal Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(15) Thermal-Elec Generation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(16) Pet Exp/Ext	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(17) Pet Refining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gross Receipts Multiplier	4.49	3.69	3.03	2.44	3.05	2.79	4.45	2.09	3.68

Sector	(10) Bus & Pers Service	(11) Prof & Soc Service	(12) Households	(13) Govt	(14) Coal Mining	(15) Thermal-Elec Generation	(16) Pet Exp/Ext	(17) Pet Refining
(1) Ag, Livestock	0.04	0.06	0.07	0.00	0.04	0.03	0.02	0.00
(2) Ag, Crops	0.02	0.02	0.03	0.00	0.03	0.03	0.01	0.00
(3) Nonmetallic Mining	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
(4) Construction	0.05	0.08	0.09	0.00	0.05	0.03	0.11	0.02
(5) Transportation	0.01	0.01	0.01	0.00	0.01	0.00	0.02	0.01
(6) Comm & Publ Util	0.11	0.12	0.11	0.00	0.07	0.04	0.05	0.01
(7) Ag Proc & Misc Mfg	0.02	0.04	0.04	0.00	0.06	0.08	0.01	0.00
(8) Retail Trade	0.45	0.67	0.74	0.00	0.40	0.23	0.18	0.05
(9) Fin, Ins, Real Estate	0.11	0.14	0.17	0.00	0.08	0.10	0.04	0.01
(10) Bus & Pers Services	1.05	0.05	0.06	0.00	0.03	0.02	0.01	0.00
(11) Prof & Soc Services	0.05	1.10	0.10	0.00	0.05	0.03	0.02	0.01
(12) Households	0.72	1.04	1.55	0.00	0.66	0.40	0.32	0.08
(13) Government	0.08	0.09	0.11	1.00	0.05	0.04	0.03	0.01
(14) Coal Mining	0.00	0.00	0.00	0.00	1.00	0.16	0.00	0.00
(15) Thermal-Elec Generation	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
(16) Pet Exp/Ext	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10
(17) Pet Refining	0.00	0.00	0.00	0.00	0.02	0.01	0.00	1.00
Gross Receipts Multiplier	2.71	3.42	3.08	1.00	2.55	2.19	1.92	1.29

The multiplier effect results when each producing sector buys some fraction of its inputs from other sectors of the state's economy and these sectors, in turn, use some fraction of that income to buy some of their inputs from still other sectors, and so on. In other words, the multiplier effect is due to the spending and respending within the state's economy of part of each dollar that enters the state through payment for products that are exported from the state. The multipliers for livestock products (4.49) and crops (3.69) do not imply that these products cost that amount to produce. (Each dollar of output costs $1.00 to produce, where any profit is part of the cost.) It simply means that the dollar that was received from the export of livestock was spent an additional 3.49 times (making a total of $4.49 of income to all sectors in the state) before the dollar leaves the state and the dollar received from the export of crops is spent another 2.69 times by others (for a total income of all sectors of $3.69).

Examination of the gross receipts multipliers in Table 1 reveals substantial differences in these values among the different sectors. These differences in multiplier values arise in large measure from variation in the extent to which the respective sectors purchase their inputs from in-state suppliers (versus buying them from entities located outside the state). The substantial differences in multiplier values also suggest that one of the major strengths of input-output in analyzing economic change in an increasingly diversified economy is the capability of input-output to account for such differences. That is, an analysis using input-output methods will reflect differences in the magnitude of multiplier effects among sectors whereas the economic base technique assumes that an initial increase in basic employment has the same effect regardless of the basic industry (e.g., agriculture versus mineral extraction) in which it occurs.

Uses of Input-Output Analysis in North Dakota

Input-output analysis is a technique that is quite easy to use to estimate the economic impacts of new income injections into the economy. A common use of input-output analysis is to assess the effect of a new manufacturing or processing plant in the state. In such a case there will be a one-time impact on the state's economy that results from the construction of the facility. There also will be annually recurring impacts associated with the operation of the plant after the plant is completed and production begins.

Information needed to estimate the economic impacts of a new plant in the state is the set of expenditures that will be injected into the respective sectors of the state's economy during the construction and the operation phases of the plant. These expenditures are multiplied by the interdependence coefficients of the appropriate columns of Table 1 to provide gross income change estimates of the respective sectors in the state that are attributable to the construction and operation of the new plant. Typically, new income is injected into the state during the construction phase through three sectors: the contract construction sector (expenditures to firms in the construction industry), the retail trade sector (expenditures for materials purchased within the state), and the household sector (payrolls of employees not already included as part of the expenditures to the contract construction sector). New income is injected into the state's economy during the operating phase of the new plant via two sectors: the retail trade sector (for materials purchased from other firms in the state each year) and the household sector (the new plant's payroll after operation begins).

A number of studies in North Dakota have employed input-output analysis to estimate the economic impacts of various types of developments. The topics addressed in these studies include the economic impacts of irrigation development in North Dakota (Leitch and Anderson, 1978; Schaffner and Carkner, 1975), the economic effects of added growing season rainfall (Schaffner et al., 1983), feasibility of agricultural processing plants in the state (Mittleider, Anderson, and McDonald, 1978; Anderson and Fraase, 1970), rural industrialization (Helgeson and Zink, 1973), recreation development (Helgeson and Holte, 1978), and energy development in North Dakota (Leistritz and Hertsgaard, 1979; Coon, Mittleider, and Leistritz, 1983). In all of these studies, input-output analysis has been used to estimate the additional gross business volume (gross receipts) received by each sector of the state's economy as a result of the initial development activity. In addition, several of these studies have utilized extensions of the basic input-output method to estimate additional employment in each sector and additional state tax revenues likely to result from the increased economic activity (for example, see Coon, Mittleider, and Leistritz, 1983).

The input-output model also has been incorporated as one module of a large economic-demographic assessment model for simulating the North Dakota economy (Leistritz et al., 1982). In this model, the input-output interdependence coefficients are applied to forecasts of future sales to final demand (exports) for each relevant sector to develop estimates of gross business volume for all sectors of a given substate region. The projected levels of gross business volume then are used to estimate employment in each sector. These employment levels then provide a basis for estimating the extent of net in- or out-migration and hence the likely extent of population growth or decline in the region. Input-output analysis serves as the driving mechanism of this comprehensive socioeconomic assessment model.

Accuracy of the Results of the Model

The validity of the results generated by an input-output model depends on how accurately the multipliers indicate the income generated in the economy by income injections in one or more of its sectors. Accuracy of the multipliers, in turn, depends on the accuracy of the technical coefficients (direct requirements) table.

There are two principal reasons why the technical coefficients may change over time. One is a change in

production technology in any sector, such as the shift from horses to tractors in farming. The other is a change in the relative prices of inputs required by the respective producing sectors.

The accuracy of the model has been tested by comparing the personal income estimates of the Department of Commerce with those obtained from the input-output model. Comparison of the two sets of estimates for the years 1959-1962, and 1965-1981 indicates that the average difference for those years was 5.25 percent. This is a remarkably high degree of correspondence between the two sets of estimates, given the highly variable nature of economic data.

Summary

The North Dakota input-output model is a useful and accurate tool for describing the economic linkages and interrelationships of North Dakota's economy. This model has been used to determine the effects of a wide variety of industrial and agricultural developments in North Dakota. Analyzing the impacts from these developments using input-output analysis has proven to be accurate and beneficial to both private industry and government personnel. The value of having economic information, such as that provided by input-output analysis, has become more apparent with the much larger developments in recent years (e.g., the coal gasification plant in Western North Dakota). The better the economic impact assessment information available to policymakers, the more effectively the impacts associated with a development can be managed.

REFERENCES

Anderson, D.E., and R.G. Fraase. 1970. **An Analysis of the Feasibility of Establishing Malt Plants in North Dakota.** Bulletin No. 487, Fargo: North Dakota Ag. Exp. Sta.

Coon, R.C., J.F. Mittleider, and F.L. Leistritz. 1983. **Economic Analysis of the North Dakota Lignite Industry.** Ag. Econ. Misc. Rpt. No. 67. Fargo: North Dakota State University.

Helgeson, D.L., and G.J. Holte. 1978. **A Socioeconomic Impact Analysis of Recreation at Lake Metigoshe, North Dakota.** Ag. Econ. Rpt. No. 93. Fargo: North Dakota State University.

Helgeson, D.L., and M.J. Zink. 1973. **A Case Study of Rural Industrialization in Jamestown, North Dakota.** Ag. Econ. Rpt. No. 95. Fargo: North Dakota State University.

Hertsgaard, T.A., A.G. Leholm, R.C. Coon, and F.L. Leistritz. 1984. **The North Dakota Input-Output Model: A Tool for Analyzing Economic Linkages.** Ag. Econ. Rpt. No. 187. Fargo: North Dakota State University.

Leistritz, F.L., and T.A. Hertsgaard (ed.). 1979. **Environmental, Economic, and Social Impacts of a Coal Gasification Plant in Western North Dakota.** Bulletin No. 509. Fargo: North Dakota Ag. Exp. Sta.

Leistritz, F.L., W. Ransom-Nelson, R.W. Rathge, R.C. Coon, R.A. Chase, T.A. Hertsgaard, S.H. Murdock, N.E. Toman, R. Sharma, and P.S. Yang. 1982. **North Dakota Economic-Demographic Assessment Model (NEDAM): Technical Description.** Ag. Econ. Rpt. No. 158. Fargo: North Dakota State University.

Leitch, J.A., and D.E. Anderson. 1978. **Impact of Inundation and Changes in Garrison Diversion Project Plans on the North Dakota Economy.** Ag. Econ. Rpt. No. 127. Fargo: North Dakota State University.

Miernyk, W.H. 1965. **Elements of Input-Output Economics.** New York: Random House.

Mittleider, J.F., D.E. Anderson, and C.E. McDonald. 1978. **An Analysis of the Economic Feasibility of Establishing Gluten Processing Plants in North Dakota.** Bulletin No. 508. Fargo: North Dakota Ag. Exp. Sta.

Schaffner, L.W., and R.W. Carkner. 1975. **Irrigation and Its Effect on the Community.** Ag. Econ. Rpt. No. 103. Fargo: North Dakota State University.

Schaffner, et al., 1983. **Economic Effects of Added Growing Season Rainfall in North Dakota.** Ag. Econ. Misc. Rpt. No. 69. Fargo: North Dakota State University.