FINAL REPORT

Volume 1: Model Revision and Simulation

THE OAP REGIONAL ECONOMETRIC MODEL: A REVISED VERSION

Prepared for:

Environmental Protection Agency
Office of Air Programs
Research Triangle Park
North Carolina

September 25, 1972

CONSAD Research Corporation

FINAL REPORT

CONTRACT NUMBER 68-04-0039

VOLUME 1: MODEL REVISION
AND SIMULATION

THE OAP REGIONAL ECONOMETRIC MODEL: THE REVISED VERSION

Prepared for:

Environmental Protection Agency
Office of Air Programs
Research Triangle Park, North Carolina

Prepared by:

CONSAD Research Corporation
121 North Highland Avenue
Pittsburgh, Pennsylvania 15206

T. R. Lakshmanan, Fu-chen Lo, Krishna Moorthi

September 25, 1972

ACKNOWLEDGEMENT

The research reported here was carried out by CONSAD Research Corporation under the direction of Dr. T. R. Lakshmanan. Dr. Fu-chen Lo was the principal investigator of the effort. S. Krishna Moorthi carried out the validation experiments on the revised model. Rajan Vaswani participated in the preparation of the Philadelphia case study. Professor P. J. Dhrymes of the University of Pennsylvania provided valuable assistance as a consultant.

In the preparation of this report, CONSAD has relied heavily on the advice and guidance of Allen Basala, the project officer. Other EPA staff members who provided valuable guidance during the various phases of the project are Dr. Joel Horowitz, Dr. Mike Lerner, John O'Connor, Ron Campbell and Warren Freas. To all of these individuals, grateful acknowledgement is made.

Any opinions expressed in this report are those of CONSAD and do not necessarily reflect the views of the individuals cited above.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION AND SUMMARY

CONSAD has developed an operational, policy-oriented regional economic model, termed the OAP Regional Econometric Model, to describe the economic system-wide effects of specific air pollution strategies in 91 metropolitan areas of the United States. This model has been utilized in two separate efforts.

The first was a simple demonstration of the model's operationality by simulating the effects of strategies that imply different levels of cost sharing by the government.* The second case of utilization was concerned with the simulation over time of more realistic strategies that reflect the standards promulgated as a result of the Clean Air Amendments of 1970.** The performance of the model as evident from these utilization experiments, while encouraging, suggested the need for further refinement of the model. This refinement took the form of improved model specification and the reestimation of the greater part of the model with better data.

The respecification of the model encompassed the following: In the manufacturing block of the OAP Model, a set of new investment

---

*CONSAD Research Corporation, An Economic Model System for the Assessment of Effects of Air Pollution Abatement, prepared for the Environmental Protection Agency, May 15, 1971.

**CONSAD Research Corporation, The OAP Regional Economic Model Utilization, Phase I, prepared for the Environmental Protection Agency, January 7, 1972.

functions with lag distributions and a set of production functions with technological change were specified. In the regional income block, the public sector equations were disaggregated to identify different local government sector tax equations.

This respecified model was then estimated with cross-sections of time-series data. The manufacturing sector equations were estimated by the data for the years 1958 through 1967. This increased the sample size and improved the statistical results of the model. The reformulated model was validated by a broad range of tests and has been used to simulate the regional economic effects of alternate strategies of implementation of air pollution abatement.

Chapter 2 gives a brief review of the history of model development and previous experience with the utilization of the model. Chapter 3 deals with both the conceptual formulation and statistical estimation of the revised model. In Chapter 4 a simulation analysis with the revised model is presented. Both aggregate impacts and regional patterns of incidence of economic effects are analyzed. The next chapter presents a validation of the revised model. In this chapter, a series of statistical tests including t-tests, regression tests, distribution of the estimates in the ranges of standard errors, and non-parametric tests are presented.

Finally, in Chapter 6, a case study of economic-environmental interaction in the Philadelphia Air Quality Control Region (AQCR) is demonstrated. This is an attempt to integrate and utilize some existing modelling efforts such as the Direct Cost of Implementation Model (DCIM), the property value damage functions and the OAP Regional Econometric Model. These modelling efforts describe the changes of air quality, property damage and the corresponding regional economic impacts upon the implementation of a given ambient air quality standard.

2.0 THE OAP REGIONAL MODEL: DEVELOPMENT, UTILIZATION AND REFORMULATION

Over the last three years, CONSAD Research Corporation has developed and demonstrated an operational Regional Economic Model for the assessment of the effects of air pollution abatement. This chapter is addressed to a review of:

- The context of development of the model,
- A brief review of the development history and scope of the model,
- The utilization experiments on the model, and
- The nature of the reformulation of the model suggested by the experience in the policy analyses with the model.

2.1 The Regional Economic Model and the RAPA Program

In July, 1968, the predecessor agency to the Office of Air Programs, Environmental Protection Agency (EPA), initiated a systems analysis of regional air pollution control. It was clear, at the outset, that this study's contribution to the pollution problem's solution would be in the integration of contemporary air pollution control developments into a workable analytical tool, rather than in fundamental research areas. With this in mind, a tool was developed -- Regional

Air Pollution Analysis (RAPA) -- to demonstrate the usefulness of looking at the many facets of the air pollution problem in an integrated manner.

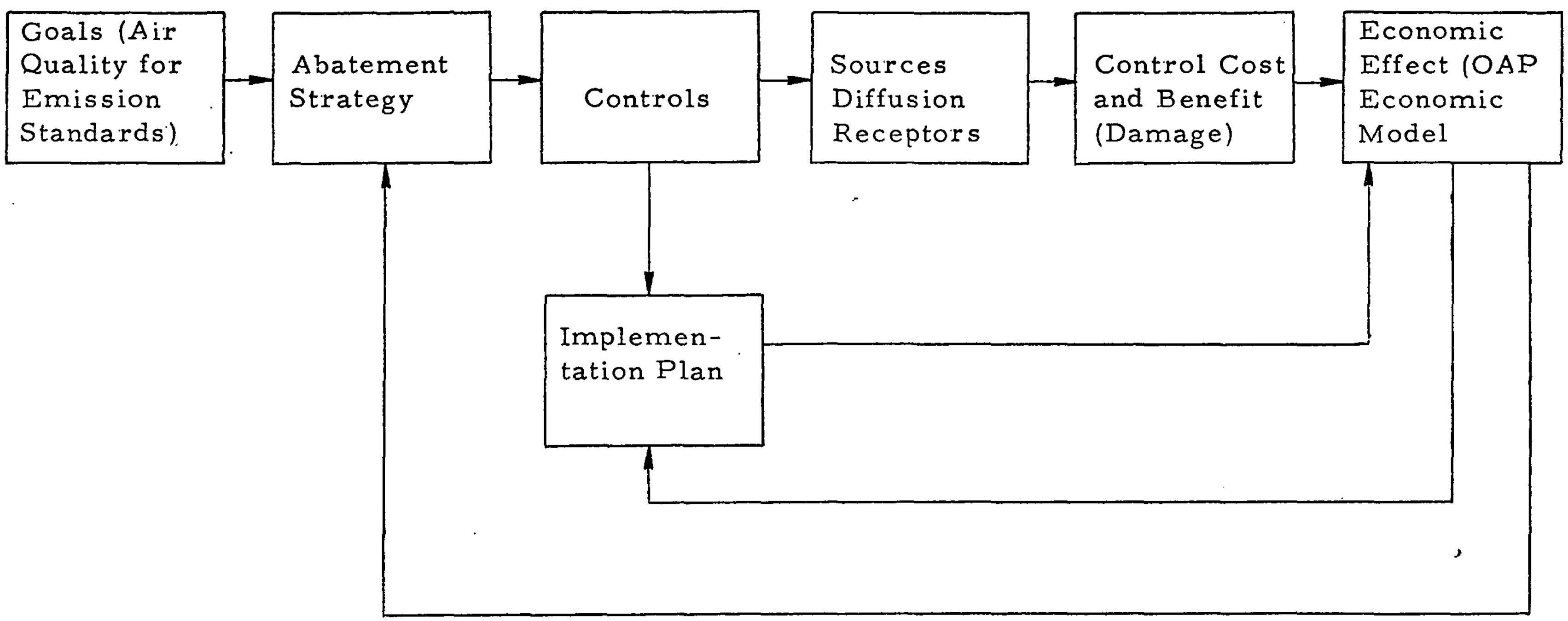
The RAPA program is a system of mathematical models arranged in a modular fashion and relating both engineering and economic effects of the analysis. Relations between the major components of the system are described in Figure 2.1.

Information on the effects of air pollution is reported in terms of air pollutant criteria, which are a compendium of today's knowledge of scientific findings on the range of adverse effects of specific air pollutants and combinations of pollutants on man and his environment.

Air quality standards that are developed with the guidance of these air quality criteria are goals established for the protection of public health and welfare. They provide a basis for controlling existing sources of pollution emissions and preventing future regional growth from adding to the pollution problem. Regional goals may reflect more than one air quality standard, insuring minimum air quality levels, as well as higher levels of air quality, to preclude any significant deterioration of existing high air quality levels.

The government's role starts with setting air quality standards which reflect goals for clean air within a specified time period. After

Figure 2.1
Regional Air Pollution Analysis Process



the air quality standards are set, an effort is made to establish implementation plans which may set forth regulatory procedures, such as pollutant source emission standards to achieve air quality standards. Limiting pollutant emissions through source emission standards, along with other types of regulatory procedures such as zoning regulations or fuel restrictions, forms an abatement strategy designed to achieve regional air quality within a specified time period.

To accomplish the task of developing abatement strategies will require an extensive examination of the factors involved in the air pollution system, such as meteorology, air pollution control technology, air pollution growth trends, source emission inventories, existing regional air quality conditions, and regional economic impact. The OAP Regional Economic Model was expressly developed as part of the RAPA program to respond to these requirements of information on the economic impacts of abatement strategies.

The Federal air pollution abatement legislation requires business and industry to control the amount of pollutants that they discharge into the air. To industry, this requirement means that the production costs for the same amount of output produced prior to the legislation will be increased in proportion to the required investments to air pollution control equipment. Thus, certain industries and regions that have in the past enjoyed the economic advantage of low-cost production may face some degree of economic decline due to the requirements of pollution abatement.

There would be offsetting economic effects from air quality control strategies in such regions in terms of (a) increased demand for the products of the industries that produce pollution control equipment and low pollutant fuels leading to increased output, employment, and income in those sectors, and (b) a variety of general economic benefits resulting from increased labor productivity, reduced health expenditures, reduced outlays on physical maintenance of homes and plants, and savings in agricultural production activities. Consequently, air pollution abatement leads to changes in economic output, labor markets, the availability of capital, as well as redistributions within the entire economy. Further, the implementation of air quality programs would have a variety of other effects, such as tax base impacts on communities or variations in land use and industrialization in various regions.

CONSAD has developed a regional economic model that will provide pollution abatement policy-makers capabilities to assess the effects of various pollution control strategies. The CONSAD model is intended to provide the following types of information for public-policy analysis:

- Regional economic changes (e.g., output, investment, employment, income, and consumption) expected to result from enforcement of varying abatement standards upon high-emission industries.

- Regional economic effects expected to result from reduction of industrial damage and growth in air pollution equipment industries.

- Fiscal effects of regional implementation of air quality control programs, including tax base impacts of economic change and the effects of tax credits upon economic change and the rate of achievement of emission standards in terms of the implementation plan.

2.2 The Phases of the Economic Model Development

During the first phase of the RAPA program, CONSAD developed a Regional Econometric Model of the St. Louis region where RAPA was explored first in depth. This model was a time series model that described the growth patterns of key economic sectors (both high emission and other industries) and estimated the regional product, employment, capital stock and investment change, and value-added by industry, tax receipts and regional unemployment. These estimates are sensitive to a variety of air pollution control strategies. In fact, the economic effects of five hypothetical air quality control strategies were simulated and interpreted, using the model for the St. Louis region.*

The next phase of model development was an extension of the model to 31 large metropolitan areas.** These large urban areas have a varied industrial structure highly representative of the national industrial composition and comprise a significant segment of national output. The structure and outputs of this cross-sectional model are very similar to those of the St. Louis model.

However, this regional model was structured as though AQCRs were economically independent of one another. There was no allowance for interregional effects. If, for example, Region A instituted air pollution control and in order to do so imported air pollution equipment from Region B, the model simulated the economic impact of Region A's program on Region A alone, and not on Region B. Thus, the regional model gave no indication of the increase in employment in Region B, resulting from the increased production of air pollution control equipment for export to Region A. There was, however, a source of pessimistic bias in the statement of economic effects of air pollution abatement embedded in the very structure of the model.

---

*See CONSAD, An Economic Model System for the Assessment of Effects of Air Pollution Abatement, Appendix A.
**See CONSAD, op. cit., Appendix B.

The model focused only on the economic impacts of control expenditures and accounted in no way for any benefits which might result from air quality improvement. This again tended to cause unjustifiably pessimistic conclusions about the economic effects of air pollution control.

CONSAD approached the problem of eliminating these biases and making some preliminary assessment of the national impact of air pollution control next. The cross-sectional Regional Model was restructured to eliminate, insofar as possible, the pessimistic bias induced by structural exclusion of interregional feedback effects and benefits and to permit preliminary estimates. A national Input-Output (I-O) model was introduced to capture (a) a preliminary estimate of structural changes in the national economy, and (b) to provide an interregional feedback scheme to the AQCRs.

This model,* termed the OAP Regional Economic Model, is operational and policy-oriented and attempts to describe the economic system-wide effects of specific air pollution strategies in 91 major metropolitan areas in the United States. Essentially, the model is a cross-sectional Keynesian-type regional macro model that describes in considerable detail, the two-digit SIC manufacturing industries,

---

*See CONSAD, op. cit.

viewed as leading regional economic growth. The Keynesian system and economic base theory are integrated in the regional income determination block of the model that describes regional personal income, consumption expenditures and local government expenditures and revenues. In addition, there is a regional labor market block that specifies the employment, unemployment and labor force equations.

Finally, the model describes the regional electricity and fuel demand patterns by the two-digit SIC industries. The regional model is hooked up to a National Input-Output Model (1963) via a Regional Share (location quotient) matrix. The I-O system is intended to serve as an external market for the regional economy and to measure the structural change in the national economy attendant on air pollution control in the regions.

The regional model was estimated using 1967 data for the 91 largest Standard Metropolitan Statistical Areas (SMSAs), using ordinary least squares except for the income block for which two-stage least squares was used.

2.3 Model Utilization

The OAP Regional Econometric Model has been utilized in three sequential steps. First was the demonstration phase when the model's operationality was demonstrated. The second step was the design and implementation of a set of realistic utilization experiments that helped to simulate the economic effects of implementation strategies over time to 1977. The third step was the use of the model after reformulation and reestimation of the investment equation and some validation experiments to assess the economic effects of air pollution strategies.

2.3.1 Demonstration Phase

The operationality of the model system was demonstrated at the end of this stage of model development. The OAP specified three alternative strategies to be tested, with the Regional Economic Model system as their basis, for the control costs envisioned in the 1970 Report to the Congress as required by Section 305(a) of the Clean Air Act of 1967.* In this report, cost estimates were made of controlling the emissions of selected pollutants within 100 AQCRs during the fiscal years 1970 through 1975. The costs reflect the emission reductions of particulates, sulfur oxides, hydrocarbons and carbon monoxides in these 100 AQCRs by 1975.

A computer simulation program of the OAP Regional Economic Model system was developed. The Regional Model, using this simulation program, could trace the effects of a variety of policy tools

---

*Fogel, M. E., _et al._, _Comprehensive Economic Cost Study of Air Pollution Control Costs for Selected Industries and Selected Regions_, Research Triangle Institute, February, 1970, Chapter 4.

such as standards or incentives available to OAP, provided the latter are converted into inputs consistent with the model logic.

Specifically, three strategies reflecting the same control costs but different in their incidence of these costs among industries, consumers and government were simulated. These simulation results demonstrated the operationality of the model. However, they suggested the need for further model utilization experiments that would lead to a more thorough utilization of the model than was possible in the development and demonstration phase.

2.3.2 Further Model Utilization Experiments

Such utilization experiments were structured in the following manner.

The first step was addressed to a specification of air pollution control implementation strategies that introduce a greater realism to the model utilization and can lead to a more thorough exercise of the model than was possible in the demonstration phase. Realism was introduced in a variety of ways. First, the standards and costs used in the strategies were the preliminary estimates corresponding to the control implied in the Federal Register of August 14, 1971, as promulgated by EPA.

Second, since control implementation would take place over a period extending to 1975 or 1977, the simulation includes the regional economies for the corresponding future years and the incidence of control costs over time is assumed to be a "step up" function (with the greatest proportion of the investments occurring closer to 1975 or 1977), rather than a uniform annual expenditure over the period, as assumed in the demonstration simulation. Since the EPA administrator can extend the period of implementation by two years under certain circumstances, strategies can also differ by implementation periods. Further, the economies of the AQCRs are likely to be larger in 1973-1975 than in 1967, and with a more realistic time scheme of cost functions as proposed here, the simulated strategies were likely to be more realistic.

Third, a greater variety of schemes, inclusive of various government cost sharing provisions, were tried in the strategies.

Fourth, alternative levels of "net" benefits of air pollution control were assumed. The institution of pollution abatement will result in increases of productivity, property values, control device production and decreases in health expenditures, housing maintenance, etc. The level of increment of national final demand resulting from such changes is termed here as "net" benefits. Estimates of "net" benefits are hard to come by and two levels are assumed for the simulation.

Six strategies are developed in the light of the above dimensions--time period of implementation, cost sharing and level of net benefits--

for simulation with the OAP model. A seventh strategy, termed as the "mixed" strategy evolves out of the simulation and implementation of the above six was also tried.

The next step in model utilization was essentially a quantification of the strategies and updating the economic data in a manner to simulate strategies such as those developed in this study. To facilitate the use of the model over the implementation period, a number of future cross-sections of the regional economies were developed for the 91 AQCRs using the OBE regional forecasts.* The simulation procedures of the OAP Model were adopted to accommodate the over time and cumulative effects of the strategies in the demonstration phase.

The final step was to apply the model to simulate and assess the economic consequences of the three strategies. As air pollution control requirements are instituted in the nation, the consequent effects are incident differentially in the various AQCRs. The primary purpose of regional economic modelling is to provide quantitative estimates of such differences among the AQCRs in any particular treatment (strategy) and among different treatments. The information on such differences has been assembled and interpreted in depth elsewhere.**

---

*U. S. Department of Commerce, Office of Business Economics, Economic Projections for Air Quality Control Regions, June, 1970.

**CONSAD Research Corporation, The OAP Regional Economic Model Utilization, Phase I, prepare for EPA, January 7, 1972.

2.4 Potentials for Model Refinement

The various efforts to utilize the model and analyze the results suggested a number of potential model refinements. First, it became obvious that the model should retain its current ability to describe the variations of economic effects among different geographic areas, but should also treat the economic changes over time more realistically. Consequently, the model has been reformulated by pooling the cross-sections over a ten-year period, 1958-1967. This procedure increases the sample size, in addition, and improves the efficiency of estimation.

Second, in view of the importance of government cost sharing schemes in implementation strategies, the need to treat the Federal, state and local governments and their component revenue sources in detail became clear.

Third, since investment expenditures are sensitive to abatement costs, a more realistic formulation of the investment equations with an appropriate lag structure is called for.

The OAP Regional Model was revised as described in the next chapter.

3.0 THE REVISED REGIONAL MODEL

Compared to national models and various industry econometric models, regional models are fewer in number and less sophisticated. Three reasons underlie this fact.

First, at the national level, good time series data have been available for most observable economic variables, while data on other variables such as capital stock are published as the result of theoretical inquiry. But at the regional level -- either state or SMSA -- data are unreliable and unavailable, especially in a continuous time series form.

Second, econometricians began the development of their models at the national level. From time to time, different equations and theories have been tested with the same data base in a well-defined economy, say the United States. By repetition of various tests and the accumulation of experience, national models calibrated to good theoretical structures are now available. On the other hand, regional models often deal with different geographic units, each often with its unique data base. Further geographic and cultural environments vary and socioeconomic structures differ from region to region.

Third, theoretically speaking, macro-economic models are usually based on well-established economic theory in their formulation.

The regional models, however, do not have a unified theory of regional growth to draw upon. Various available concepts such as economic base theory, location theory, gravity concepts, migration theory, and especially the concept of "distance" emphasized by regional scientists for some time are much harder to integrate into an overall hierarchical system. In spite of these shortcomings, some notable regional models have been recently estimated.*

An example of a regional econometric model developed specifically for EPA to assess regional economic effects of environmental control strategies is the OAP Regional Economic Model.** The OAP Model was estimated with cross-sectional data for 91 AQCRs.

---

*See Frederick W. Bell, "An Econometric Forecasting Model for a Region," Journal of Regional Science, Vol. 7, No. 2, 1967; B. H. Tuck, An Aggregate Income Model of a Semi-Autonomous Alaskan Economy, Anchorage, Federal Field Development Committee for Development Planning, 1967; T. R. Lakshmanan and Fu-Chen Lo, A Regional Growth Model of Puerto Rico: An Analysis of Municipal Growth Patterns and Public Investments, Pittsburgh, Pa., CONSAD Research Corporation, September, 1970; Robert Crow, "Econometric Model of the Northeast Corridor," (mimeograph) MATHEMATICA, October, 1967; Daniel B. Suits, "Econometric Model of Michigan," (mimeograph), Research Seminar in Quantitative Economics of the University of Michigan; Norman J. Glickman, "An Annual Econometric Model of the Philadelphia SMSA, 1949-1966," (mimeograph), Ph. D. Dissertation, Department of Economics, University of Pennsylvania, November, 1968; Yukio Kaneka, "An Econometric Approach to Annual Forecast on Regional Economy by Local Government," Paper and Proceedings, The Second Far East Conference of Regional Science Association, 1965, University of Tokyo Press, Tokyo, 1967; pp. 119-144.

**CONSAD Research Corporation, An Economic Model System for the Assessment of Effects of Air Pollution Abatement, prepared the Environmental Protection Agency, May 15, 1971.

Utilization of the OAP Model suggested the need for explicitly introducing the time element for use in policy simulation. So a reformulation of the OAP Regional Economic Model into a dynamic model has been found necessary. Specifically, a reestimation of the greater part of the model with pooled cross-section and time series data has been carried out here. This approach provides three advantages:

- A dynamic model that incorporates the interrelationships between economic growth and the effects of control will be more realistic for the over time policy simulation than the the use of the trend projections used so far.

- By pooling cross-section and time series data, the sample size will increase considerably. Therefore, statistically, more efficient estimates of model parameters can be expected.

- The advantage of cross-sectional observations of policy impacts among different regions still remains. Therefore, as an operational tool, policy impacts over time and over different geographic units can be investigated in this reformulated model.

The revised model extends the data to the period of 1958 through 1967. Details of the revised model are given in two parts, a section on formulation, followed by the actual estimation of the model.

3.1 Model Formulation

There is a fundamental difference between the economy of metropolitan regions and the national economy. The former is based on an open economy where growth and development is closely related to its capability to carry on external trade with other regions. The latter is rather more self-contained by its nature. The concept of "export-base" or economic base theory, has been the core of the analytical frameworks of urban economies since its first appearance in 1928.* However, the measurement of the economic base multipliers originally based on a calculation of ratios between export-oriented (or basic) employment and local-oriented (or service) employment has been changed by using the concept of output level, say value added, instead of employment.**

---

*Haig, Robert M., _Major Economic Factors in Metropolitan Growth and Arrangement,_ Vol. I, Regional Survey of New York and Environs, New York, 1928. See also Thompson, Wilbur R., _A Preface to Urban Economics,_ Resources for the Future, 1965.

**As an early example, see Leven, Charles L., "Measuring the Economic Base," _Papers and Proceedings,_ Vol. 2, The Regional Science Association, 1956.

This later development now takes into account different production structures among local industries, so that factor intensities of capital and labor may contribute different weights to the multiplier. Since manufacturing industries are more capital-intensive, the role of manufacturing industries in regional growth becomes decisive in that they usually dominate the value of exports (greater than 80 percent of the total value-added in some cases).*

Moreover, the dimension of space or distance plays an important role in the modelling of a system of regions. In other words, the interaction between regions must be treated in the model. Tinbergen** has argued that one of the simpler ways of dealing with such problems is to classify industries into regional, national, and international. It if therefore quite safe to treat manufacturing industry as an export-oriented industry in the regional growth model. Some of the recent

---

*In a case study of five midwest metropolitan areas, Charles C. Leven reported that manufacturing industry dominates 80 to 96 percent of export measured by value-added, while it only counts 45 to 71 percent if it were measured by employment.

**Tinbergen, J., "The Economic Framework of Regional Planning", The Econometric Approach to Development Planning, Pontifical Academy of Sciences, 1965, pp. 1233-1244.

successful regional econometric models explicitly or implicitly embody a causal relationship of manufacturing industry and the over-all regional growth. *

The change in measurement from employment to value-added in economic base theory has not only improved the applicability of the regional multiplier in recent regional growth analysis, but also seems to be consistent with the familiar Keynesian-type trade multiplier in the open economic system.

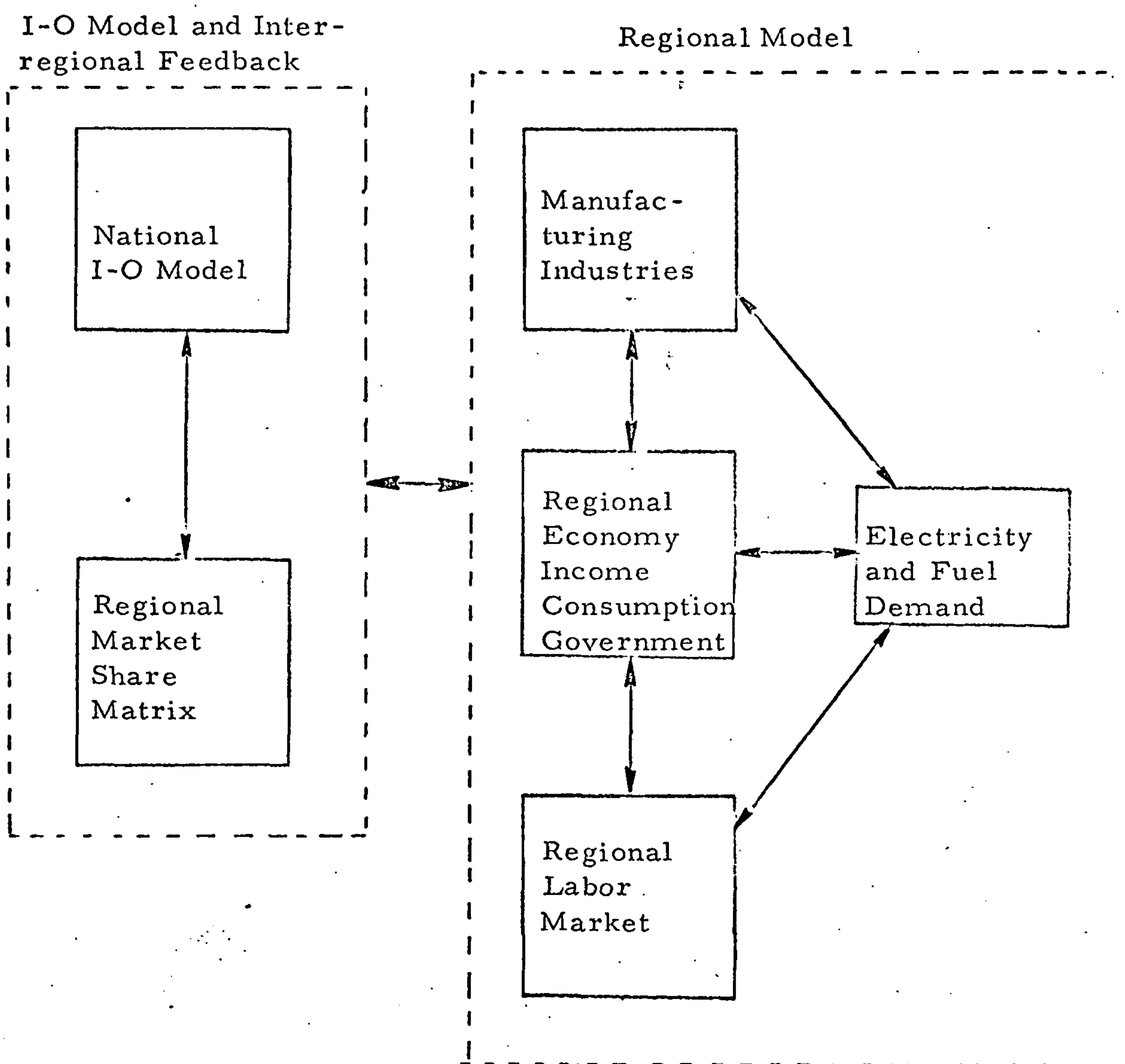
By treating manufacturing sectors as export-oriented industries, the OAP Model framework is essentially block recursive, followed by a regional income determination block and labor market block. One additional block, namely interregional feedback scheme, was introduced to treat interregional interaction of a system of regions. In order to measure fuels and electricty demands in response to air pollution control strategies, a fuel demand block was added to complete the model. The major components of the model are given in Figure 3. 1.

---

*A typical and successful model of this nature if Frederick W. Bell, op. cit.

FIGURE 3.1

MAJOR COMPONENTS OF THE MODEL



3.2 Input-Output Model and Interregional Feedback Scheme

As emphasized earlier, a region's growth is closely dependent upon its capability to carry on external trade with other regions. However, the formulation of an interregional I-O system of this scale, say a 20-sector regional I-O system with 100 SMSAs, will create a matrix of 2000 x 2000, requiring information that is largely non-existent.* A national I-O system linked to a regional market share matrix is therefore introduced to serve the role of external market for the regional economy and to capture the regional feedback.

It is argued that the regional share of the national market by industry, or location quotient, is relatively stable. (See Table 3.1.) By definition:

$$b_{ij} = \frac{x_{ij}}{x_j}$$

where:

b_{ij} is the regional market share, or location quotient, of jth industry produced in the ith region;
x_{ij} is the output of jth industry in the ith region;
x_j is the output of jth industry in the nation.

---

*Interregional feedback phenomenon was formulated and observed in a pioneer study by Miller (1966).

In the regional model, only manufacturing industries were treated as export-oriented industries; so the demands of regional manufacturing products are determined by the regional matrix share or the location quotient and national demand by each manufacturing industry. Thus,

$$X_R = BX , \tag{1}$$

where:

matrix $X_R = [x_{ij}]$ is the regional share of demand for manufacturing products at national market;

matrix $B = [b_{ij}]$ is the regional market share (or location quotient) coefficient matrix;

matrix X = contains diagonal elements x_j which is the total national demand by each manufacturing industry.

By introducing a national I-O model, the menu of final demand by sectors can be captured by the inverse matrix:

$$X = (I - A)^{-1}Y , \tag{2}$$

where:

matrix A is the national I-O coefficient matrix;

Y is a vector with element y_j which is the final demand of sector j;

X is a vector with element x_j which is the gross product or value of shipment by sector j.

The link provided between the regional model and the national I-O model is best explained in the following manner: since the regional model has manufacturing industries as export-oriented industries, demands for manufacturing products remain to be determined at the national markets. The I-O model and the regional share matrix serve to link the regions with the nation, or time series data of national product by industry x_j, can be a set of exogeneous variables to the model.

Some data on air pollution control impact are obtainable only at the national level, for example, rough estimates on benefits accruable from air pollution control. These estimates can be treated at the national level by the I-O model and distributed through the regional share matrix to the regions. Assuming an equilibrium economy, air pollution control costs will shift up supply curves of high emission industries (which are manufacturing industries) and cut down the production levels of such industries in each region.* Since manufacturing industries are export-oriented, changes in regional

---

*LeSourd, D. A., et al., Comprehensive Study of Specified Air Pollution Sources to Assess Economic Effects of Air Quality Standards, Research Triangle Institute, December, 1970.

manufacturing production will generate a sequence of interregional effects and feedbacks from other regions, including the regions under study and the rest of the United States. The use of the national I-O model and regional market share matrix as proposed here, provides a reasonable simulation of these interregional effects.

In the revised model, regional market share matrices were estimated with time series data from 1958 to 1967 based on Census of Manufacturing and Annual Survey of Manufacturers data. For those AQCRs without a complete time series data, the coefficients are estimated by data on 1958, 1963 and 1967. Standard errors associated with each estimate are also obtained. The results show a remarkable stability of the coefficients as shown in Table 3. 1 for all manufacturing. *

National products by manufacturing industries over time can be taken as a set of exogeneous variables to the model. Therefore, equation (1) can be given as:

$$x_{ijt} = b_{ij} x_{jt} \qquad \begin{array}{l} i = 1, \ldots n \text{ (regions)} \\ j = 1, \ldots m \text{ (industries)} \\ t = 1, \ldots T \text{ (years)} \end{array}$$

---

*The estimates by 2 digit SIC industries also gave similar stability and are too voluminous to be included here.

Table 3.1
Regional Share of Manufacturing Industry

AQCR Code	AQCR	Estimated Regional Share (%)	Standard Error
1	New York, New York	6.003	.184
2	Chicago, Illinois	5.474	.053
3	Los Angeles, Calif.	4.737	.096
4	Philadelphia, Pa.	3.186	.047
5	Detroit, Michigan	3,422	.075
6	San Francisco, Calif.	1.350	.033
7	Boston, Mass.	1.664	.037
8	Pittsburgh, Pa.	1.624	.041
9	St. Louis, Missouri	1.636	.011
10	Washington, D. C.	.260	.020
11	Cleveland, Ohio	1.768	.024
12	Baltimore, Maryland	1.263	.051
14	Minneapolis-St. Paul, Minnesota	1.028	.027
15	Houston, Texas	.952	.058
16	Buffalo, New York	1.041	.058
17	Milwaukee, Wisconsin	1.237	.036
18	Cincinnati, Ohio	1.053	.007
19	Louisville, Kentucky	.808	.009
20	Dallas, Texas	.699	.060
21	Seattle-Everett, Wash.	.780	.031
22	Kansas City, Missouri	.776	.010
23	San Diego, Calif.	.342	.015
24	Atlanta, Georgia	.565	.019
25	Indianapolis, Indiana	.716	.004
26	Miami, Florida	.237	.036
27	Denver, Colorado	.434	.011
28	New Orleans, Louisiana	.317	.011
29	Portland, Oregon	.413	.003
30	Providence-Pawtuckett, Rhode Island	.615	.009
31	Phoenix, Arizona	.228	.039
32	Tampa, Florida	.197	.015
33	Columbus, Ohio	.463	.008
34	San Antonio, Texas	.111	.001
35	Dayton, Ohio	.681	.009
36	Birmingham, Alabama	.392	.016
37	Toledo, Ohio	.476	.017
38	Steubenville-Weirton, Ohio/ Wheeling, West Virginia	.290	.050

Table 3.1
(continued)

AQCR Code	AQCR	Estimated Regional Share (%)	Standard Error
39	Chattanooga, Tenn.	.226	.011
40	Memphis, Tennessee	.296	.003
41	Salt Lake City, Utah	.181	.015
42	Oklahoma City, Oklahoma	.128	.015
43	Omaha, Nebraska	.225	.003
44	Honolulu, Hawaii	.088	.006
45	Beaumont-Port Arthur-Orange, Texas	.360	.051
46	Charlotte, N. C.	.149	.006
47	Portland, Maine	.072	.003
48	Albuquerque, N. M.	.035	.003
50	El Paso, Texas	.068	.003
51	Las Vegas, Nevada	.031	.003
52	Fargo-Moorhead, N.D., Minnesota	.014	.001
53	Boise, Idaho	.015	.000
54	Billings, Montana	.025	.001
55	Sioux City, Iowa	.037	.005
61	Allentown-Bethlehem-Easton, Pa.	.586	.058
63	Bakersfield, Calif.	.041	.002
64	Davenport-Rock Island-Moline, Iowa, Illinois	.279	.011
66	Grand Rapids/Muskegon-Muskegon Heights, Migh.	.384	.026
67	Greensboro, N. C.	.239	.045
68	Harrisburg, Pa.	.252	.068
69	Jacksonville, Florida	.126	.001
70	Knoxville, Tenn.	.205	.005
71	Nashville, Tenn.	.238	.012
72	Peoria, Illinois	.297	.008
73	Richmond, Virginia	.301	.004
74	Rochester, New York	.883	.041
75	Saginaw/Bay City, Mich.	.260	.020
76	Scranton/Wilkes Barre-Hazelton, Pa.	.270	.010
77	Syracuse, New York	.421	.011
78	Tulsa, Oklahoma	.177	.013
80	Youngstown-Warren, Ohio	.480	.009
81	Albany-Schenectady-Troy, New York	1.283	.908

Table 3.1
(continued)

AQCR Code	AQCR	Estimated Regional Share (%)	Standard Error
82	Binghamton, New York	.201	.012
83	Charleston, S. C.	.056	.001
84	Charleston, W. Va.	.270	.035
85	Des Moines, Iowa	.156	.007
86	Fresno, Calif.	.091	.003
87	Fort Wayne, Indiana	.221	.010
88	Jackson, Mississippi	.062	.002
89	Johnstown, Pa.	.109	.005
90	Lancaster, Pa.	.271	.005
91	Mobile, Alabama	.123	.009
92	Norfolk-Portsmouth/Newport News-Hampton, Va.	.162	.037
93	Raleigh/Durham, N. C.	.159	.012
94	Reading, Pa.	.234	.002
95	Rockford, Illinois	.277	.020
96	Sacramento, Calif	.233	.021
97	South Bend, Indiana	.206	.025
98	Utica-Rome, New York	.238	.003
99	Wichita, Kansas	.287	.025
100	York, Pa.	.246	.009

where:

$x_{ij,t}$ is manufacturing product (value added) of industry j, in region i, year t

b_{ij} is regional market share of manufacturing industry j in region i

x_j is national manufacturing product (value added) of industry j in year t

For example,

$$x_{5,37,t} = \underset{(.004)}{.1249}\, x_{37,t}$$

which indicates that transportation equipment production (SIC 37) in Detroit (AQCR 5) is 12.49% of the national output in that industry and that the standard error of such estimates is .004.

3.3 The Manufacturing Block of the Regional Model

It has been suggested earlier that for a regional model, the export sector usually plays an important role. Regional export is strongly related with metropolitan's interindustrial structure. Thomassen, Bell, Glickman, and Klein* link exports also with the Gross National Product (GNP). However, it is important that the export sector be disaggregated. The reason is that the inter-industrial structure of a large metropolitan area may be quite different from that at the national level. As suggested by location theory, regional resource endowments and other socio-economic characteristics determine the industrial structure of a local economic unit. Therefore, the use of a GNP trend is a less desirable indicator of external market demand than national outputs by industry.

Moreover, the present model is designed to measure the economic impacts of air pollution control, and it is more realistic to observe the impact for each major manufacturing industry at the two-digit SIC level.

---

*See H. Thomassen, "A Growth Model for a State," Southern Economic Journal, No. 24, 1957, pp. 123-139;

Frederick W. Bell, "An Econometric Forecasting Model for a Region," Journal of Regional Science, Vol. 7, No. 2, 1967;

Norman J. Glickman, "An Annual Econometric Model of the Philadelphia SMSA, 1949-1966," (mimeograph), Ph.D. Dissertation, Department of Economics, University of Pennsylvania, November, 1968;

Klein, L.R., "The Specification of Regional Econometric Models," Papers, Regional Science Association, Vol. 23, 1969, pp. 153-166.

The two-digit SIC manufacturing industries included in the regional model are:

SIC	Industry
20	food and kindred products
22	textile mill products
23	apparel and related products
24	lumber and wood products
25	furniture and fixtures
26	paper and allied products
27	printing and publication
28	chemicals and allied products
29	petroleum and coal products
30	rubber and plastics products
31	leather and leather products
32	stone, clay, and glass products
33	primary metal industries
34	fabricated metal products
35	machinery, except electrical
36	electrical machinery
37	transport equipment
38	instruments and related products
39	miscellaneous products.

The manufacturing block consists of the following equations:

$$X_{ijt} = A_j e^{r_j t} N_{ijt}^{\alpha_j} K_{ijt}^{1-\alpha_j} \tag{3}$$

$$\Pi_{ijt} = (1 - \alpha_j) X_{ijt} \tag{4}$$

$$I_{ijt} = a_j (I_{ijt-1} - \alpha_j K_{ijt-1}) + b_j (\Pi_{ijt} - \Pi_{ijt-1}) + C_j K_{ijt} \tag{5}$$

$$K_{ijt} = K_{ijt-1} + I_{ijt} - \alpha_j K_{ijt} \tag{6}$$

$$W_{ijt} = a_j + b_j W_{ijt-1} + c_j \left(\frac{K_{ijt}}{L_{ijt}} \right) \tag{7}$$

The details of formulation and estimation of each set of equations follows.

3.3.1 Production Functions and Capital Shares

Equation (3) is a typical Cobb-Douglas production function. In this formulation, a measure of technical change $e^{r_j t}$ has been introduced. This gives a separate measurement of production efficiency over time by labor and capital.

The results are shown in Table 3.2. The technical change coefficients, $r_j t$ show a 2-5% increase in the productivity of labor and capital annually. The parentheses under each estimated coefficient shows the standard error, followed by the regression coefficient R^2 and sample size in each estimation.*

---

*The estimation procedure consists of first estimating the the factor share α_j by geometric mean of observed factor shares

$$\ln \hat{\alpha}_j = \frac{1}{T}\frac{1}{N}\sum_{i=1}^{N}\sum_{t=1}^{T} \ln \alpha_{ijt} \quad ; \quad \alpha_{ijt} = \frac{(\text{Wage bill})_{ijt}}{(\text{Value added})_{ijt}}$$

Then other coefficients A_j and γ_j by

$$\ln(X_{ijt} / N_{ijt}^{\hat{\alpha}_j} K_{ijt}^{1-\hat{\alpha}_j}) = \ln A_j + \gamma_j t$$

See Dhrymes, P. J., "On Devising Unbiased Estimators for the Parameters of the Cobb-Douglas Production Function", Econometrica, Vol. 30, (1962), pp. 297-304.

Table 3.2
Production Functions

$$X_{ijt} = A_j e^{r_j t} N_{ijt}^{\alpha_j} K_{ijt}^{1-\alpha_j}$$

SIC	ln A_j	A_j	r_j	ln α	α	R^2	Sample Size
All mfg.	1.3154	3.7262	0.0324	-0.6539	0.5200	0.9927	370
	(0.0107)		(0.0020)	(0.0001)			
20	1.2037	3.3326	0.0215	-0.9177	0.3994	0.9814	330
	(0.0175)		(0.0033)	(1.3010)			
22	1.0552	2.8727	0.0327	-0.5428	0.5811	0.9680	160
	(0.0283)		(0.0053)	(0.8563)			
23	1.8111	6.1170	0.0229	-0.5362	0.5850	0.9760	210
	(0.0274)		(0.0051)	(1.0394)			
24	1.1606	3.1919	0.0496	-0.5589	0.5718	0.8964	40
	(0.0475)		(0.0089)	(0.4089)			
25	1.5174	4.5602	0.0384	-0.5494	0.5773	0.9889	120
	(0.0256)		(0.0048)	(0.0000)			
26	1.0571	2.8781	0.0169	-0.6783	0.5075	0.9768	250
	(0.0166)		(0.0031)	(1.0252)			
27	1.6053	4.9794	0.0227	-0.5594	0.5716	0.9877	270
	(0.0137)		(0.0026)	(0.7586)			
28	0.8850	2.4230	0.0320	-1.2118	0.2977	0.9561	260
	(0.0279)		(0.0052)	(1.6355)			
29	0.3416	1.4072	0.0533	-1.1451	0.3182	0.8143	80
	(0.0397)		(0.0074)	(1.0068)			
30	1.3139	3.7205	0.0262	-0.6797	0.5068	0.8598	130
	(0.0394)		(0.0074)	(1.1580)			
31	1.5805	4.8573	0.0252	-0.4959	0.6090	0.9695	100
	(0.0331)		(0.0062)	(0.5047)			

Table 3.2
(continued)

SIC	ln A_j	A_j	r_j	ln α	α	R^2	Sample Size
32	1.1051	3.0195	0.0256	-0.7615	0.4670	0.9575	240
	(0.0187)		(0.0035)	(0.0001)			
33	1.1214	3.0690	0.0421	-0.6053	0.5459	0.9283	250
	(0.0228)		(0.0043)	(1.2586)			
34	1.4037	4.0701	0.0389	-0.5939	0.5522	0.9394	330
	(0.0148)		(0.0028)	(0.0001)			
35	1.4979	4.4723	0.0434	-0.5936	0.5523	0.9815	280
	(0.0142)		(0.0027)	(0.9407)			
36	1.6552	5.2343	0.0252	-0.6388	0.5279	0.9846	230
	(0.0196)		(0.0037)	(1.0229)			
37	1.5521	4.7213	0.0457	-0.5794	0.5602	0.9596	230
	(0.0227)		(0.0042)	(1.6513)			
38	1.7540	5.7776	0.0221	-0.6069	0.5450	0.9362	90
	(0.0320)		(0.0060)	(0.6944)			
39	1.5356	4.6439	0.0139	-0.5895	0.5546	0.9757	130
	(0.0318)		(0.0060)	(0.6947)			

Equation (4) is an identity defining the gross profit as residuals of value added and wage bill. Since a Cobb-Douglas production function is homogeneous of degree one

$$\Pi = (X - \frac{\partial X}{\partial N} \cdot N) = \frac{\partial X}{\partial K} \cdot K$$

$$= (1 - \alpha)X$$

The capital share coefficients $(1 - \alpha_j)$, can be obtained from Table 3.2.

3.3.2 Investment Functions and Capital Stock

It is argued that the investment behavior of manufacturing industries will be considerably effected by the pollution control expenditures likely to be made in response to recent legislative requirements. Although such expenditures involve both investment and operating costs of control, they are non-productive, and may have a sequential impact over time on investment behavior of production capacities of manufacturing industries.

In a recent survey Jorgenson* indicated that most recent investment studies were formulated on the flexible accelerator model

---

*Jorgenson, D.W., "Econometric Studies of Investment Behavior: A Survey", Journal of Economic Literature, Vol. 15, 1971, pp. 1111-1147.

of investment focusing on the time structure of investment behavior directed to achieving a desired capital stock. However, the specification of desired capital varying among alternative theories; further, time structure of investment expenditures is different among many empirical studies. No attempt is made to review the various approaches here. It may suffice to indicate that the new formulation will be based on the neoclassical theory of optimal accumulation of capital in the formulation of desired capital stock. *

The case of the neoclassical theory of optimal accumulation of capital is to determine optimal (desired) capital stock which maximizes net worth. According to Jorgenson**

$$\text{(a)} \quad NW = \int_{o}^{\infty} e^{-rt} \left[Z(t) - T(t) \right] dt$$

Net worth (NW) is the sum of the discounted value of the difference between revenue Z(t) and rental outlay of capital services T(t) integral over time with a discount rate of r. Under

---

*This seems to be a plausible approach in the light of the studies reported by Jorgenson.

**Jorgenson, D. W., "Anticipations and Investment Behavior", in The Brookings Quarterly Econometric Model of the United States, J. S. Duesenberry et al. (eds.), Rand McNally & Co., 1965, pp. 35-94.

neoclassical conditions of production, maximization of net worth is subject to two constraints, namely, the production function and that replacement is proportional to capital stock.

(b) $X = A L^{\alpha} K^{\beta}$

(c) $I^{+} = I - \delta K$

Equation (b) is a Cobb-Douglas production function, where X, L, and K are output, labor and capital inputs respectively. I^{+} is rate of change of capital stock (net investment), I is gross investment and δ is depreciation rate of capital.

By maximizing net worth in equation (a) subject to (b) and (c) the desired capital K^{+} is determined as follows *

(d) $K^{+} = \beta \frac{X}{C}$

---

* In detail formulation see Jorgenson, op. cit., pp. 43-53.

** User cost of capital is defined as

$$C = q \left[\frac{1 - UV}{1 - U} \delta + \frac{1 - UW}{1 - U} r \right]$$

where q is the price of capital good, U the rate of direct taxation, V the proportion of replacement changeable against income for tax purpose, W the proportion of the cost of capital allowable for tax purpose, r the cost of capital or interest rate and δ is replacement rate. In the later study, capital gain or loss on assets has been added to this formulation.

where β is capital share coefficient or elasticity of output with respect to capital from a Cobb-Douglas production function (3) and C is the user cost of capital. The user cost of capital is the implicit price that the capital stock must earn to pay for itself and is, in general, a function of the price of the stock, the cost of capital funds to the firm, and any tax treatment accorded to capital stock**.

Given the desired capital stock K_t^+, the time scheme of investment behavior to complete the delivery of the demand capital is considered to be lag distribution.

This is to say, that on the investment orders, which represent the difference between desired capital and actual capital holdings $(K_t^+ - K_t)$, only a certain fraction is delivered in each period.

$$\alpha_0, \alpha_1, \alpha_2, \ldots \qquad 0 \leq \alpha_i < 1 \quad i = 0, 1, 2, \ldots$$

In his pioneering study of investment behavior, Koyck suggested a lag distribution with a series of geometrically declining weights.* The actual investment at time t will be the sum of a weighted fraction of investment projects initiated in all previous periods $(X_{t-i}, \ i = 0, 1, 2, \ldots)$

$$I_t^+ = \alpha_o X_t + \alpha_1 X_{t-1} + \ldots \ \delta_n X_{t-n} + \ldots$$

---

*In an earlier estimation of investment equations, Almon's weights were also used. See Appendix A.

Koyck assumed that

$$\alpha_1 = \lambda\alpha_0$$

$$\alpha_2 = \lambda\alpha_1 = \lambda^2 \alpha_0$$

- - - - - - - - - - -

$$\alpha_n = \lambda \alpha_{n-1} = \dots = \lambda^n \alpha_0$$

than

(e) $$I_t^+ = \sum_{i=0}^{\infty} \alpha_o \lambda^i X_{t-i}$$

Suppose the investment plan started in each time t is given by the difference between optimal capital stocks at time periods t and t - 1

$$X_t = (K_t^+ - K_{t-1}^+)$$

A fraction of the above will be delivered each time according to Koyck lag distribution; then the actual investment at time t will be

(f) $$I_t^+ = \alpha_o \sum_{i=o}^{\infty} \lambda^i (K_{t-i}^+ - K_{t-1-i}^+)$$

Then (f) can be transformed to *

(g) $I_t^+ = \lambda I_{t-1}^+ + \alpha_o \left[K_t^+ - K_{t-1}^+\right]$

Substituting (d) into (g) to get

(h) $I_t^+ = \lambda I_{t-1}^+ + \alpha_o \beta \left[\frac{X_t}{C_t} - \frac{X_{t-1}}{C_{t-1}}\right]$

Assume that the user cost is relatively homogeneous, then,

$$\left(\frac{X_{jt}}{C_{jt}} - \frac{X_{jt-1}}{C_{jt-1}}\right) \approx \frac{1}{C}\left(X_{jt} - X_{jt-1}\right)$$

Therefore Equation (h) becomes

(i) $I_{jt} = \lambda I_{jt-1} + \frac{\alpha_0 \beta}{C} \left[X_{jt} - X_{jt-1}\right] + v_{jt}$ $\quad j=1, \ldots, n$

---

* Suppose L is a lag operator that by definition

$$L^i X_t = X_{t-i}$$

and I is an identity operator that $IX_t = X_t$, then equation (5) becomes

$$I_t^+ = \alpha_o \sum_{i=o}^{\infty} \lambda^i X_{t-i} = \frac{I}{I - \lambda L} \alpha_o X_t$$

Apply $I - \lambda L$ to both sides

$$I_t^+ = \lambda I_{t-1}^+ + \alpha_o X_t$$

Therefore,

$$I_t^+ = \lambda I_{t-1}^+ + \alpha_o \left[K_t^+ - K_{t-1}^+\right]$$

See Dhrymes, P. J. Econometrics: Statistical Foundations and Application. pp. 509-517.

This foundation is thus a generalized version of the accelerator model. With a Cobb-Douglas Production function (3), by definition, gross profit Π is a fixed proportion to output X

$$\Pi_{jt} = \beta X_{jt}$$

Then equation (i) becomes

$$\text{(j)} \qquad I^{+}_{jt} = \lambda I^{+}_{jt-1} + \frac{\alpha_o}{C} \cdot \left[\Pi_{jt} - \Pi_{jt-1}\right] + v_{jt}$$

However, I^{+} is the net investment; therefore, the formulation for gross investment I_t will be

$$\text{(5)} \qquad I_t = \lambda(I_{t-1} - \delta K_{t-2}) + \frac{\alpha_o}{C} (\Pi_t - \Pi_{t-1}) + \delta K_t + v_t$$

The results of estimation of Equation (5) by pooling cross-section data of 1958 through 1967 is given in Table 3.3.

The capital stock identities are given as

$$\text{(6)} \quad K_{ijt} = K_{ijt-1} + I_{ijt} - \delta_j K_{ijt} \qquad j = 1, \ldots m$$

Some data and pre-estimated parameters need further explanation. Depreciation rates for all manufacturing industry and each of two digit SIC industries were estimated from actual depreciation and gross book value of fixed assets of 1957 U.S. data.* The time series data of capital stock by metropolitan regions and by 2-digit SIC industries are non-existant. Therefore capital output ratios of U.S. in 1958 were applied to the value added by regions by industries in 1958 to obtain the initial capital stock. That is

$$K_{ij\ 1958} = \alpha_j \cdot X_{ij\ 1958}$$

where α_j is capital output ratio of industry j of U.S.

Using $K_{ij\ 1958}$ as bench mark estimates of regional capital stock by industries in the base year 1958, time series estimates of capital stock were derived as follows:

$$K_{ijt} = K_{ijt-1} + I_{ijt} - \delta_j K_{ijt}$$

where initial capital stocks, K_{ijo}, investment I_{ijt} and depreciation rates, δ_j are given. The pre-estimated depreciation rates and capital-output ratios are given in Table 3.4.

---

*U.S. Department of Commerce, Bureau of the Census, 1958 Census of Manufacturers, Vol. 1, Summary Statistics, Section 9, Selected Costs and Book Value of Fixed Assets".

Table 3.3
Investment Functions

$$I_{ijt} = \lambda_j(I_{ijt-1} - \delta_j K_{ijt-1}) + \frac{a_o}{c}(\Pi_{ijt} - \Pi_{ijt-1}) + \delta_j K_{ijt}$$

SIC	λ_j	$\frac{a_o}{c}$	δ_j	R^2	Sample Size
All manufacturing	0.9913 (0.0284)	0.0778 (0.0112)	0.0692 (0.0008)	0.9519	342
20	0.6910 (0.0492)	0.0104 (0.0094)	0.0719 (0.0010)	0.9270	297
22	0.6579 (0.0693)	0.0146 (0.0123)	0.0540 (0.0017)	0.7821	144
23	0.0026 (0.0784)	0.0035 (0.0014)	0.1108 (0.0026)	0.9240	189
24	0.3907 (0.1592)	0.0355 (0.0310)	0.1108 (0.0086)	0.9240	36
25	0.4474 (0.0878)	0.0561 (0.0145)	0.0692 (0.0029)	0.7815	117
26	0.2955 (0.0651)	0.0550 (0.0489)	0.0703 (0.0033)	0.6179	225
27	0.5496 (0.0608)	0.0057 (0.0185)	0.0765 (0.0023)	0.9284	243
28	0.8550 (0.0368)	0.0909 (0.0136)	0.0699 (0.0023)	0.8721	234
29	0.4138 (0.1320)	0.0510 (0.0250)	0.0860 (0.0069)	0.6952	72
30	-0.0191 (0.1023)	-0.0168 (0.0442)	0.1027 (0.0055)	0.7023	117
31	0.5388 (0.0879)	0.0662 (0.0065)	0.0704 (0.0042)	0.7333	90

Table 3.3
(continued)

SIC	λ_j	$\frac{\alpha_o}{c}$	δ_j	R^2	Sample Size
32	0.5454 (0.0667)	0.0087 (0.0187)	0.0751 (0.0023)	0.7295	216
33	0.2936 (0.0671)	-0.0714 (0.0230)	0.0811 (0.0028)	0.8627	225
34	0.4472 (0.0542)	0.0899 (0.0205)	0.0837 (0.0026)	0.8488	297
35	1.0472 (0.0549)	-0.0060 (0.0091)	0.0830 (0.0023)	0.9330	252
36	0.5226 (0.0702)	0.0622 (0.0136)	0.0963 (0.0041)	0.8648	207
37	0.7500 (0.0467)	0.0517 (0.0095)	0.0878 (0.0036)	0.8704	207
38	0.4549 (0.1248)	0.0761 (0.0153)	0.1882 (0.0138)	0.8970	81
39	0.2270 (0.0920)	0.0518 (0.0092)	0.0594 (0.0023)	0.8728	117

Table 3.4
Pre-estimated Parameters

Industry	Depreciation rate δ_j	Output-Capital ratio
All Manf.	.0662	1.271
SIC 20	.0674	1.394
22	.0525	1.043
23	.0906	6.032
24	.0915	1.126
25	.0737	2.415
26	.0539	.799
27	.0686	2.142
28	.0669	.952
29	.0614	.409
30	.0618	1.381
31	.0755	4.053
32	.0646	.966
33	.0560	.769
34	.0700	1.670
35	.0722	1.696
36	.0738	2.353
37	.0738	2.353
38	.0671	3.276
39	.0732	2.389

3.3.3 Wage Equations

Wage differentials among regions in the U.S. have been observed by many studies.* Theoretically, such regional wage differentials can be explained by production factor ratios, namely capital labor ratio on the assumption that (1) production function is neo-classical and homogeneous of degree one, (2) wages and rentals are equal to their marginal productivities, respectively. More precisely, with a Cobb-Douglas production function it can be shown that if capital labor ratio in region 1 is greater than region 2, then wage rates in region 1 will be greater than that of region 2 and vice versa.**

Scully has empirically estimated the cross-sectional wage equations and finds that the capital-labor ratio seems to be a significant explanatory variable in his estimation.*** By pooling over time of cross-section data, the bargaining power of unions is

---

*See Block, J.W., "Regional Wage Differentials, 1907-1946", Mon. Lab. Rev., April, 1948, pp. 371-77, Gallaway, L.E., "The North-South Wage Differential", Review of Economics and Statistics, Aug. 1963, Vol. 45, pp. 264-72.

**See Lo, Fu-chen, "A Two-Region Growth Model with Imperfect Mobility of Factors", Ph.D. thesis, University of Pennsylvania, 1968.

***Scully, G.W., "Interstate Wage Differentials: A Cross Section Analysis", American Economic Review, Vol. LIX, 1969, pp. 757-773.

is likely to be reflected in a "mark up over years". Therefore, a lag variable was introduced in the wage equation which gives

$$(7) \qquad W_{ijt} = a_j + b_j W_{ijt-1} + c_j \left(\frac{K_{ijt}}{L_{ijt}} \right)$$

The results given in Table 3.5 suggest a good fit of the equation. The coefficients of capital-labor ratios are positive in most cases, as expected by theoretical formulation, and also significant. Only in three cases (SIC 25, 31, 32), are negative signs evident; however, they are statistically insignificant.

Table 3.5
Wage Equations

$$W_{ijt} = a_j + b_j W_{ijt-1} + c_j \left(\frac{K_{ijt}}{L_{ijt}} \right)$$

SIC	a	b	c	R^2	Sample Size
All manufacturing	1.1145 (0.2095)	0.7018 (0.0339)	0.1043 (0.0162)	0.6239	342
20	0.6795 (0.1282)	0.7869 (0.0297)	0.0649 (0.0110)	0.8264	297
22	0.3423 (0.1103)	0.7973 (0.0341)	0.0961 (0.0173)	0.8979	144
23	0.3372 (0.0941)	0.8391 (0.0371)	0.4095 (0.0999)	0.8836	189
24	0.2159 (0.2426)	0.8502 (0.0689)	0.1113 (0.0505)	0.9053	36
25	0.6296 (0.2119)	0.9048 (0.0459)	-0.0202 (0.0614)	0.8067	117
26	0.9218 (0.1413)	0.8302 (0.0288)	0.0096 (0.0040)	0.8394	225
27	0.8674 (0.1616)	0.8341 (0.0333)	0.0492 (0.0217)	0.8068	243
28	1.172 (0.2057)	0.8115 (0.0360)	0.0077 (0.0044)	0.7347	234
29	1.2442 (0.4726)	0.8122 (0.0773)	0.0065 (0.0034)	0.7606	72
30	1.0146 (0.2694)	0.7910 (0.0529)	0.0299 (0.0240)	0.7177	117
31	0.8352 (0.2676)	0.8104 (0.0866)	-0.0342 (0.0743)	0.6110	90

Table 3.5
(continued)

SIC	a	b	c	R^2	Sample Size
32	0.6770 (0.1702)	0.9211 (0.0287)	-0.0059 (0.0085)	0.8329	216
33	0.8643 (0.1678)	0.8877 (0.0295)	0.0030 (0.0054)	0.8459	225
34	1.0987 (0.2172)	0.6757 (0.0417)	0.1651 (0.0289)	0.6255	297
35	0.6009 (0.1423)	0.9338 (0.0227)	0.0059 (0.0158)	0.8837	252
36	0.6556 (0.1427)	0.9144 (0.0247)	0.0097 (0.0149)	0.8797	207
37	3.1635 (0.4106)	0.5444 (0.0586)	0.0411 (0.0302)	0.3193	207
38	1.9113 (0.3780)	0.6317 (0.0786)	0.1368 (0.0516)	0.7056	81
39	0.9781 (0.2602)	0.8064 (0.0564)	0.0216 (0.0182)	0.7007	117

3.4 Income Determination Block

Integration of the Keynesian system and economic base theory can be best explained by the income determination block of this model,

(8) $Y_{it} = f(C_{it} \; \sum_j X_{ijt} \; G_{it})$

(9) $C_{it} = f(Y_{it}, \; C_{it-1})$

(10) $G_{it} = f(T_{it})$

(11) $T_{it} = T^P_{it} + T^O_{it} + T^A_{it}$

(12) $T^P_{it} = f(A_{it})$

(13) $T^O_{it} = f\left[Y_{it}, \; \left(\frac{Y}{P}\right)_{it} \right]$

(14) $T^A_{it} = f\left[\left(\frac{T^P + T^O}{T}\right)_{it,} \; \left(\frac{Y}{P}\right)_{it,} \; \left(\frac{T^P + T^O}{P}\right)_{it,} \; Y_{it} \right]$

This model is a cross-sectional regional growth model. Thus, the national influence upon a local economy can be measured by the regional market share of the output in each manufacturing industry. Since manufacturing is also regarded as export-oriented, the level of production (value-added), $\sum_j X_{ij}$, also reflects the role of economic base theory in Equation (8). Regional consumption C_{it} and local govenment expenditure also are included in regional income determination. Equation (9) is a typical consumption function.

Equations (10) through (14) give local government revenues and expenditures sub-block. Equation (10) is merely a simple relation between local government expenditure, G_{it}, and total local government revenue, T_{it}. Equation (11) is an identity that treats total local government revenue as the sum of three components: local property tax, T^p_{it}, other local taxes and revenues, T^o_{it}, and federal and state transfer payment to the local government, T^A_{it}. Equation (12) is a property tax equation that states that local property tax is a function of gross assessed property value, A_{it}. Equation (13) relates other local taxes and revenues to per capita income of region, $(\frac{Y}{P})_{it}$, and regional income Y. Finally, a behavior equation of federal and state transfer payment to local government is given in Equation (14).* Transfer payment to the local government, T^A, is determined by the local taxes and the total local revenue effort $(T^p+T^o)/T$, regional per capita income $(\frac{Y}{P})$, per capita local tax, $(T^p+T^o)/P$, and regional income Y.

The results are given in Table 3.6. Since there is a dearth of consistent time series data for most of the variables contained in this block, the equations in this block (i.e., (11-14) were reestimated with 1967 data. Equations (8) through (10), as well as those in the labor market and fuel damand blocks, are the previously estimated equations (May 15, 1971). They are presented here for completeness.

---

*Originally, Federal and state transfer payments were treated as exogenous to the model. However, it was suggested by EPA staff that a behavior equation should be attempted in this model.

Table 3.6
Income Determination Block Equations

(8)	$Y_{it} = .4284 \sum_j X_{ijt} + .9481 C_{it} + 2.840 G_{it}$ $(.0564) \quad (.0661) \quad (.309)$	$(R^2=.997)$
(9)	$C_{it} = 137.99 + .6133 Y_{it} + .01214 C_{it-1}$ $(50.09) \quad (.0057) \quad (0012)$	$(R^2=.992)$
(10)	$G_{it} = 23.4227 + .9421 T_{it}$ $(4.108) \quad (.0048)$	$(R^2=.998)$
(11)	$T_{it} = T^p_{it} + T^o_{it} + T^A_{it}$	
(12)	$T^p_{it} = 0.568 A_{it}$ $(.0071)$	$(R^2=.915)$
(13)	$T^o_{it} = -.0045 \left(\frac{Y}{P}\right)_{it} + .0121 Y_{it}$ $(.0016) \quad (.0008)$	$(R^2=.756)$
(14)	$T^A_{it} = 317.84 - 815.72 \left(\frac{T^p + T^o}{T}\right)_{it} - .0272 \left(\frac{Y}{P}\right)_{it}$ $(80.76) \quad (154.7) \quad (.0125)$ $+ 1.055 \left(\frac{T^p + T^o}{P}\right)_{it} + .0471 (Y)_{it}$ $(.367) \quad (.0021)$	$(R^2=.881)$

Note:

- Y: Regional income
- C: Regional consumption
- G: Local government expenditures
- T: Total local revenue
- T^p: Local property tax
- T^o: Other local taxes and revenues
- T^A: Federal and state transfer payment
- A: Gross assessed value of regional property
- P: Population

3.5 Labor Market Block

In a recursive fashion, level of export activities by manufacturing block and regional income generates derived demand of labor in the regional labor market. The labor market block includes the following equations:

$$(15) \quad N_{it} = f(Y_{it} - \sum_j X_{ijt})$$

$$(16) \quad N_{it} = \bar{N}_{it} + \sum_j N_{ijt}$$

$$(17) \quad L_{it} = f(N_{it}, U_{it})$$

$$(18) \quad U_{it} = \frac{L_{it} - N_{it}}{L_{it}}$$

In Equation (15), employment in the sectors other than manufacturing industries, $\bar{N}_{it}$, is a function of the non-manufacturing income, $(Y_{it} - \sum_j X_{ijt})$, which is approximated by taking the difference between regional income and total value added by manufacturing industries. Equation (16) is an identity that shows that total regional employment, N_{it}, is the sum of employment in the sector other than manufacturing industries. $\bar{N}_{it}$, and manufacturing employment $\sum_j N_{ijt}$, were determined in the manufacturing block of the model. The regional labor force, L_{it}, is given as a function of total regional employment, N_{it}, and regional unemployment rate, U_{it}, in Equation (17). Finally, regional unemployment rate, U_{it}, is defined in Equation (18). The results are given in Table 3.7.

Table 3.7
Labor Market Block Equations

(15)	$\bar{N}_{it} = \underset{(9.52)}{56.36} + \underset{(.0016)}{.1032}(Y_{it} - \sum_j X_{ijt})$		$(R^2 = .978)$
(16)	$N_{it} = \bar{N}_{it} + \sum_j N_{ijt}$		
(17)	$L_{it} = \underset{(2.080)}{-13.958} + \underset{(.0009)}{1.0392}N_{it} + \underset{(55.97)}{361.37}U_i$		$(R^2 = .999)$
(18)	$U_{it} = \dfrac{L_{it} - N_{it}}{L_{it}} \times 100$		

Note:

- $\bar{N}$: Regional employment in the sectors other than manufacturing industries
- Y: Regional income
- $\sum_j X_j$: Manufacturing value added
- N: Total regional employment
- L: Regional labor force
- U: Regional unemployment rate

3.6 Regional Fuel Demand Block

It has been observed that the burning of coal, fuel oil and natural gas to produce power and heat is one of the most important sources of particulates, sulfur oxides, and nitrogen emission to the air. Coal, coke, fuel oil, natural gas and electricity are also the most important energy sources available to the manufacturing industries in the nation. Demand for energy increases as the manufacturing output increases. However, each type of manufacturing industry differs from the other in the production process; therefore, the type of fuels and combination of different type of fuel and electric power also differ from industry to industry.

On the other hand, it is true that there are substitutional relations among the different types of fuel and/or electricity to produce the energy (power and heat) necessary for any given level of product of an industry. Hence, industry may choose an optimal combination of fuels and electricity which minimizes the total cost of energy. This is to say, the prices of fuels and electricity also affect the demand for each type of fuel or amount of electricity in the production process of each type of manufacturing industry. Therefore, if the price of electricity or any type of fuel changes, then the demand for the fuels and electricity changes according to a new optimal combination which minimizes the total cost of the energy.

As the air pollution control policy is implemented, sulfur content in coal and fuel oils will greatly affect the price because of increased demand for low sulfur fuels and their limited supply. Prices of natural gas and electricity (partly by the increase in production cost) tend to change because of changes in demand and supply relations.

Demand for energy, and hence fuels, like the demand for labor or capital is an induced demand from moderation. Therefore, an appropriate way to incorporate an energy demand model into the regional model would be to reformulate the production functions in the regional model.

A production function describes the maximum output obtainable from every possible combination of inputs. Some of the inputs are substitutable for one another while others are non-substitutable and are proportional to the output. A general production relation can be conceived of various types of inputs, with substitutional relations among a group of inputs categorized into a number of sub-groups. Between any pair of sub-groups of inputs there is no substitutional relation. Further assume that inputs for a given industry have been classified into 3 groups of inputs. Since there is no substitutional relations among those 3 inputs, the productions function can be given as

$$X = \min\left(\frac{1}{a_1} X_1, \frac{1}{a_2} X_2, \frac{1}{a_3} X_3\right)$$

Each group's input is proportionate to the output. However, within each group of inputs there are substitutional relations:

$$X_i = f(x_{i1}, x_{i2}, \ldots, x_{in}), \qquad (i = 1, 2, 3),$$

f has all properties of a neo-classical production function. Therefore,

$$X = \min\left[\frac{1}{a} f_1(x_{11}, \ldots, x_{1n}), \frac{1}{a} f_2(x_{21} + 1, \ldots, x_{2n}), \frac{1}{a} f_3(x_{31} + 1, \ldots, x_{3n})\right].$$

Assume that X is gross product (or value of shipments of a given industry, V is its value-added, Z is energy requirement in this production, M is other intermediate good. Then

$$X = \min\left(\frac{1}{a_1} V, \frac{1}{a_2} Z, \frac{1}{a_3} M\right).$$

Thus, we can derive the relation between value-added and total energy as:

$$Z = \frac{a_2}{a_1} V ;$$

that is, energy demand is proportionate to the value-added.

Cost of energy equals the sum of the costs of all types of fuels which is the product of price q_r and the quantity demand of fuel E_e. For the 19 manufacturing industries we have*:

$$(19) \quad \sum_r E_{rij} q_{ri} = a_j V_{ij} \qquad (j = 1, \ldots, 19).$$

On the other hand, a Cobb-Douglas type of energy production function can be introduced which specifies the technical relation between fuels as inputs and total energy produced. Suppose there are five types of fuel, then:

$$(20) \quad Z_{ij} = B_{ij} \prod_{r=1}^{5} E_{rij}^{\beta ij} \qquad (j = 1, \ldots, 19),$$

$$(21) \quad \frac{E_{rij}}{E_{sij}} = \frac{q_{si}}{q_{ri}} \frac{\beta_{rj}}{\beta_{sj}} \qquad (j = 1, \ldots, 19) \quad (s \neq r, \ r, s = 1, \ldots, 5).$$

---

*For notational convenience, E_5 has been used for electricity instead of Q, thus $E_{5ij} \equiv Q_{ij}$. And E_1, E_2, E_3, and E_4 represent coal, coke, fuel oil, and natural gas, respectively. Not all two-digit SIC manufacturing industries use all five types.

Equation (20) gives the energy production by each manufacturing industry while equation (21) is simply derived from the equilibrium condition that price ratio between two types of fuels equals the ratio of marginal productivity of fuels.*

Residential and other non-manufacturing industry demands of electricity are given as:

(22) $Q_{ci}(t) = f[C_i(t)]$;

(23) $\bar{Q}_i(t) = f\left[Y_i(t) - \sum_j V_{ij}(t)\right]$;

(24) $Q_i(t) = \Sigma[Q_{ij}(t) + Q_{ci}(t) + \bar{Q}_i(t)]$.

Equation (22) relates regional industrial demand of electricity to regional consumption, while in equation (23) the demand of electricity by other industries is a function of non-manufacturing regional income. Equation (24) gives the total regional demand for electricity.

---

*Equation (15) can be derived from the equilibrium conditions of the minimization of energy cost ($Z_r = \Sigma q_r E_r$) subject to the energy production function [equation (14)]:
Minimize

$$Z = q_1E_1 + q_2E_2 + \ldots + q_5E_5 ,$$

subject to

$$Z = BE_1^{\beta_1} E_2^{\beta_2} E_3^{\beta_3} E_4^{\beta_4} E_5^{\beta_5} .$$

Since fuel prices (q_r) are exogenous variables, equations (13) through (15) solve for Z, E_1, E_2, E_3, E_4, E_5, for each industry.

This block of equations, estimated by cross-section data of 1967 earlier, is presented here in Tables 3.8, 3.9, and 3.10.

Table 3.8
Energy Demand Function

$$Z_{ij} = a_j V_{ij}$$

Industry SIC	a_j
20	2.13525
22	3.04152
23	0.74246
24	2.57780
25	1.33572
26	3.97124
27	0.61895
28	2.79554
29	9.43424
30	2.83225
31	1.15811
32	6.14368
33	10.68980
34	2.10111
35	1.34915
36	1.19740
37	1.35564
38	1.00903
39	1.44677

Table 3.9
Energy Production Function

$$Z_{ij} = B_j E_{1ij}^{\gamma_{1j}} E_{2ij}^{\gamma_{2j}} E_{3ij}^{\gamma_{3j}} E_{4ij}^{\gamma_{4j}} E_{5ij}^{\gamma_{5j}}$$

SIC Code	B_{ij}	γ_1	γ_2	γ_3	γ_4	γ_5	R^2
20	17.304	.0993	.0	.1107	.2250	.5651	.984
		(.0597)		(.0687)	(.0908)	(.0820)	
22	19.563	.1133	.0	.1544	.1070	.6254	.976
	(5.246)	(.0523)		(.0786)	(.0429)	(.1204)	
23	21.914	.0	.0	.0934	.0822	.8244	.998
	(7.570)			(.0572)	(.0359)	(.0817)	
24	19.061	.0	.0	.1707	.1110	.7183	.970
	(3.693)			(.0337)	(.0323)	(.0493)	
25	23.206	.0882	.0	.0873	.1243	.7002	.995
	(4.134)	(.0237)		(.0282)	(.0280)	(.0618)	
26	20.941	.2150	.0	.1318	.1378	.5154	.930
	(4.732)	(.1233)		(.0961)	(.0995)	(.1390)	
27	19.616	.0	.0	.0670	.1325	.8006	.982
	(1.963)			(.0206)	(.0352)	(.0503)	
28	12.312	.1564	.0	.0587	.2067	.5782	.920
	(4.514)	(.0798)		(.0618)	(.1109)	(.1352)	
29	3.063	.0	.0	.0620	.5371	.4009	.959
	(.700)			(.0594)	(.1387)	(.1308)	
30	14.935	.0	.0	.1030	.1236	.7734	.989
	(1.617)			(.0307)	(.0347)	(.0436)	
31	17.965	.1191	.0	.1535	.1105	.6169	.941
	(12.313)	(.0318)		(.0387)	(.0199)	(.0601)	
32	9.586	.1382	.0	.0818	.3780	.4020	.857
	(2.476)	(.0785)		(.0455)	(.1195)	(.0857)	

Table 3.9
(continued)

33	19.482	.0465	.1838	.1062	.2293	.4342	.983
	(4.450)	(.0195)	(.0852)	(.0546)	(.0701)	(.0982)	
34	17.059	.0352	.0	.1108	.2338	.6202	.993
	(1.719)	(.0173)		(.0588)	(.0762)	(.0691)	
35	19.981	.0688	.0	.1087	.1656	.6569	.987
	(2.734)	(.0363)		(.0663)	(.0597)	(.0687)	
36	16.827	.0493	.0	.0800	.1567	.7139	.955
	(2.912)	(.0142)		(.0391)	(.0436)	(.0556)	
37	17.572	.0905	.0	.0717	.1345	.7032	.990
	(5.738)	(.0321)		(.0406)	(.0394)	(.0536)	
38	18.982	.1141	.0	.1159	.1199	.6500	.969
	(8.577)	(.0591)		(.0226)	(.0197)	(.0593)	
39	20.846	.0608	.0	.1289	.1437	.6666	.985
	(4.008)	(.0182)		(.0436)	(.0661)	(.0980)	

Table 3.10
Regional Electricity Demand Function

(22)	$Q_{ci} = \underset{(.0022)}{.0472}C_i$	($R^2 = .880$)
(23)	$\overline{Q}_i = \underset{(.0042)}{.07947}(Y_i - \sum_j X_{ij})$	($R^2 = .846$)
(24)	$Q_i = Q_{ci} + \overline{Q}_i + \sum_j Q_{ij}$	

4.0 REGIONAL ECONOMIC IMPACTS OF AIR POLLUTION ABATEMENT: A SIMULATION WITH THE REVISED MODEL

As air pollution control requirements are instituted in the nation, the consequent effects are incident differentially in the various AQCRs. The primary purpose of regional economic modelling is to provide quantitative estimates of such differences among the AQCRs in any particular treatment (strategy) and among different treatments.

The second purpose of the model is to provide information on such differences among regions and among strategies that is useful in assessing implementation strategies. For example, it is possible to argue that the "perfect" strategy is one in which each AQCR suffers the same degree of economic hardship. Exact measurement of such a condition is impossible, since there is no single measure of economic hardship. However, the use of this regional model permits useful estimation of the degree of differences in the treatment of AQCRs necessary to achieve some degree of uniformity in the effects of implementation of pollution control requirements.

Other forms of targeted assistance (differential cost sharing, etc.) are also possible. Consequently, the regional model can be used to design and assess such "mixed" implementation strategies (in which different AQCRs are treated differently) by trial and error, so that some guidance may be available to EPA officials to achieve some degree of equity among AQCRs in control implementation.

This chapter is addressed to a description of the effort directed to both of the above purposes of the revised OAP Regional Econometric Model. First, it opens with a brief description of the framework analyses of economic impacts and the rationale for the measures of impact of control used in this chapter. It proceeds to a comparative description of the economic effects over time aggregated over 91 AQCRs under the alternative strategies. Next, it provides a comparison of strategies in terms of the geographic pattern of incidence of economic effects, specifically, the geographic distribution of economic hardships.

4.1 Alternative Implementation Strategies and Measures of Their Economic Effects

Two alternative strategies were formulated for simulation through the revised model.* These two strategies assume the preliminary EPA cost estimates based upon the standards resulting from the EPA Federal Register of August 14, 1971. Thus, they both assume the same aggregate costs for 91 AQCRs over the implementation period.

---

*These are the first two of the seven strategies formulated and simulated in the earlier model utilization experiments. See CONSAD Research Corporation, The OAP Regional Economic Model Utilization, Phase I, *op. cit.*, pp. 9-30.

However, they differ in the following manner:

Strategy 1: (Straight Implementation)	The actual implementation period is assumed to be 1973-1975. This is because states are expected to get their implementation plan approval and regulations in force by the end of fiscal year 1972. No additional governmental financial assistance than what is implicit in the existing tax structure is provided.
Strategy 2: (Extended Implementation)	Same as Strategy 1, except that it allows all AQCRs to extend the target year to 1977, as the maximum extension permitted by law, without any financial assistance from the government.

Given this difference in implementation costs, the geographic and time incidence of control costs vary among AQCRs (apart from their differences in terms of industrial composition). These varying levels of control costs lead, in turn, through the operation of the complex interrelationships of regional economies (as captured by the OAP model) to a range of effects on high emission industries, consumers, employment, taxpayers, local governments, and regional growth.

The simulation of the strategies through the OAP model provides a large number of measures of these economic effects (Figure 4. 1). Figure 4. 1 gives a sample output for the Pittsburgh AQCR in the year 1975 under strategy 1. There is a list of variables and four columns of outputs. The first column -- "without control" -- shows economic projections without any air pollution control. The second column --

FIGURE 4.1

THREE YEAR STRAIGHT IMPLEMENTATION -
WITHOUT GOVERNMENT ASSISTANCE

TOTAL NET EFFECT OF ALL CONTROL STRATEGIES PURSUED IN THIS RUN

AQCR 8 PITTSBURGH, PA.

	WITHOUT CONTROL	FOR 1975 WITH (T-1)	NET CHANGE	PERCENT CHANGE
MANUFACTURING INDUSTRIES				
VALUE ADDED (MILLIONS)	4676.742	4605.688	-71.916	-1.5615
PROFIT (MILLIONS)	1782.223	1727.928	-77.325	-4.4750
INVESTMENT (MILLIONS)	438.381	357.064	-78.209	-21.9033
CAPITAL STOCK (MILLIONS)	3679.000	3623.104	-73.906	-2.0398
EMPLOYMENT (1000 S)	309.880	308.086	-7.004	-2.2732
OTHER INDUSTRIES				
EMPLOYMENT (1000 S)	749.84	748.92	-1.741	-0.2325
TOTAL PERSONAL INCOME FOR THE REGION (MILLIONS)	10604.863	10525.047	-88.809	-0.8438
REGIONAL CONSUMPTION (MILLIONS)	6323.469	6265.809	-64.805	-1.0343
TOTAL REGIONAL EMPLOYMENT (1000 S)	1059.723	1057.007	-8.767	-0.8294
REGIONAL UNEMPLOYMENT (PERCENT)	4.000	4.000	0.7993	19.9817
TOTAL LABOR FORCE (1000 S)	1103.878	1101.048	-9.111	-0.8275
GOVERNMENT REVENUE FROM THE REGION (MILLIONS)	733.777	729.040	-5.269	-0.7227
GOVERNMENT REVENUE FROM PROPERTY TAXES (MILLIONS)	310.428	310.427	0.0	0.0
GOVERNMENT REVENUE OTHER THAN PROPERTY TAX (MILLIONX)	90.148	88.865	-2.019	-2.2725
INTRAGOVERNMENT AID TO THE REGION (MILLIONS)	333.201	328.260	-7.777	-2.3693
ELECTRIC POWER DEMAND				
TOTAL ELECTRIC CONSUMPTION FOR THE REGION (10 M KWS)	1476.774	1459.219	-18.722	-1.2830
ELECTRICITY USED BY MANUFACTURING INDUSTRIES (10 M KWH)	710.333	696.184	-14.322	-2.0572
ELECTRICITY USED BY OTHER INDUSTRIES (10 M KWH)	360.964	360.280	-1.342	-0.3726
RESIDENTIAL CONSUMPTION IN THE REGION (10 M KWH)	405.476	402.755	-3.057	-0.7591

"with (T-1)" -- provides the projection of the variable in column 1 with air pollution control to year T-1 (which is 1974) but before control is applied in 1975. It shows the cumulative effects of control through 1974 before control of 1975. The third column shows "net change" of control in year 1975 and the last column shows percentage change of control in year 1975. An assessment of these effects is best organized by identifying from among this long list a few indicators of strategic importance to the purpose at hand. The purpose at hand is:

- To compare alternative strategies in terms of effects aggregated over 91 AQCRs.
- To compare the alternative strategies in terms of the degree of adverse effects in different AQCRs.
- To explore the geographic patterns of impacts in terms of industries, regions, government and communities.
- To describe the geographic patterns of these effects in terms of the locational factors, industrial structure and economic histories of these AQCRs. The objective of this speculation is to identify to some degree the transitional adjustment problems in severely affected AQCRs.

The measures that appear to be relevant from these criteria for five major economic indicators in the regional economy are as follows:

Measure

1. Manufacturing production (value-added)
2. Manufacturing investments (for production)
3. Regional personal income
4. Unemployment rate
5. Manufacturing gross profit

The rest of this chapter interprets the results of the simulation of the various strategies in terms of these five measures.

4.2 Total Net Effects of Alternative Strategies

This section presents the effects of the two major strategies aggregated over all these 91 AQCRs. The 91 AQCRs included in the current study are the major metropolitan areas of the United States. They account for 64 percent of the regional personal income, 56 percent of total labor force, and 60 percent of the total manufacturing industries in the United States.* In general, these AQCRs have a lower than national average of agriculture and mining production but a higher than average of manufacturing, transportation, wholesale-retail trade, finance and service sectors.

Table 4.1 provides the economic effects aggregated over 91 AQCRs under two strategies, namely, a straight implementation by 1975 and an extended implementation by 1977.**

Several points are fairly evident when these tables are examined:

- The economic effects under the different strategies are sufficiently different to suggest that the regional economies are sensitive to the

---

*Personal income projections of the United States and regional aggregations for the year 1967 and manufacturing production percentages in 91 AQCRs is estimated from Census of Manufactures, 1967.

**For a detailed description of control strategy alternatives, see T. R. Lakshmanan, F. Lo, and R. Byrne, The OAP Regional Economic Model Utilization, Volume I, Simulation and Analysis, prepared for the Environmental Protection Agency, by CONSAD Research Corporation, Pittsburgh, Pennsylvania, January, 1972.

Table 4.
Aggregate Economic Effects on 91 AQCRs

	Three Year Straight Implementation			Five-Year Extended Implementation				
Regional	1973	1974	1975	1973	1974	1975	1976	1977
Employment (1000)								
without control	588.41	617.44	648.05	588.41	617.44	648.05	679.86	713.42
Change with control	-.70	-1.84	-2.96	-.25	-.54	1.81	-2.47	-1.65
Percentage change	-.12	-.30	-.46	-.04	-.08	-.28	-.36	-.23
Manufacturing								
Value-added ($ billion)								
without control	188.50	195.50	202.75	188.50	195.49	202.75	210.55	218.65
Change with control	-.39	-.95	-1.42	-.14	-.28	-.97	-1.18	-.48
Percentage change	-.21	-.49	-.71	-.07	-.14	-.48	-.57	-.22
Regional Personal								
Income ($ billion)								
without control	561.69	589.23	618.19	561.69	589.23	618.19	648.40	680.16
Change with control	-.54	-1.37	-2.16	-.19	-.38	-1.38	-1.77	-.92
Percentage change	-.10	-.23	-.34	-.03	-.06	-.22	-.27	-.14
Manufacturing								
Investment ($ billion)								
without control	13.97	14.50	15.04	13.97	14.49	15.03	15.62	16.22
Change with control	-.35	-.83	-1.19	-.12	-.25	-.86	-.99	-.27
Percentage change	-2.53	-5.87	-8.66	-.87	-1.71	-5.86	-6.92	-1.97
Manufacturing Gross Profit								
Value-added minus wage bill ($ billion)								
without control	89.79	93.15	96.63	89.78	93.14	96.63	100.38	104.27
Change with control	-.21	-.67	-1.28	-.07	-.20	-.68	-1.15	-1.17
Percentage change	-.24	-.72	-1.33	-.08	-.22	-.71	-1.16	-1.15

differences in the strategies. The different economic indicators move in the same consistent direction among the strategies.

- Expectedly, the economic indicators of the manufacturing sector (high emission) show the greatest range of differences on a percentage scale among the strategies. The regional economy and government indicators show a narrower range of variations.

- Extension of the implementation period from three to five years in each case reduces the aggregate adverse economic effects. This is to be expected in view of the spread of control costs over a longer period. Further, the regional economies of 1977 are larger than those of 1975 and the control costs may be a smaller percentage of the aggregate regional economies.

More specifically, Table 4.1 shows that, with straight implementation by 1975, manufacturing production (measured by value-added) in these AQCRs will decrease 1.42 percent by 1975. Further, investment in manufacturing industries (for production capacity) will drop from $15 billion to $12.6 billion which is about a 16 percent drop. Personal income is expected to decrease 0.34 percent while the unemployment rate will increase by 0.46 percent. This indicates that the manufacturing sector, bearing the brunt of the control costs, will be more sensitive to the air pollution control compared with regional income, and unemployment rate. Manufacturing gross profits will drop about 2.3 percent. Consequently, when comparing the 1973-1975 strategies with 1973-1977 strategies, it is clear that extension of the time of implementation is likely to help.

4.3 Geographical Patterns of Economic Growth

The previous section dealt with only the aggregate effects of 91 AQCRs during the implementation periods with and without two-year extensions. However, behind these aggregate patterns lies a wide variation in economic effects among the different AQCRs. For example, if implementation is required by 1975, manufacturing production (value-added) will drop 0.8 percent by 1975. However, there will be 28 out of 91 AQCRs which have one percent or more reduction in the manufacturing production, and six AQCRs will be in the range of 3.0 percent and over.

It also shows that most of the AQCRs seriously adversely affected are located in the heavily-industrial north-central (Michigan, Ohio, Indiana, Illinois) and central-east (Pennsylvania, West Virginia) states. AQCRs located in the west and south, in general, do not seem to be affected by air pollution control and some are even better off. Therefore, air pollution control under Strategy 1 may conceivably lead to a locational redistribution of the economic activity of the nation as a result of increased growth in the newer metropolitan areas and the greater economic pressure on the older heavy industrial areas.

The degree of economic impacts upon each AQCR can be analyzed by identifying the AQCRs into different groups as shown in Tables 4.2 through 4.6 for five variables, and geographic distribution of the corresponding tables are given in Figures 4.2 through 4.6.

- Regional unemployment rate (Table 4.2 and Figure 4.2)
- Manufacturing value-added (Table 4.3 and Figure 4.3)
- Manufacturing gross profit (Table 4.4 and Figure 4.4)
- Manufacturing investment (Table 4.5 and Figure 4.5)
- Regional personal income (Table 4.6 and Figure 4.6)

A more detailed result on two groups of AQCRs, namely, AQCRs with regional unemployment rate expected to increase 0.5 to one percent, and AQCRs with unemployment rate expected to increase one percent and over, are shown in Table 4.7.

Table 4.2

Three-year Straight Implementation by 1975

AQCRs with less than .49 percent increase in the regional unemployment:

1. New York
3. Los Angeles
4. Philadelphia
6. San Francisco
7. Boston
10. Washington, D.C.
11. Cleveland
12. Baltimore
14. Minneapolis
15. Houston
20. Dallas
21. Seattle-Everett
22. Kansas City, Mo.
23. San Diego
24. Atlanta
25. Indianapolis
26. Miami
27. Denver
29. Portland, Oregon
30. Providence
31. Phoenix
32. Tampa
33. Columbus
34. San Antonio
35. Dayton
39. Chattanooga
40. Memphis
41. Salt Lake City
42. Oklahoma City
44. Honolulu
48. Albuquerque
50. El Paso
51. Las Vegas
53. Boise
66. Grand Rapids, Mich.
67. Greensboro, N.C.
69. Jacksonville, Fla.
71. Nashville
73. Richmond, Va.
74. Rochester, N.Y.
78. Tulsa, Okla.
81. Albany-Troy.
87. Fort Wayne
88. Jackson, Miss.
92. Norfolk/Newport
95. Rockford, Ill.
96. Sacramento
99. Wichita

AQCRs with an increase in unemployment rate between .50 and .99 percent:

2. Chicago
5. Detroit
8. Pittsburgh
9. St. Louis
16. Buffalo
17. Milwaukee
18. Cincinnati
19. Louisville
28. New Orleans
36. Birmingham
37. Toledo
43. Omaha
46. Charlotte
47. Portland, Maine
55. Sioux City, S.D.
61. Allentown-Easton
64. Davenport
68. Harrisburg, Pa.
70. Knoxville, Tenn.
72. Peoria, Ill.
75. Saginaw/Bay City
77. Syracuse
82. Binghamton, N.Y.
83. Charleston, S.C.
84. Charleston, W.V.
85. Des Moines
86. Fresno, Calif.
90. Lancaster, Pa.
91. Mobile, Ala.
93. Raleigh/Durham
94. Reading, Pa.
97. South Bend, Ind.
98. Utica-Rome
100. York, Pa.

AQCRs with an increase in unemployment greater than 1.0 percent:

38. Steubenville area
45. Beaumont, Texas
52. Fargo-Moorehead
54. Billings
63. Bakersfield, Calif.
76. Scranton area
80. Youngstown-Warren
89. Johnstown, Pa.

Figure 4.2
Geographic Distribution of Economic Effects Measured by Change of Regional Unemployment Rate

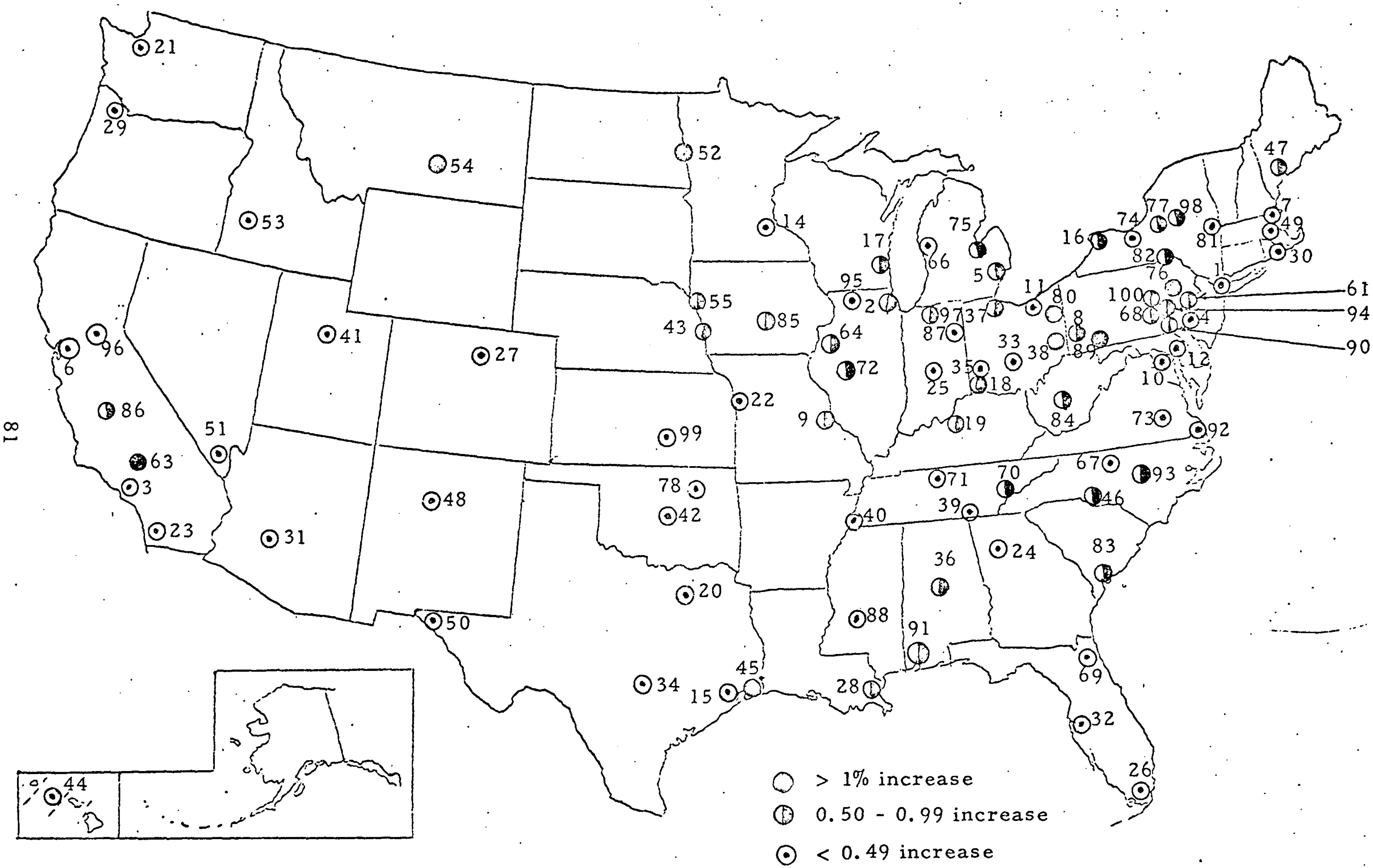


Table 4.3

Three-year Straight Implementation by 1975

AQCRs with a decrease in Manufacturing Production (Value Added) of less than .99 percent:

1. New York
2. Chicago
3. Los Angeles
4. Philadelphia
5. Detroit
6. San Francisco
7. Boston
11. Cleveland
12. Baltimore
14. Minneapolis
15. Houston
17. Milwaukee
18. Cincinnati
19. Louisville
20. Dallas
21. Seattle-Everett
22. Kansas City
23. San Diego
24. Atlanta
25. Indianapolis
26. Miami
27. Denver
29. Portland, Ore.
30. Providence
31. Phoenix
33. Columbus
34. San Antonio
35. Dayton
39. Chattanooga
40. Memphis
41. Salt Lake City
42. Oklahoma City
43. Omaha
44. Honolulu
46. Charlotte, N.C.
47. Portland, Maine
48. Albuquerque
50. El Paso
51. Las Vegas
53. Boise
64. Davenport/Moline
66. Grand Rapids
67. Greensboro, N.C.
71. Nashville
72. Peoria, Ill.
73. Richmond, Va.
74. Rochester, N.Y.
75. Saginaw/Bay City
77. Syracuse
81. Albany Area
82. Binghamton, N.Y.
84. Charleston, W.Va.
87. Fort Wayne, Ind.
90. Lancaster, Pa.
93. Raleigh/Durham
94. Reading, Pa.
95. Rockford, Ill.
96. Sacramento
97. South Bend
98. Utica Rome, N.Y.
99. Wichita
100. York, Pa.

AQCRs with a decrease in Manufacturing Production (Value Added) of between 1.0 and 2.99 percent:

8. Pittsburgh
9. St. Louis
10. Washington, D.C.
16. Buffalo, N.Y.
32. Tampa
36. Birmingham, Ala.
37. Toledo
52. Fargo-Moorehead
55. Sioux City, S.D.
61. Allentown/Easton area
68. Harrisburg
69. Jacksonville, Fla.
70. Knoxville, Tenn.
76. Scranton, Pa.
78. Tulsa
80. Youngstown/Warren
83. Charleston, S.C.
85. Des Moines
86. Fresno, Calif.
88. Jackson, Miss.
91. Mobile, Ala.
92. Norfolk, Va. area

AQCRs with a decrease in Manufacturing Production of over 3 percent:

28. New Orleans
38. Steubenville area
45. Beaumont/Orange
54. Billings
63. Bakersfield, Calif.
89. Johnstown, Pa.

Figure 4.3
Geographic Distribution of Economic Effects
Measured by Change of Manufacturing Production
(Value-Added)

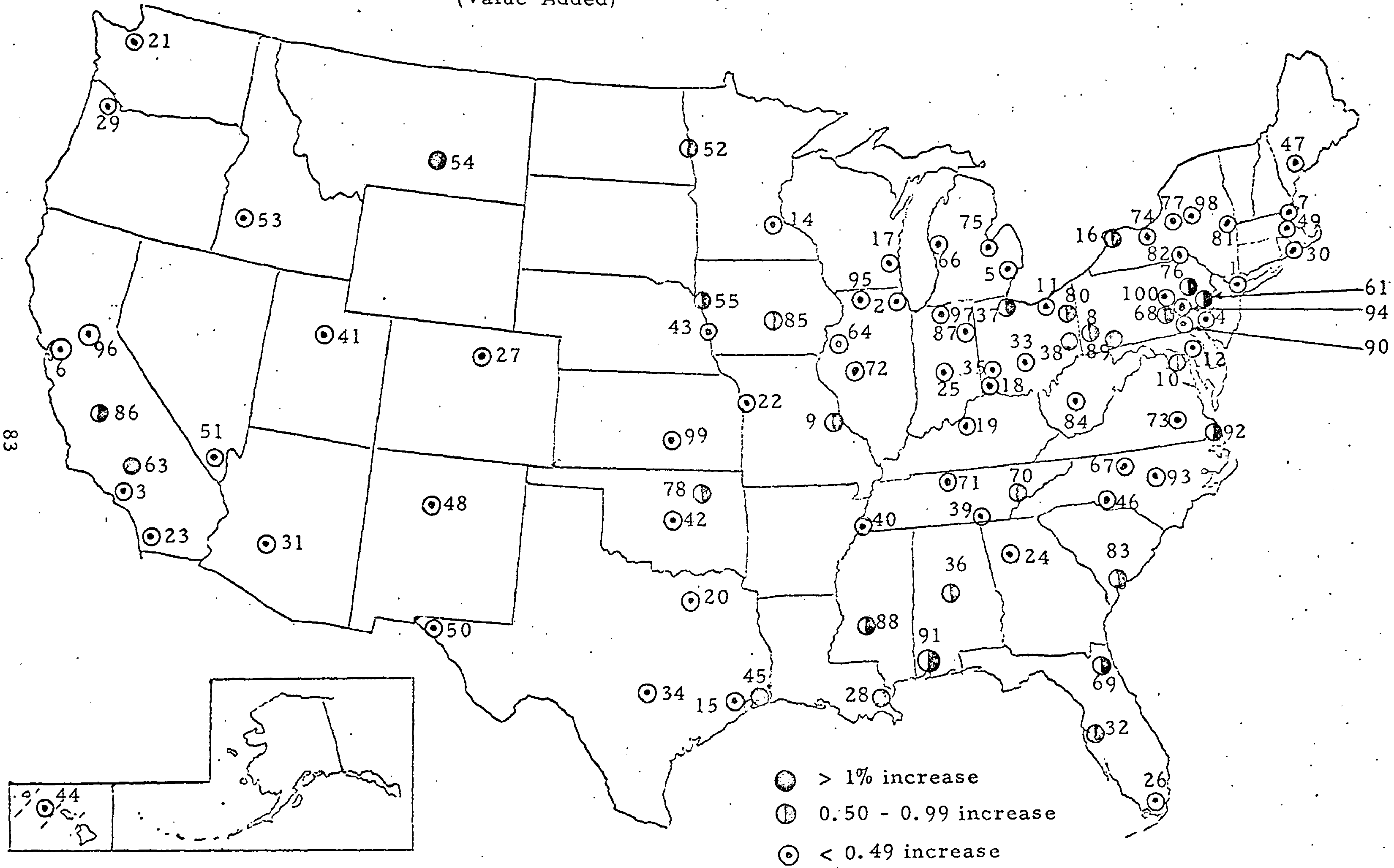


Table 4.4
Three-year Straight Implementation by 1975

AQCRs with a decrease in Manufacturing Investment of less than 9.9 percent:

1. New York
3. Los Angeles
4. Philadelphia
5. Detroit
6. San Francisco
7. Boston
11. Cleveland
14. Minneapolis
15. Houston
17. Milwaukee
18. Cincinnati
19. Louisville
20. Dallas
21. Seattle-Everett
22. Kansas City, Mo.
23. San Diego
24. Atlanta
25. Indianapolis
26. Miami
27. Denver
30. Providence
31. Phoenix
33. Columbus
34. San Antonio
35. Dayton
38. Steubenville area
39. Chattanooga
40. Memphis, Tenn.
41. Salt Lake City
42. Oklahoma City
43. Omaha
44. Honolulu
46. Charlotte
47. Portland
48. Albuquerque
50. El Paso
51. Las Vegas
53. Boise, Idaho
64. Davenport
66. Grand Rapids
67. Greensboro
71. Nashville
72. Peoria
73. Richmond
74. Rochester
75. Saginaw/Bay City
81. Albany/Troy
82. Binghamton
84. Charleston, W. Va.
87. Fort Wayne, Ind.
90. Lancaster, Pa.
93. Raleigh/Durham
94. Reading
95. Rockford
96. Sacramento
97. South Bend
98. Utica-Rome, N.Y.
100. York, Pa.

AQCRs with a decrease in Manufacturing Investment of between 10.0 and 19.9 percent:

2. Chicago
9. St. Louis
10. Washington, D.C.
12. Baltimore
16. Buffalo
29. Portland, Ore.
45. Beaumont/Orange
52. Fargo-Moorehead
54. Billings
61. Allentown area
69. Jacksonville, Fla.
76. Scranton
77. Syracuse
83. Charleston, S.C.
85. Des Moines
86. Fresno, Calif.
88. Jackson, Miss.
91. Mobile, Ala.
92. Norfolk, Va. area
99. Wichita

AQCRs with a decrease in Manufacturing Investment of more than 20 percent:

8. Pittsburgh
28. New Orleans
32. Tampa
36. Birmingham
37. Toledo
55. Sioux Falls, S.D.
63. Bakersfield, Calif.
68. Harrisburg, Pa.
70. Knoxville, Tenn.
78. Tulsa
80. Youngstown/Warren
89. Johnstown, Pa.

Figure 4.4
Geographic Distribution of Economic Effects
Measured by Change of Manufacturing Investment

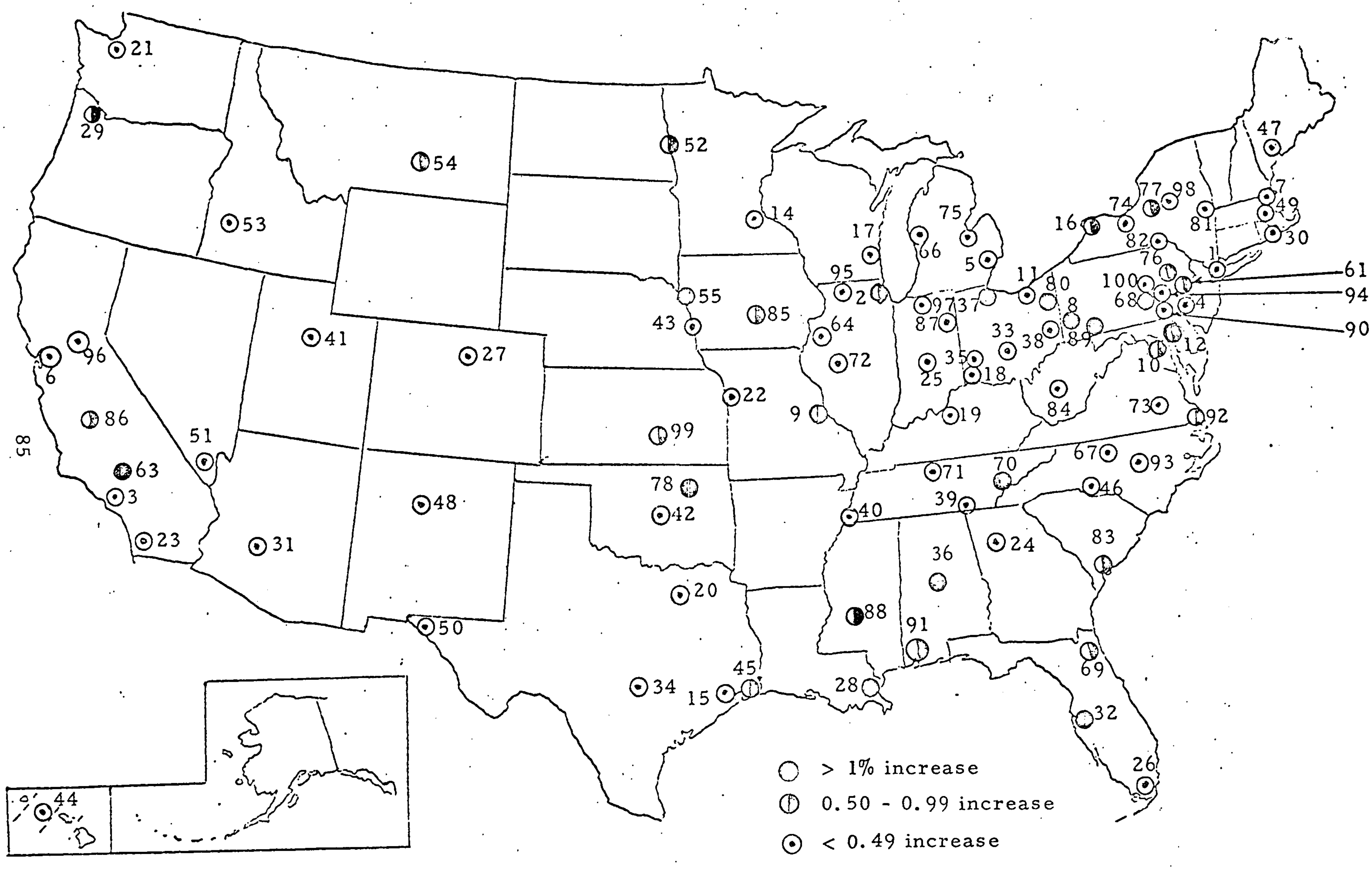


Table 4.5
Three-Year Straight Implementation by 1975

AQCRs with decrease in Manufacturing Profit of less than .99 percent.

1. New York
3. Los Angeles
6. San Francisco
7. Boston
14. Minneapolis
15. Houston
19. Louisville
20. Dallas
22. Kansas City
23. San Diego
24. Atlanta
25. Indianapolis
26. Miami
27. Denver
29. Portland, Ore.
30. Providence
33. Columbus
35. Dayton
39. Chattanooga
40. Memphis
44. Honolulu
50. El Paso
51. Las Vegas
67. Greensboro
74. Rochester
84. Charleston, W. Va.
87. Fort Wayne
95. Rockford, Ill.
96. Sacramento

AQCRs with decrease in Manufacturing Profit of between 1.0 and 2.99 percent.

2. Chicago
4. Philadelphia
5. Detroit
9. St. Louis
11. Cleveland
12. Baltimore
16. Buffalo
17. Milwaukee
18. Cincinnati
21. Seattle-Everett
31. Phoenix
32. Tampa
34. San Antonio
41. Salt Lake City
42. Oklahoma City
43. Omaha
45. Beaumont/Orange
46. Charlotte, N. C.
47. Portland, Maine
48. Albuquerque
64. Davenport
66. Grand Rapids
69. Jacksonville
71. Nashville
72. Peoria
73. Richmond
75. Saginaw/Bay City
77. Syracuse
81. Albany-Troy
82. Binghamton
85. Des Moines
86. Fresno, Calif.
88. Jackson, Miss.
90. Lancaster, Pa.
91. Mobile, Ala.
93. Raleigh/Durham
94. Reading, Pa.
97. South Bend, Ind.
98. Utica-Rome
99. Wichita
100. York, Pa.

AQCRs with a decrease in Manufacturing Profit of more than 3 percent.

8. Pittsburgh
10. Washington, D. C.
28. New Orleans
36. Birmingham
37. Toledo
38. Steubenville
39. Fargo-Moorehead
53. Boise
54. Billings
55. Sioux City
61. Allentown area
63. Bakersfield, Calif.
68. Harrisburg, Pa.
70. Knoxville, Tenn.
76. Scranton area
78. Tulsa, Okla.
80. Youngstown-Warren
83. Charleston, S. C.
89. Johnstown, Pa.
92. Norfolk area

Figure 4.5
Geographic Distribution of Economic Effects
Measured by Change of Manufacturing Profit

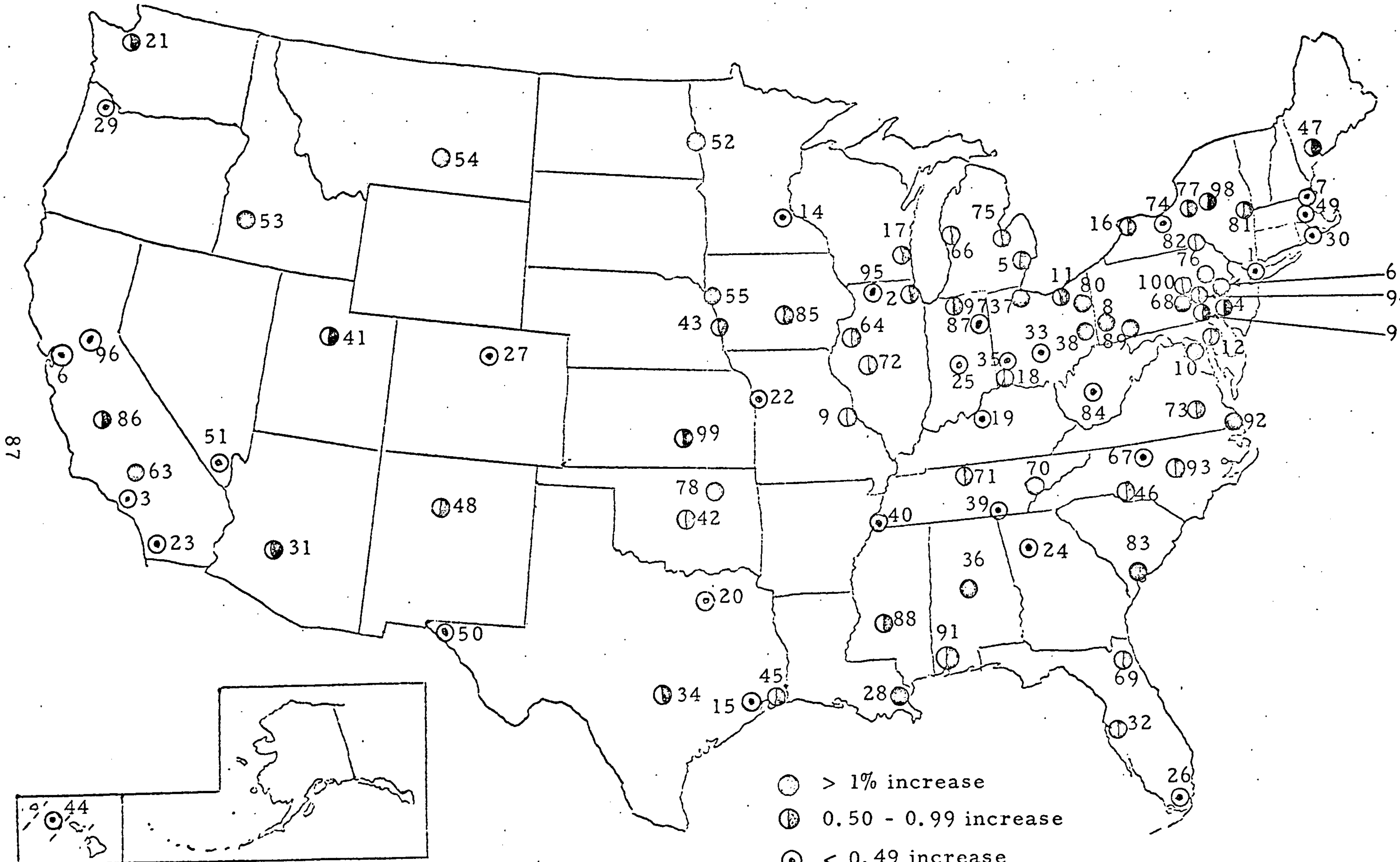


Table 4.6
Three-Year Straight Implementation by 1975

AQCRs with decrease in regional personal income of less than .49 percent.

1. New York
3. Los Angeles
4. Philadelphia
5. Detroit
6. San Francisco
7. Boston
10. Washington, D.C.
11. Cleveland
12. Baltimore
14. Minneapolis
15. Houston
20. Dallas
21. Seattle-Everett
22. Kansas City
23. San Diego
24. Atlanta
25. Indianapolis
26. Miami
27. Denver
29. Portland, Ore.
30. Providence
31. Phoenix
32. Tampa
33. Columbus
34. San Antonio
35. Dayton
40. Memphis
41. Salt Lake City
42. Oklahoma City
43. Omaha
44. Honolulu
46. Charlotte, N.C.
47. Portland, Maine
48. Albuquerque
50. El Paso
51. Las Vegas
53. Boise
66. Grand Rapids
67. Greensboro
69. Jacksonville
71. Nashville
73. Richmond
74. Rochester
78. Tulsa
81. Albany-Troy
83. Charleston, S.C.
86. Fresno, Calif.
87. Fort Wayne
88. Jackson, Miss.
91. Mobile, Ala.
92. Norfolk, Va. area
93. Raleigh/Durham
94. Reading, Pa.
95. Rockford, Ill.
96. Sacramento, Calif.
99. Wichita
100. York, Pa.

AQCRs with decrease in regional personal income between .50 and .99 percent.

2. Chicago
8. Pittsburgh
9. St. Louis
16. Buffalo
17. Milwaukee
18. Cincinnati
19. Louisville
28. New Orleans
36. Birmingham, Ala.
39. Chattanooga
52. Fargo-Moorehead
55. Sioux City
61. Allentown area
63. Bakersfield, Calif.
64. Davenport
68. Harrisburg, Pa.
72. Peoria, Ill.
75. Saginaw/Bay City
76. Scranton area
77. Syracuse
82. Binghamton
84. Charleston, W.Va.
85. Des Moines
90. Lancaster, Pa.
97. South Bend, Ind.
98. Utica-Rome

AQCRs with decrease in regional personal income of more than 1.0 percent.

37. Toledo
38. Steubenville
45. Beaumont-Orange
54. Billings
70. Knoxville, Tenn.
80. Youngstown-Warren
89. Johnstown, Pa.

Figure 4.6
Geographic Distribution of Economic Effects
Measured by Change of Regional Personal Income

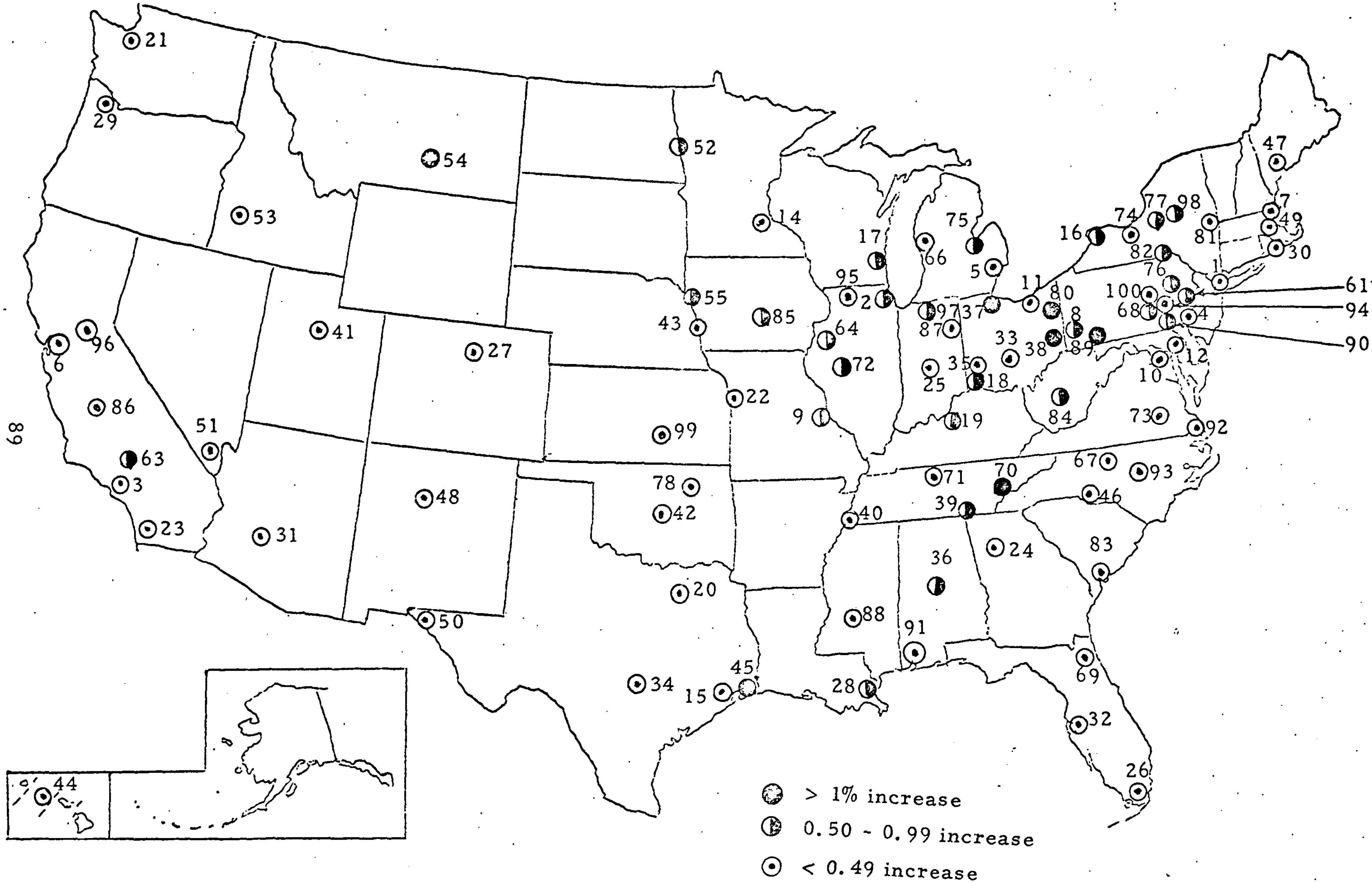


Table 4.7
Economic Effects on Selected AQCRs Under the Two Alternative Strategies as Measured by Five Key Variables

Selected AQCRs	Strategy 1 (1975)					Strategy 2 (1976)				
	Mfg. Value % Change	Mfg. Invest. % Change	Reg. P. Inc. % Change	Reg. Unemp. % Change	Mfg. Profit % Change	Mfg. Value % Change	Mfg. Invest. % Change	Reg. P. Inc. % Change	Reg. Unemp. % Change	Mfg. Profit % Change
2 Chicago	-.95	-16.11	-.53	.61	-1.68	-.69	-11.24	-.41	.52	-1.89
5 Detroit	-.56	- 5.93	-.42	.63	-1.28	-.41	- 4.16	-.34	.55	-1.44
8 Pittsburgh	-1.56	-21.90	-.84	.80	-4.48	-1.19	-16.99	-.65	.60	-4.31
9 St. Louis	-1.04	-14.62	-.62	.71	-2.11	-.73	-9.93	-.47	.60	-2.28
16 Buffalo	-1.20	-16.05	-.91	.87	-2.89	-1.01	-13.66	-.82	.76	-2.22
17 Milwaukee	-.54	-4.72	-.58	.90	-1.21	-.45	-3.96	-.47	.72	-.97
18 Cincinnati	-.75	-9.92	-.62	.75	-1.09	-.53	-6.35	-.39	.54	-1.28
19 Louisville	-.62	-7.87	-.64	.81	-.75	-.40	-4.46	-.46	.69	-1.01
28 New Orleans	-3.20	-75.47	-.82	.53	-4.92	-2.58	-61.47	-.66	.42	-4.49
36 Birmingham	-1.97	-33.91	-.95	.76	-3.21	-1.38	-23.16	-.70	.64	-3.91
37 Toledo	-1.82	-24.59	-1.12	.97	-3.15	-1.39	-18.76	-.88	.81	-3.22
43 Omaha	-.71	-7.04	-.44	.74	-1.14	-.65	-7.80	-.36	.54	-.58
46 Charlotte	-.52	-2.12	-.31	.53	-1.47	-.54	-2.74	-.27	.38	-.63
47 Portland, Me.	-.67	-6.12	-.38	.56	-1.54	-.62	-6.56	-.31	.47	-.78
55 Sioux City, SD	-2.50	-96.79	-.54	.60	-3.56	-2.08	-90.62	-.42	.43	-2.43
61 Allentown Area	-1.30	-11.36	-.77	.82	-4.18	-1.16	-10.37	-.64	.60	-2.74
64 Davenport	-.68	-4.97	-.56	.60	-1.32	-.65	-5.43	-.46	.40	-.57

Economic Effects on Selected AQCR's (continued)

Selected AQCRs	Strategy 1 (1975)					Strategy 2 (1976)				
	Mfg. Value % Change	Mfg. Invest. % Change	Reg. P. Inc. % Change	Reg. Unemp. % Change	Mfg. Profit % Change	Mfg. Value % Change	Mfg. Invest. % Change	Reg. P. Inc. % Change	Reg. Unemp. % Change	Mfg. Profit % Change
68 Harrisburg	-2.34	-40.31	-.88	.88	-4.87	-2.15	-43.26	-.73	.63	-2.68
70 Knoxville	-2.67	-50.01	-1.14	.97	-3.39	-2.37	-49.40	-.94	.71	-2.17
72 Peoria, Ill.	-.80	-5.36	-.56	.61	-1.61	-.73	-5.15	-.47	.44	-.99
75 Saginaw/ Bay City	-.74	-1.33	-.57	.88	-2.06	-.63	-1.15	-.44	.66	-1.55
77 Syracuse	-.77	-4.71	-.55	.84	-2.56	-.76	-6.18	-.45	.58	-1.19
82 Binghamton NY	-.56	-4.99	-.50	.78	-1.72	-.53	-6.01	-.44	.59	-.85
83 Charleston, SC	-2.18	-10.99	-.40	.53	-4.43	-2.11	-12.35	-.34	.38	-2.27
84 Charleston, W. Va.	-.51	-2.97	-.53	.52	-.98	-.46	-2.64	-.48	.47	-.72
85 Des Moines	-1.22	-12.09	-.66	.79	-2.82	-1.01	-10.30	-.52	.60	-2.18
86 Fresno, Calif.	-1.92	-12.51	-.48	.88	-2.64	-1.66	-12.66	-.38	.64	-1.50
90 Lancaster, Pa.	-.52	-5.37	-.51	.61	-2.25	-.58	-7.13	-.46	.44	-.99
91 Mobile, Ala.	-1.21	-11.86	-.42	.50	-2.47	-1.18	-12.22	-.37	.39	-1.43
93 Raleigh/ Durham	-.77	-3.47	-.34	.92	-2.18	-.81	-5.42	-.27	.62	-.87
94 Reading, Pa.	-.61	-5.92	-.45	.59	-1.99	-.62	-6.51	-.38	.41	-.94
97 South Bend	-.56	-4.88	-.51	.82	-1.40	-.53	-5.57	-.41	.58	-.68
98 Utica/Rome	-.60	-5.58	-.57	.94	-1.49	-.54	-6.13	-.45	.66	-.86
100 York, Pa.	-.50	-5.45	-.40	.52	-1.06	-.46	-5.06	-.39	.40	-.66

Economic Effects on Selected AQCRs (continued)

Selected AQCRs	Strategy 1 (1975)					Strategy 2 (1976)				
	Mfg. Value % Change	Mfg. Invest. % Change	Reg. P. Inc. % Change	Reg. Unemp. % Change	Mfg. Profit % Change	Mfg. Value % Change	Mfg. Invest. % Change	Reg. P. Inc. % Change	Reg. Unemp. % Change	Mfg. Profit % Change
38 Steubenville Area	-4.85	-7.78	-4.72	1.60	-8.42	-3.76	-3.94	-4.15	1.50	-11.55
45 Beaumont, Tex.	-3.48	-18.23	-4.25	1.01	-1.53	-2.81	-14.77	-3.75	.80	-1.39
52 Fargo/ Moorehead	-2.95	-17.90	-.63	1.10	-6.39	-2.64	-24.15	-.39	.66	-2.93
54 Billings	-3.05	-18.15	-1.30	2.01	-4.61	-2.86	-18.13	-1.09	1.48	-2.77
63 Bakersfield	-7.13	-45.09	-.77	1.70	-9.61	-5.88	-38.37	-.62	1.33	-7.63
76 Scranton Area	-1.32	-13.78	-.92	1.68	-7.43	-1.61	-27.07	-.85	1.19	-2.87
80 Youngstown/ Warren	-1.71	-47.75	-1.24	1.06	-4.71	-1.49	-43.45	-1.01	.76	-3.37
89 Johnstown, Pa.	-3.50	-30.53	-1.53	1.51	-8.76	-3.17	-31.17	-1.27	1.05	-4.97

5.0 VALIDATION OF THE OAP ECONOMIC MODEL: REVISED VERSION

5.1 Introduction

The essential stages of the development of a simulation model may be represented as systems analysis, synthesis, verification, validation and inference.* The previous sections have dealt with analysis, synthesis and inference. This section deals with "validation" and the next section deals with "verification" in the sense in which Fishman and Kiviat** segmented the problem of checking the reliability of the model:

- validation--testing the agreement between the behavior of the simulation model (i.e., the estimates) and the real system (i.e., the actuals),
- verification--ensuring that the model behaves in special cases as the experimenter/model-builder intends.

Section 5.2 discusses the methods used in this study for the validation of the OAP Regional Economic Model in its revised form: t-test, distribution over intervals of 1, 2, and 3 standard errors, regression between estimates and actuals and the non-parametric U-test.

---

* Mihram, G.A., "Some Practical Aspects of the Verification and Validation of Simulation Models," Operational Research Quarterly, Vol. 23, No. 1, March 1972.

** Fishman, G.S., and Kiviat, P.J., "Digital Computer Simulation: Statistical Considerations," Rand Corp. (RM-5387), Santa Monica, Calif., 1967. (Also published as "The Statistics of Discrete-Event Simulation," Simulation, 10, page 185).

Section 5.3 presents the results with a brief discussion. Then the conclusions of validation are summarized in section 5.4.

5.2 Method

5.2.1 General

In accordance with Fishman and Kiviat,* Van Horn** defines validation as "the process of building an acceptable level of confidence that an inference about a simulated process is a correct inference for the actual process." Mihram*** has surveyed the literature on the methods available for the validation of simulation models defined as above. From the literature, five methods have been adopted as the most suitable for the present validation. By testing validity by five different methods and noting how far their results converge or diverge, greater confidence can be placed on the predictions from the model.

---

* Fishman, G.S., and Kiviat, P.J., op. cit.

** Van Horn, R., "Validation," in "The Design of Computer Simulation Experiments," (ed. T.H. Naylor), Duke University Press, Durham, 1969, pp. 232-251.

*** Mihram, G.A., op. cit., pp. 25-27.

5.2.2 The Model

The main components of the OAP Regional Economic Model* are 120 equations in the manufacturing sector to predict the six variables--employment, value added, investment, profit, wage rate, and capital stock--for the manufacturing sector of 19 two-digit SIC detail industries and one aggregate of all 19 two digit-detail industries. There are also 15 equations in the other sectors combining manufacturing and non-manufacturing aspects for varaibles such as personal income, government expenditure, consumption, labor, employment (total), unemployment, non-manufacturing employment, electric consumption of four kinds and taxes of four types.

The model can be considered to consist of equations of the general form $YE_{ij}=f_j(X_{ij})$ where YE_{ij} is the estimate of the actual dependent variable Y_{ij} for Air Quality Control Regions $i = 1, 2, \ldots, 91$ for industrial sectors $j = 1, 2, \ldots, 20$, "all manufacturing industries" together being included in the twenty.

---

* Please see Section 3.0 for details.

5.2.3 Validation Tests

By definition of validation, validation consists in building an acceptable level of confidence that YE_{ij} are in agreement with Y_{ij}.

It has been stated earlier that five different methods will be used for this purpose. The five different methods of comparison of YE and Y_{ij} used in this study are the following: (1) applying t-test to detect the difference between the means of actuals Y and estimates YE; (2) finding how many and which AQCRs have estimates off by 1, 2, or 3 standard errors of estimate; (3) doing regression of the form YE=a+bY; (4) doing regression of the form YE=bY; and (5) doing a distribution-free non-parametric test to detect differences between YE and Y.

In the next pages, the different methods are discussed in detail.

The twenty manufacturing sectors and the aggregate sector are taken up separately. Hence, the subscript j is omitted in the following discussion.

5.2.4 The t-test.

The aim is to compare the means of the two sets of observations of Y_i and YE_i, and test the null hypothesis that the means are not different. This can be done by calculating the t-statistic,

$$t = \frac{\overline{Y} - \overline{YE}}{\sqrt{\left(\frac{s_Y^2}{n_1 - 1}\right) + \left(\frac{s_{YE}^2}{n_2 - 1}\right)}}$$

where: $\overline{Y}$ = mean of Y_i for i = 1, 2, ... , n_1

$\overline{YE}$ = mean of YE_i for i = 1, 2, ... , n_2

s_Y = standard deviation of Y_i

s_{YE} = standard deviation of YE_i

It can be shown that t follows student's t-distribution with $(n_1 + n_2 - 2)$ degrees of freedom.* Suppose the calculated t is less than the tabulated value of t-distribution for $(n_1 + n_2 - 2)$ degrees of freedom at a probability of 0.05. Then the researcher can state that the means of Y_i and YE_i are not significantly different at accepted confidence levels.

Thus, there is the desirable result of actuals and estimates being equal on average if the computed t-statistic is smaller than approximately 1.986. (Note that this is not what is expected when usually t-test is used to show that two groups are in fact different.)

5.2.5 Standard Error of Estimate

In forecasting time-series, it is desirable to have as few of the estimates as possible, off by more than three standard errors of estimate from the actuals. This is based on the normality assumptions of regression. The report shows in turn:

---

* Snedecor, G.W., and W.G. Cochran, "Statistical Methods," Ames, Iowa, Iowa State University Press, 1968, pp. 100-103.

- How many AQCRs have estimates within one standard error of estimate from actuals,
- How many AQCRs have estimates within a wider interval of two standard errors of estimate from actuals, and
- How many AQCRs have estimates within a still wider interval of three standard errors of estimate from actuals.

Then the report identifies the AQCRs which have more error of estimate than each of these intervals. For such AQCRs, the simulation results may be qualified by judgment.

It may be noted that in a normal distribution, only two-thirds of the points need be within one standard error, only 95 percent of the points need be within two standard errors, and 99 percent fall within three standard errors. (This statement is to caution the reader against any hasty conclusions on four or five AQCRs being off by more than two standard errors.)

It is also worth noting that these percentage guidelines will not apply if the distribution of actual data is far from the normal distribution.

5.2.6 Regression $YE_i = a + bY_i + e_i$

The validator wishes to check the assumption of the user of the model that the change in Y-estimate equals the change in Y-actuals for most AQCRs with a high probability. To do this, a general linear function is fitted between YE_i and Y_i as $YE_i = a + bY_i + e_i$ by linear squares regression. The R^2 of this regression shows what proportion of the variance in actuals is reflected in estimates. A high R^2 closer to 1 is desirable. If b is found to be significantly different from unity, the assumption of changes in YE_i reflecting changes in Y_i is invalid.*

To test the hypothesis that b is not different from unity, the following procedure is adopted following J. Johnston.** The regression $YE_i = a + bY_i + e_i$ can be expressed in the standard matrix form, $Y = X\beta + U$, for convenience in following standard treatises on regression. For the significance test, the assumption has to be made that the residuals U_i are normally and independently distributed with 0 mean

---

* Meier, R.C., W.T. Newell and H.L. Pazer, "Simulation in Business and Economics," Englewood Cliffs, New Jersey, Prentice-Hall, 1969, pp. 294-295.

** Johnston, J., "Econometric Methods," McGraw-Hill, Inc., New York, 1963, pp. 115-18. The test could not be done in a theoretically pure form. Hence the following discussion of assumptions.

and constant variance σ^2 over different AQCRs. If this assumption can be made, β can be estimated by the least-squares estimate $\hat{\beta} = (X'X)^{-1} X'Y$. With the same assumptions, β is normally distributed with variance $\sigma^2(X'X)^{-1}$ where σ^2 is the constant variance assumed over all the AQCRs for U.

σ^2 is estimated by $\hat{\sigma}^2$ = the residual sum of squares

$$\frac{\sum_{i=1}^{n} e_i^2}{(n - k)}$$

where k is the number of parameters, equal to 2 here, and $e_i = YE_i - a - bY_i$. The aim is to test the null hypothesis that $\hat{\beta}_j$, (the jth element of $\hat{\beta}$) is not different from β_j. It can be shown that

$$t = \frac{\hat{\beta}_j - \beta_j}{\sqrt{\sigma^2 \cdot a_{jj}}}$$

has the t-distribution with n-k degress of freedom, where a_{jj} is the jth diagonal element in $(X'X)^{-1}$.* If the hypothesized value $\beta_j = 0$, the usual t-statistic printed in regression program outputs is obtained. In trying to prove that b=1 in the relation $YE = a + bY + e_i$, β_2 is taken as 1. If the computed t is more than the critical value of t

---

* Johnston, J., op. cit., p. 118.

tabulated for the t-distribution at the accepted confidence level of 0.05, (approximately 1.986 at the degrees of freedom in this study), b has to be taken as different from 1. Then changes in estimates do not duplicate changes in actuals exactly.

The assumption of "homoscedasticity," i.e., of constant variance σ^2 for the population of residuals; often cannot be made with the cross-sectional data of the present study, especially in the case of AQCRs with a large number of small AQCRs and a small number of large AQCRs. In such cases, the t-statistic for the difference of b from unity calculated as above can be an overestimate leading to the wrong inference that b is different from 1. Inferences from such a test can be misleading to the extent the population residuals are heteroscedastic.*

---

* Johnston, J., "Econometric Methods," op. cit., pp. 207-11 has suggested a method to correct for heteroscedasticity if the form of deviation from homoscedasticity is known for each AQCR. The correction could not be done in this study since the form is unknown with present data.

In the homoscedastic case, it was assumed that the residuals U have a constant variance σ^2. Instead of that, in the heteroscedastic case, the residual variance

$$E(UU') = \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & \cdot \\ \cdot & 0 & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \ddots & \cdot \\ 0 & 0 & \cdots & \sigma_n^2 \end{bmatrix} = \sigma^2 \begin{bmatrix} 1/\lambda_1 & 0 & \cdots & 0 \\ 0 & 1/\lambda_2 & \cdots & 0 \\ \cdot & \cdot & \ddots & \\ \cdot & \cdot & & 1/\lambda_n \\ 0 & 0 & \cdots & \end{bmatrix}$$

If Λ is the diagonal matrix with ith element $\sqrt{\lambda_i}$, it can be shown (footnote continued on page 102)

The closer $\hat{\beta}_j$ is to β_j, i.e., the closer the R^2 of the original regression was to unity, the more is the t-test in validation regression affected in reliability due to violations in assumptions. This can lead to the ironic conclusion that the best regressions by the usual criteria of high R^2 and significant regression coefficients are also the worst by the validation test with t = (b-1)/standard error of b.*

(footnote continued from page 101)
that the least squares estimator $\hat{\beta}$ is really

$$\hat{\beta} = (X'\Lambda^2 X)^{-1} X'\Lambda^2 Y,$$

with $$\text{var}(\hat{\beta}) = \sigma^2 (X'\Lambda^2 X)^{-1},$$

Λ is not known for the data in the present study. The homoscedastic estimate $\hat{\beta}_h = (X'X)^{-1} X'Y$ is still an unbiased estimate, but Var $(\hat{\beta}_h) = \sigma^2(X'X)^{-1}$ is different from actual. (Johnston, op. cit., p. 209).

* The following example illustrates the dilemma. Referring to Table 3.3 in Section 3.3.1, in SIC0 (all manufacturing), the estimating equation for investment has $R^2=0.952$ with all regression coefficients significant at 0.01 level. Thus, it is a satisfactory equation by the usual criteria of regression. Referring to the Table 5.1 in Section 5.3 giving the results of validation for SIC0, for investment,

$$YE_i = \underset{(3.595)}{-0.953} + \underset{(0.016)}{1.044} \; Y_i + e_i \;,$$

the numbers in parentheses being associated standard errors. The R^2 is 0.9861 showing that the variance in actuals accounts for 98.6 percent of the variance in YE, i.e., almost all the variance in estimates. Since 1.044 is an unbiased estimate of b, changes in YE_i are on the average only 4.4 percent more than corresponding changes in Y_i, which means the estimated changes are very close to actual. But the low biased estimate of standard error of b equal to 0.016 gives t for H_0:b=1 as (1.044 - 1)/0.016 = 2.75, which is signficant at 0.05 level. This suggests the misleading inference that YE is far different from Y since b is far different from 1. On the other hand, in SIC 29, the estimating equation for investment has $R^2=0.695$ which is not so satisfactory; and in validation YE=a+bY, it shows up in the value of b being 0.7057, nearly 30 percent off from 1. But the standard error of b is 0.27. This gives the misleading inference that b is not different from 1, since t for H_0: b=1 is (1-0.7057)/0.27=1.08 which is not significant at .05 level.

The heteroscedasticity of the residuals could not be corrected without further assumptions which may need exploratory work into the form of heteroscedasticity for justification. Therefore a weaker test was adopted as below. In the regressions $YE_i = a + bY + e_i$, if b is numerically close to +1 and statistically significantly different from 0 by the t-statistic t = b/standard error of b, b is taken to be not different from 1, since the estimate of b with homoscedastic assumption is an unbiased estimate of the actual b.* Then a small change in YE_i equals the corresponding change in Y_i. A still weaker result would be that b is not numerically close to +1, but is positive and significantly different from 0. Then the observer can say that a change in YE estimates a part of the corresponding actual change consistently. If b is far different from one or b is not signficant at all, the estimation of change can be declared as poor.

5.2.7 Regression $YE_i = bY_i + e_i$

If a is nearly zero really and the validator forces the regression $YE_i = a + bY_i + e_i$ as in 5.2.6 on such data, there will be serious computational errors in R^2, b and its standard error. Therefore, for such cases, it is desirable to fit a regression without intercept $YE_i = bY_i + e_i$. If b is not significantly different from 1 in this case, $YE_i = Y_i$. The estimates themselves are equal to actuals, a stronger result than the previous one that changes in estimates reflect changes in actuals.

* Johnston, J., op. cit., p. 209.

5.2.8 Non-Parametric Test--
(Mann-Whitney U-Test)

The validation tests mentioned previously have the limitation that they assume normal distributions for the population for the different variables. The t-test assumes in addition the homogeneity of variances of estimates and actuals.* The results of validation may be prejudiced by these assumptions. Therefore it is desirable to test the difference between estimates and actuals without making such assumptions. A non-parametric test will serve this purpose.

The non-parametric test chosen was the Mann-Whitney U-test. This is one of the most powerful of the non-parametric tests; it is a most useful alternative to the parametric t-test when the researcher wishes to avoid the assumptions of the t-test.**

Suppose two independent samples have been drawn from two populations, population A and population B. The Mann-Whitney U-test tests whether the two populations have different distributions.

---

* Siegel, S., "Non-parametric Statistics for the Behavioral Sciences," McGraw-Hill, Inc., New York, 1956, p. 19.

** Siegel, S., op. cit., p. 116. Mihram, G.A., ("Practical Aspects of Simulation Models," Operational Research Quarterly, Vol. 23, No. 1, March 1972, pp. 26-7) suggests the Mann-Whitney U-test, Kolmogorov-Smirnov 2-sample test and the Wald-Wolfowitz Runs test as non-parametric tests suitable for validation. The other tests suggested are the chi-square test and the median test. Following the comparison of these tests in Siegel, S., op. cit., pages 126, 136, and 144-45, the Mann-Whitney U-test was preferred as the best test of differences in location and variability for the sample-sizes in this study.

The hypotheses are as follows:

Null Hypothesis, H_0:

A and B have the same distribution, i.e., the probability that an observation from A is larger than an observation from B is exactly one-half. If a is an observation from population A and b is an observation from population B, H_0 can be stated briefly as:

H_0: Probability $(a > b) = 0.5$

The alternative hypothesis, H_1:

A and B have different distributions, i.e.,

H_1: Probability $(a > b) \neq 0.5$.

Calculation of U-Statistic*

Let n_1 be the number of cases in the smaller (A) of two independent groups and n_2 be the number of cases in the larger (B). The observations from both groups are combined and the combination is ranked in order of increasing size, being careful to retain a tag on each observation as to which sample it came from. The U-statistic U is given by the number of times that an observation in the sample with n_2 cases precedes an observation in the sample with n_1 cases. This is practically computed by the formula

$$U = n_1 n_2 + n_1 (n_1 + 1)/2 - R_1$$

---

* Siegel, S., pp. 116-127.

where

R_1 = sum of the ranks assigned to the sample A, when the whole combination is ranked 1, 2, 3, ...

The computed U is tested against values of the sampling distribution of U under H_0, given in published tables* for the larger sample size up to 20. For n_2 greater than 20, the sampling distribution of U approaches the normal distribution regardless of the distribution of the samples. For a given U, the equivalent normalized statistic Z_u is given by

$$Z_u = \frac{U - n_1 n_2 / 2}{\sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}}$$

If the computed Z_u is larger than the tabulated critical value (1.96) of the the normal distribution at a confidence level of 0.95, the null hypothesis is rejected and the two samples, (estimates and actuals) are considered to have different distributions. A two-tailed test has been done since the hypotheses in this study are as follows:

Null hypothesis:

H_0: Y estimates and Y actuals are not different in their distributions;

Alternative hypothesis:

H_1: Y estimates are stochastically larger or smaller than Y actuals.

---

* Siegel, S., pp. 271-77.

Only the normalized equivalent of the U-statistic is presented in the results since most of the samples are larger than 20, and the regular U-statistic critical values are not tabulated for n_2 greater than 20.

5.2.9 Computer Program

A flow chart based on this section is given in Appendix B. This served as the basis for the computer program in FORTRAN IV developed for IBM 370/165. The program took 20 to 50 seconds for validation of estimates for one year, depending on the printout of some or all data and some or all results for checking.

5.2.10 Data Used for Validation

The model was estimated using data from 1958 to 1967. Therefore, to validate the model, it is desirable to compare the actuals and estimates for a period other than that, preferably closer to 1972 when the model is applied to policy decisions. The only year outside 1958-67 and closer to 1972 for which data was available was 1969. Hence, data for 1969 was used to validate the model in the manufacturing sector.

To compare the estimates and actuals for 1969, the estimates for 1969 have to be computed first. For this, actual data from 1968 is necessary since the investment and wage equations involve lagged variables. Unfortunately the variables for 1968 are available only by states (not by AQCR) and only for all manufacturing (without 2-digit industry detail). Therefore, 1968 data by AQCR and 2-digit detail was approximated as below.

Approximation of 1968 Data

The problem is to get approximations to 1968 data without prejudicing the validation by depending on either the 1958-67 data or the model being validated. The solution adopted was to project backwards from 1969 data assuming that the growth rate of any industry in any AQCR from 1968 to 1969 was the same as the growth rate of the aggregate manufacturing sector in the state or states in which the AQCR lies, in the same period of 1968-1969,

i.e., $$\text{variable}_{i,\ j,\ 1968} = \text{variable}_{i,\ j,\ 1969} \times \frac{\text{variable}_{si,\ 1968}}{\text{variable}_{si,\ 1969}}$$

for, AQCR i, industry j, state s_i in which AQCR i lies,

where, "variable" stands for employment, wage bill, value added, investment, and capital stock.

Missing Data Problems

In the manufacturing sector, if data are missing in any of the unlagged independent variables in 1969 or lagged independent variables in 1968, the particular dependent variable could not be estimated for that AQCR and SIC. This reduced the sample size to a low figure in SIC 24, 29, and 31. Then the question arises whether the validation results are affected by the small sample size. In such cases, the validation results comparing estimates and actuals for 1967 were computed in addition to 1969.

Validation of first differences could not be done since actual data for 1968 were not available. In calculating the 1969 estimates, the approximated 1968 data for independent variables play only a minor role supporting the actual 1969 data. Therefore, there was some justification for using them. But using the approximations as actual independent variables for 1968 to estimate dependent variables for 1968 and to calculate first differences in actuals of dependent variables would vitiate the very basis of validation, namely the comparison of the real system with the estimated system. The comparison would now be between one estimate and another estimate. Therefore, first differences were not validated due to missing data in 1968.

In the non-manufacturing sector, the only year with data available for income, unemployment, etc., and taxes, was 1967. Therefore, the only way is to compare estimates and actuals for 1967 for which the parameters were estimated.

Thus, due to missing data, the "external validity" of the non-manufacturing sector could not be checked; only its "internal validity" could be checked.* For the manufacturing sector, both internal and external validity were tested.

---

*Hermann, C., "Validation Problems in Games and Simulation," Behavioral Science, 12, page 216.

5.3 Results and Discussion

5.3.1 Summary

Table 5.1 shows a summary of the main results of validation for the manufacturing sector (1969) and the other sectors (1967) for the whole economy. Column 0 shows the SIC code of the industry considered, and the symbol of the variable. For 2-digit SIC detail, the symbols mean the following:

N = Employment (Manufacturing)

V = Value-added

I = Investment

Π = Profit

W = Wage rate

K = Capital stock

"Other sectors" variables are named directly in the table. Column 1 gives the year whose actual data were compared with estimates for validation of the econometric model. This may be 1969 or 1967 or both.

Column 2 gives the non-parametric U-statistic in normalized form. If it is greater than 1.96, the actuals and estimates are different in their distribution at a confidence level of 0.95.

Columns 3 to 5 can help to check how far the estimates from the model are different from the actual on the average. Column 3 gives the mean of the actual data of the variable considered in the year shown in column 1 for the relevant industry. By comparing the estimate mean in column 4 with the actual mean in column 3, the observer can notice if they are too different. The t-statistic in column 5 is the difference between actual mean and estimate mean, standardized by the standard error of the difference. By comparing the computed t-statistic with values given in published tables of the t-distribution, an asterisk has been marked wherever the estimate mean is different from the actual mean. If the estimates are reasonably good, there should be only a small number of asterisks. In other words, a low t-test result shows the model is working well; a high t-test result with an asterisk shows that the model is not working well for the particular industry, variable and year.

Columns 6 to 10 give a measure of different levels of divergence of model estimates from the actual. The standard error of estimate of each regression equation is used as a device to measure the deficiency in prediction. This is given in column 6. Column 7 shows the actual number of observations for which this check was done. (This may be less than the total number of AQCRs since data were missing for some in the validating year). Column 8 gives the most stringent test of error in prediction by the model. This is the number of AQCRs for which estimates are accurate within one standard error. If this count is a high proportion of the total number of AQCRs, obviously the model is excellent in estimation.

Some AQCRs did not fall within this interval. To find whether all these were far wrong or only some of them were, the interval is widened. A count is made as to how many AQCRs are accurate within two standard errors. The results appear in column 9. If column 9 includes most of the AQCRs, the model is good. Column 10 extends the idea to an interval of three standard errors.

A regression of the form YE = a + b (Y actual) was estimated. If the model is good, the t-statistic of b in column 11 must be significant (larger than the critical t around 1.7). Also, the value of b in column 12 must be near one. The R^2 of this regression in column 13 shows the proportion of the variance in YE explained by the variance in Y. This should be as close to one as possible. Columns 14 to 16 repeat t_b, b, R^2 for the regression YE = bY without intercept.

Table 5.2 shows the AQCRs whose estimates are off by three standard errors of estimate for five selected variables.

Now the results are discussed for the different sectors.

5.3.2 Manufacturing Sector

Table 5.1 shows the validation results for the aggregate sector. The first section is the manufacturing aspect for the year 1969. For all six variables (employment, value-added, investment, gross profit,

Table 5.1

Summary of Validation Results, 1969 and 1967

0	1	2	3	4	5	6	7	8	9	10
Variables	Year	Normalized U-statistic	Actual Mean $\bar{Y}$	Est. Mean $\bar{Y}e$	t-Stat.	Stand. Error of Est. Sy.	No. of Ob. n	No. of Obvs. within Interval $\hat{Y} \pm 1s$	$\hat{Y} \pm 2s$	$\hat{Y}$-
Mfg. Employment N_M	1969	1.85	172.	208.6	.79	23.8	59	33	49	
Mfg. Value-added V_M	1969	1.83	2271.	2811.9	.90	236.8	59	27	43	
Mfg. Investment I_M	1969	.30	144.	149.8	.17	31.0	59	51	57	59
Mfg. Gross Profit M	1969	.12	1074.	1090.4	.06	202.5	59	51	56	57
Mfg. Wage Rate W_M	1969	1.09	5.7	6.8	1.19	.3	59	38	56	59
Mfg. Capital K_M	1969	.15	1787.0	1774.3	.03	31.5	59	38	54	57
Mfg. Employment N_M	1967	1.08	181.0	193.9	.30	23.8	56	41	53	56
Mfg. Value-added V_M	1967	1.00	1552.4	1682.1	.35	236.8	89	67	80	88
Mfg. Investment I_M	1967	.05	161.6	160.1	.03	31.0	56	45	54	55
Mfg. Gross Profit M	1967	.15	736.8	745.1	.05	202.5	89	80	86	87
Mfg. Wage Rate W_M	1967	.36	6.5	6.5	.45	.3	56	39	55	56
Mfg. Capital K_M	1967	.73	1484.1	1602.6	.37	327.3	56	45	50	54
Regional personal income Y	1967	N.A.	4416.9	4478.1	.06	469.5	91	77	86	87
Local govt. expenditure G	1967	"	375.2	375.2	.00	35.05	91	78	85	88
Regional consumption C	1967	"	2844.7	2846.7	.00	411.6	91	76	81	91
Regional total empl. N_T	1967	"	458.8	453.4	.05	83.07	91	75	86	89
Regional labor force L	1967	"	475.4	469.7	.05	84.23	91	76	86	88
Regional unempl. rate U	1967	"	.0345	.0323	.97	.0105	91	67	85	88
Employment of non-manufacturing $\bar{N}$	1967	"	337.8	339.0	.01	79.26	91	76	85	88
Total elec. consumption Q_T	1967	"	628.7	694.9	.43	443.5	91	82	86	88
Residential use Q_C	1967	"	173.9	139.2	1.24	95.6	91	77	87	88
Manufacturing use Q_M	1967	"	145.0	334.4	3.25*	418.5	91	80	86	88
Other industrial use $\bar{Q}$	1967	"	308.3	308.3	1.36	211.5	91	75	84	90
Taxes--										
Total local revenue T	1967	.22	370.3	321.4	.41	235.0	82	69	77	80
Property tax T_p	1967	.66	148.2	158.1	.21	76.6	82	70	76	79
Other taxes T_o	1967	2.82*	32.5	30.8	.11	51.0	82	74	79	80
Federal and state aid T_A	1967	.65	189.5	132.5	.92	257.5	82	62	78	81

Table 5.1 (continued)
Summary of Validation Results, 1969 and 1967

0	1	11	12	13	14	15	16
		YE = a + bY			YE = bY		
Variables	Year	t_b	b	R^2	t_b	b	R^2
Mfg. Employment N_M	1969	133.4	1.18	0.99	165.4	1.19	.99
Mfg. Value-added V_M	1969	107.8	1.26	0.99	136.8	1.25	.99
Mfg. Investment I_M	1969	64.1	1.04	.99	85.2	1.04	.99
Mfg. Gross Profit $_M$	1969	57.5	1.06	.98	72.9	1.04	.98
Mfg. Wage Rate W_M	1969	32.9	.80	.95	208.8	1.02	.87
Mfg. Capital K_M	1969	270.4	.99	0.99	348.0	.99	.99
Mfg. Employment N_M	1967	100.1	1.00	.99	n.a.	n.a.	n.a.
Mfg. Value-added V_M	1967	120.2	1.03	.99	"	"	"
Mfg. Investment I_M	1967	43.7	.99	.97	"	"	"
Mfg. Gross Profit $_M$	1967	71.9	1.06	.98	"	"	"
Mfg. Wage Rate W_M	1967	19.8	.84	.88	"	"	"
Mfg. Capital K_M	1967	50.7	1.12	.98	"	"	"
Regional personal income Y	1967	152.0	.99	0.99	"	"	"
Local govt. expenditure G	1967	196.2	1.00	0.99	"	"	"
Regional consumption C	1967	105.4	.99	.99	"	"	"
Regional total empl. N_T	1967	86.0	.95	.99	"	"	"
Regional labor force L	1967	88.5	.95	.99	"	"	"
Regional unempl. rate U	1967	20.0	1.52	.82	"	"	"
Employment of non-manufacturing $\overline{N}$	1967	63.2	.98	.98	"	"	"
Total elec. consumption Q_T	1967	27.8	1.32	.90	"	"	"
Residential use Q_C	1967	22.0	.94	.84	"	"	"
Manufacturing use Q_M	1967	15.5	2.37	.73	"	"	"
Other industrial use $\overline{Q}$	1967	20.5	.81	.82	"	"	"
Taxes--							
Total local revenue T	1967	29.9	.89	.92	33.0	.89	.92
Property tax T_p	1967	35.0	.98	.94	39.6	1.00	.94
Other taxes T_o	1967	16.8	.73	.78	17.9	.75	.77
Federal and state aid T_A	1967	12.1	.81	.64	13.1	.79	.64

n.a. = not available.

TABLE 5.2

AQCRS Whose Estimates Are Off by 3 or More Standard Errors of Estimate for Five Selected Variables are Listed Below*

Variable	AQCRs Off by 3 or more standard errors of estimate	
Manufacturing Value-added (69)	1 New York 2 Chicago 3 Los Angeles 4 Philadelphia 5 Detroit	7 Boston 8 Pittsburgh 9 St. Louis 11 Cleveland 20 Dallas
Manufacturing Gross Profit (69)	1 New York	5 Detroit
Manufacturing Investment (69)	NONE	
Manufacturing Wage rate (69)	NONE	
Manufacturing Capital Stock (69)	1 New York	15 Houston
Regional personal income (67)	19 Louisville, Ky.	
Regional unemployment (67)	90 Lancaster, Pa.	

*It appears that estimates of some large AQCRs tends to fall off by three standard errors of estimates which indicates the existence of a strong heteroskedasticity of the model. See pp. 100-103.

wage rate and capital stock), the means of actual and estimate are quite close. All the t-statistics are lower than the tabulated value of 1.986 for 110 (=2 x 56 - 2) degrees of freedom at a confidence level of 0.95. Therefore, none of the variables in the aggregate manufacturing sector has the model estimates different from the actual on the average. All the normalized U-statistics are less than 1.96. This shows that the distributions of estimates are not different from that of the actuals. Thus, the model is good in predicting the six variables regarding location and validity. This can be stated with 95 percent confidence.

Next, the proportion of observations falling within one, two and three standard errors is considered. A standard to compare is the normal distribution which has more than two-thirds of the observations within one standard error, nearly 95 percent within two standard errors and nearly 99 percent within three standard errors. In Table 5.1, the columns 8, 9 and 10 giving the number of observations within intervals of 1, 2 and 3 standard errors show the results to be good for the first six variables for the manufacturing sector for 1969.

The results of the regression YE = a + bY and YE = bY in Table 5.1 (continued) show that generally the coefficient b is nearly equal to one numerically and is significant at 0.95 confidence level by the t-statistic being greater than the tabulated t-statistic (1.673 at 54 degrees of freedom and 1.662 at 87 degrees of freedom). This shows that changes in the actual variables are predicted well by the changes in the estimates used by the model.

Appendix C gives detailed results by 2-digit detail for manufacturing (1969).

In Table 5.1, below the results of external validity tests using 1969 data, the results of internal validity tests using 1967 data are presented. These results support the conclusions of the external validity tests.

Appendix D gives the internal validity results by 2-digit detail for 1967 for selected industries, viz., 23, 29, 31, where the external validity results are unreliable due to sample size being too small because of missing data in 1968-69.

Changes in manufacturing employment and value added are generally overestimated as shown by b being greater than one in YE = a + bY in many industries. This may be explained by the fact that due to the cyclical downswing in 1969, capacity was not being fully utilized. (The model could not be corrected for capacity utilization due to non-availability of data by AQCR and SIC). Changes in wage rate are generally underestimated, i.e., the model estimates a part of the change in wage rate consistently, although not the whole.

5.3.3 Other Sectors

The internal validity results (1967) for the national economy in variables like personal income, unemployment, consumption, electric power consumption and taxes are summarized in Table 5.1.a and b and Appendix E. External validity tests could not be done due to lack of data in other years. Most of the results show validity except unemployment, electric consumption in manufacturing and other taxes.

Changes in unemployment rate are overestimated since b = 1.52 and significant. But t-test shows that still the estimate of unemployment rate is not significantly different from the actual. (The t-statistic 0.97 is much less than the critical value of 1.96 at 180 degrees of freedom).

In the case of electric consumption for manufacturing, there is overestimation of change and the estimate is significantly different by t-test from the actual. But such an error is unavoidable since its regression parameters were not based on actual data but on estimated data from other variables.

Other taxes fail the U-test, but are not different on the average in estimates and actuals by t-test.

Variables like wage rate and unemployment perform well in the usual test of nearly 95 percent of the observations falling within two standard errors, although their distribution is flatter than the normal.

5.4 A Comparison of the OAP Model and the St. Louis Model for the St. Louis Region

The previous section provided a full-scale evaluation of the model. This section presents a comparison of the actual values of a key economic variable for the St. Louis AQCR and the estimates as simulated through the OAP Regional Econometric Model and the St. Louis Regional Model.*

The St. Louis Regional Model is a time series econometric model estimated for St. Louis,* while the OAP Regional Model has been estimated with cross-section data pooled over ten years for 91 AQCRs. A comparison of the simulations through the two models should throw some light on the performance <u>over time</u> of the OAP Regional Econometric Model for a specific AQCR.

Manufacturing product (value-added) by aggregate manufacturing sector and each of 2-digit SIC sectors from 1958 to 1967 as estimated

---

*For details of the St. Louis Regional Model, see CONSAD Research Corporation, <u>An Economic Model System for the Assessment of Air Pollution Abatement</u>, Appendix A: A Model to Assess the Economic Effects of Air Pollution Abatement in the St. Louis AQCR, prepared for the Environmental Protection Agency, May 15, 1971.

by the two models are compared with the actuals in Figure 5.1. Table 5.3 compares these two forecasts with the actuals for all manufacturing products by each year. It appears that both models provide a good forecast of the aggregate manufacturing sector. However, the performance of the two models is more variable for the 2-digit SIC sectors.

5.5 Conclusion

Different validation tests of the revised OAP Regional Economic Model converge to the following conclusion: the model estimates almost all variables with satisfactory accuracy in almost all industrial sectors even in a time period two years after the estimation period. This is all the more interesting since the model parameter estimation was limited by lack of full data at the time of estimation in many cases.

The model seems to have some difficulty in predicting the cyclical downswing in value added and employment in 1969. This suggests one direction for further study: the inclusion of cyclical capacity utilization factors or a national cyclical economic indicator like GNP as an exogenous variable in the estimation and simulation of the model. The performance of the model may be improved by this extension.

Figure 5.1
Simulation of Manufacturing Product (Value-Added) in St. Louis Region, 1958-1967

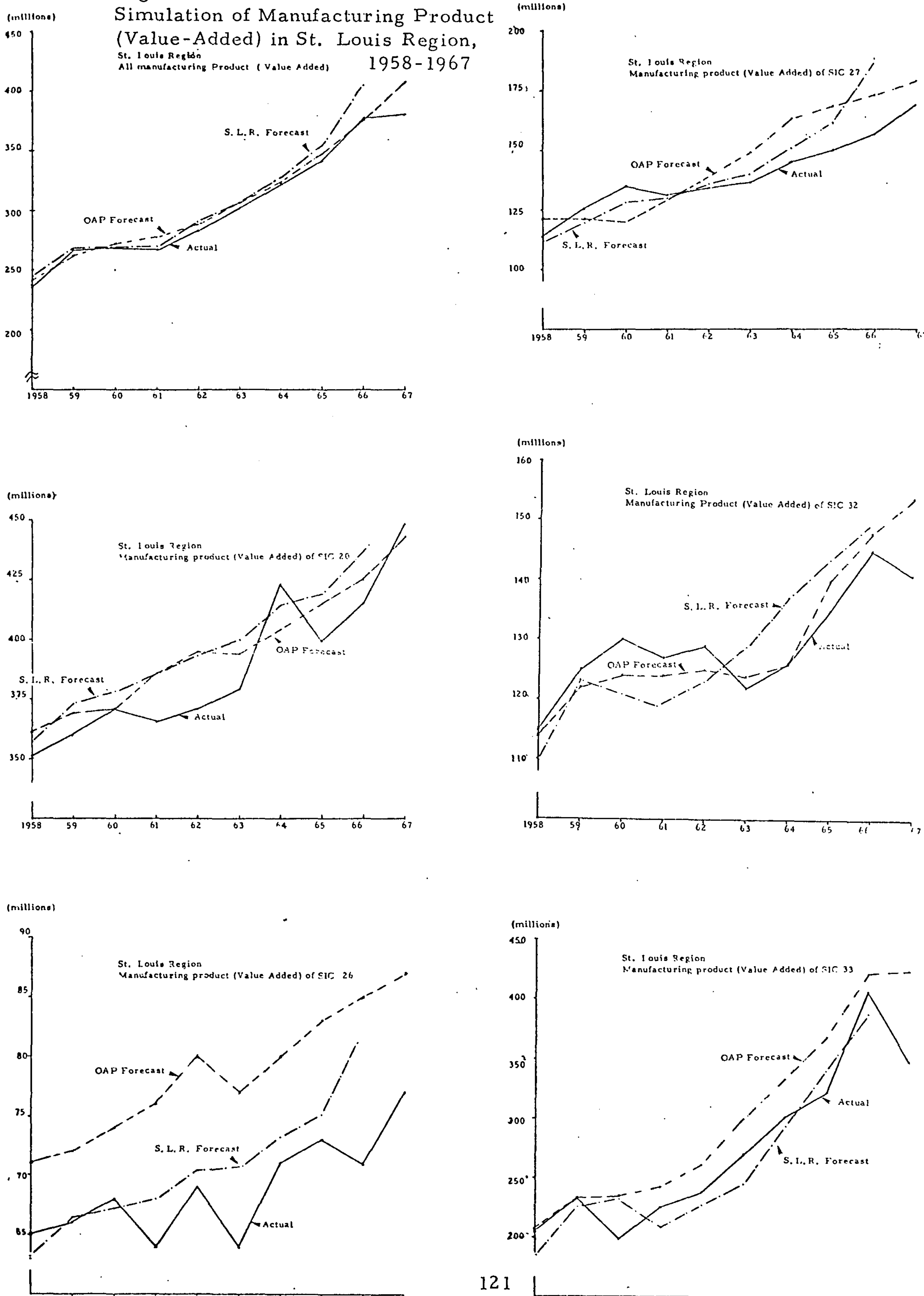
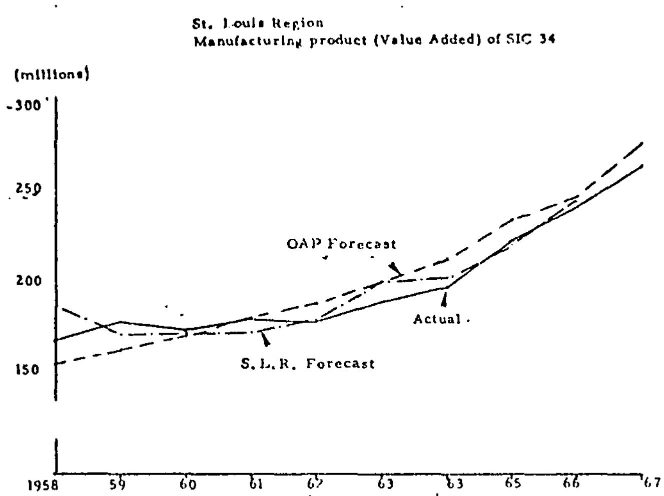
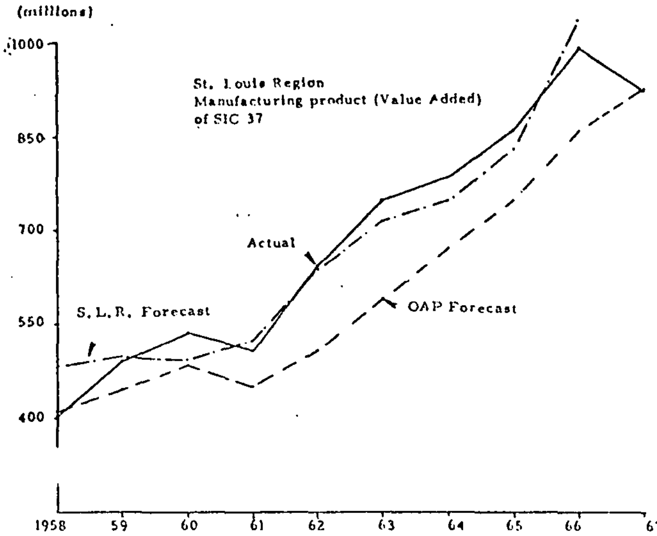
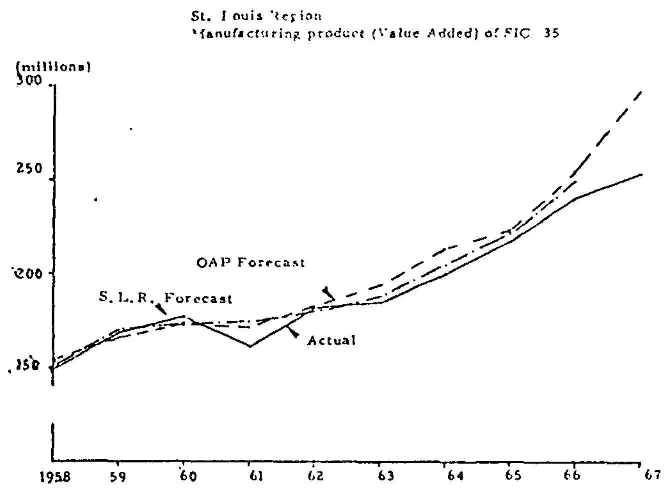
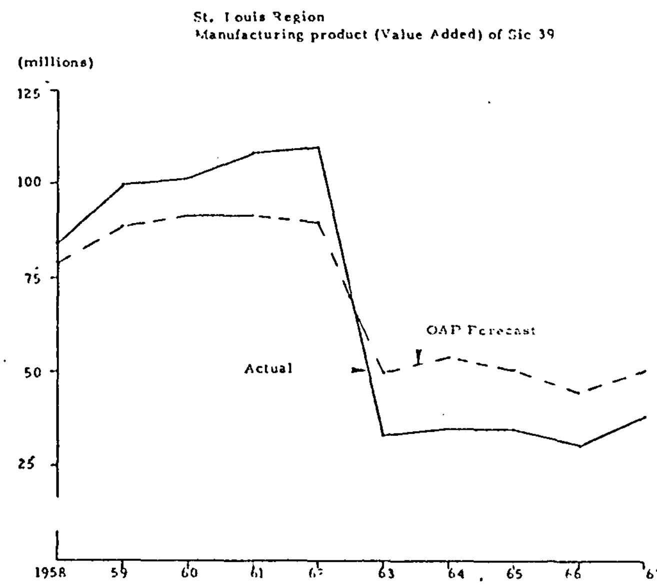


Figure 5.1 (continued)









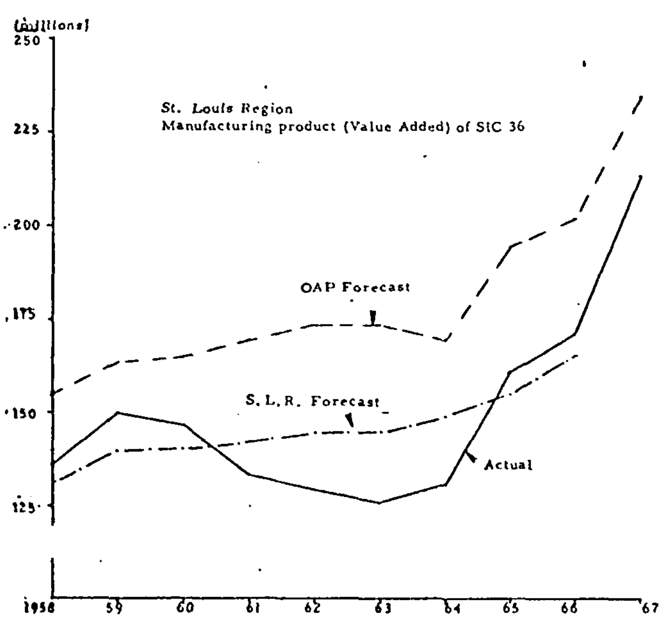


TABLE 5.3
Simulation of Manufacturing Product
(Value Added) of St. Louis AQCR

All Manufacturing Product

Year	Actual	OAP Forecast	SLR Forecast
1958	2382.8	2417.1	2459.6
1959	2673.4	2631.1	2681.8
1960	2699.5	2733.7	2684.4
1961	2674.6	2768.0	2699.5
1962	2835.9	2885.1	2928.3
1963	3026.3	3061.0	3073.5
1964	3227.9	3248.5	3271.1
1965	3422.2	3487.5	3552.2
1966	3794.0	3791.3	4064.3
1967	3804.8	4086.3	

SIC 20

Year	Actual	OAP Forecast	SLR Forecast
1958	352.6	362.8	357.6
1959	360.0	369.0	373.0
1960	371.7	371.2	378.1
1961	366.5	386.5	383.8
1962	371.5	395.7	389.1
1963	377.2	394.2	399.6
1964	423.7	404.5	414.9
1965	399.7	415.0	419.0
1966	415.1	425.7	444.8
1967	448.8	443.1	

SIC 26

Year	Actual	OAP Forecast	SLR Forecast
1958	65.6	71.7	62.4
1959	66.7	72.7	65.5
1960	68.7	74.8	67.3
1961	64.7	76.2	68.4
1962	69.3	80.2	70.3
1963	64.1	77.0	70.7
1964	71.7	80.9	73.2
1965	73.0	83.6	75.1
1966	71.1	85.0	81.6
1967	77.4	87.8	

SIC 27

Year	Actual	OAP Forecast	SLR Forecast
1958	114.4	122.7	112.0
1959	126.8	122.8	121.6
1960	135.9	120.7	123.1
1961	132.1	129.5	129.9
1962	134.9	139.9	136.2
1963	137.8	149.8	139.6
1964	145.4	163.5	151.6
1965	150.8	168.4	162.2
1966	157.9	173.8	184.5
1967	169.2	179.3	

SIC 32

Year	Actual	OAP Forecast	SLR Forecast
1958	115.9	114.3	109.6
1959	125.5	122.9	123.3
1960	130.0	124.3	120.8
1961	127.1	124.0	118.9
1962	129.8	125.7	123.0
1963	122.6	124.5	129.3
1964	126.8	126.2	136.7
1965	135.4	140.9	143.7
1966	145.5	148.7	149.9
1967	141.3	154.0	

SIC 33

Year	Actual	OAP Forecast	SLR Forecast
1958	205.2	206.9	185.2
1959	233.3	233.0	226.6
1960	199.2	235.0	232.8
1961	225.1	242.3	206.9
1962	238.9	261.9	227.8
1963	270.8	300.8	245.3
1964	301.8	334.8	293.2
1965	322.4	369.6	341.9
1966	407.4	421.4	388.3
1967	348.9	422.5	

TABLE 5.3 (continued)

SIC 34

Year	Actual	OAP Forecast	SLR Forecast
1958	171.6	159.2	192.6
1959	181.1	166.1	175.7
1960	177.3	174.8	176.1
1961	182.8	184.4	176.1
1962	181.1	192.5	186.4
1963	192.0	203.2	192.2
1964	200.1	215.2	206.4
1965	225.5	236.7	224.7
1966	243.1	249.9	248.2
1967	265.0	277.9	

SIC 35

Year	Actual	OAP Forecast	SLR Forecast
1958	149.2	154.5	154.2
1959	168.1	166.0	169.7
1960	177.0	173.2	170.5
1961	161.5	172.0	170.0
1962	182.5	183.2	182.4
1963	185.4	194.6	188.2
1964	200.8	214.5	205.8
1965	217.0	224.7	223.8
1966	241.2	255.1	250.4
1967	254.6	298.1	

SIC 36

Year	Actual	OAP Forecast	SLR Forecast
1958	136.6	155.5	132.6
1959	150.5	163.1	139.3
1960	147.5	165.7	140.4
1961	133.8	169.3	142.0
1962	129.5	173.0	146.6
1963	126.7	173.6	147.5
1964	131.4	169.7	149.3
1965	161.6	194.5	154.7
1966	171.4	202.1	166.1
1967	213.3	234.2	

SIC 37

Year	Actual	OAP Forecast	SLR Forecast
1958	405.0	412.7	483.2
1959	495.2	446.1	507.2
1960	536.8	487.9	490.5
1961	511.8	451.6	523.8
1962	642.3	510.2	654.3
1963	747.0	594.0	715.7
1964	786.1	674.7	752.0
1965	863.1	751.1	835.3
1966	992.0	859.4	.072.1.
1967	925.5	927.0	

SIC 39

Year	Actual	OAP Forecast	SLR Forecast*
1958	84.0	79.7	
1959	100.1	89.5	
1960	102.1	92.7	
1961	108.2	92.1	
1962	110.9	90.5	
1963	33.5	50.9	
1964	35.2	54.5	
1965	35.3	51.1	
1966	31.4	45.0	
1967	38.4	51.4	

* Data not available in this model.

6.0 ECONOMIC-ENVIRONMENTAL INTERACTION: A CASE STUDY OF PHILADELPHIA

6.1 Air Pollution and Public Policy

Effects upon those external to, or not associated with, consumption or production activities--like blowing soot over one's neighbors--are described as externalities, spillovers of simple external effects. Externalities explain to a large degree why reliance on autonomous control mechanisms of the market leads to results less than desirable. They are, in a sense, the heart of the air pollution problem.

Technological externalities, which are more or less direct effects, but not priced, that one decision unit imposes on another, are an inherent and normal part of the production and consumption process in highly developed economies. They become progressively more important over time as population and level of economic activity increase. They cannot be realistically treated as somewhat occasional anomalies in an otherwise smoothly working economic system.

An approach to compensate the parties adversely affected is not feasible in the case of the technological externality of air pollution, which has the nature of a public "bad." Damages caused by air pollution, in general, are incident in varying degrees on individuals and property such that compensation schemes may have to be infeasibly complex. Further, given the growing concept of dealing with air pollution problems as a management of common property resources, private exchange cannot be expected to assign accurate relative values to alternative uses of the air resource.* Consequently, it becomes a function of the government to adjust the framework for voluntary economic exchanges so as to lead to efficient resource allocation.

A whole series of proposals have been advanced to deal with problems associated with setting standards and stimulating the progress toward improved air quality. None of these proposals, at least in the current stage of our knowledge, appears to be perfect for the purpose at hand. Neither does it appear that any one of this imperfect lot clearly dominates.

The existence of systematic interdependencies between economic and environmental systems imply that any piecemeal remedies suggested from a normative approach may pose serious problems.* Further, the emission standards, fuel regulations, and financial incentive structure that may make up a typical pollution control strategy may be so diverse that normative models may be complex and risky.

---

*Kneese, A. V., "The Environmental Pollution: Economics and Policy," American Economic Review, 61, 1971, pp. 153-166.

**Solow, R. M., "The Economist's Approach to Pollution and its Control," Science, 173, 1971, p. 499.

Instead, information based on system-wide analysis of abatement strategies could be generated from positivist models. Such models will generate empirical information to a typical policy planner's question: If abatement strategy A is implemented, what are the likely consequences in terms of:

- Costs of control to various industries?
- Levels of air quality to be achieved?
- Levels of damages?
- Impacts on regional economy?

This chapter represents one such attempt at integrating three types of models that can be simulated to provide such information. A case study of Philadelphia to demonstrate the interaction between economic and environmental systems is provided.

These three models are:

- The Direct Cost of Implementation Model (DCIM), *

- Property damage functions by Anderson and Crocker, ** and

- The revised OAP Regional Econometric Model.

---

*CONSAD Research Corporation, "The Direct Cost of Implementation Model (DCIM)," prepared for the Environmental Protection Agency, January, 1972.

**Anderson, Jr., R. J., and T. D. Crocker, "Air Pollution and Residential Property Values," Urban Studies, 8, No. 3, October, 1971, pp. 171-180.

The interactions between the models are presented in Figure 6.1. These three models are combined together to provide a case study of economic-environmental effects in the Philadelphia AQCR.

Section 6.2 describes the procedures used to estimate emission and air quality levels before control and emission and air quality levels after the implementation of a control strategy predicated on the implications of the Federal Register of August 14, 1971. Section 6.3 discusses how an objective measure of benefits due to air pollution control, namely property value, is expected to improve in Philadelphia due to air pollution control with the interesting second-order effects of increased tax revenues. Section 6.4 studies the effects of air pollution control on the regional economy of the Philadelphia AQCR.

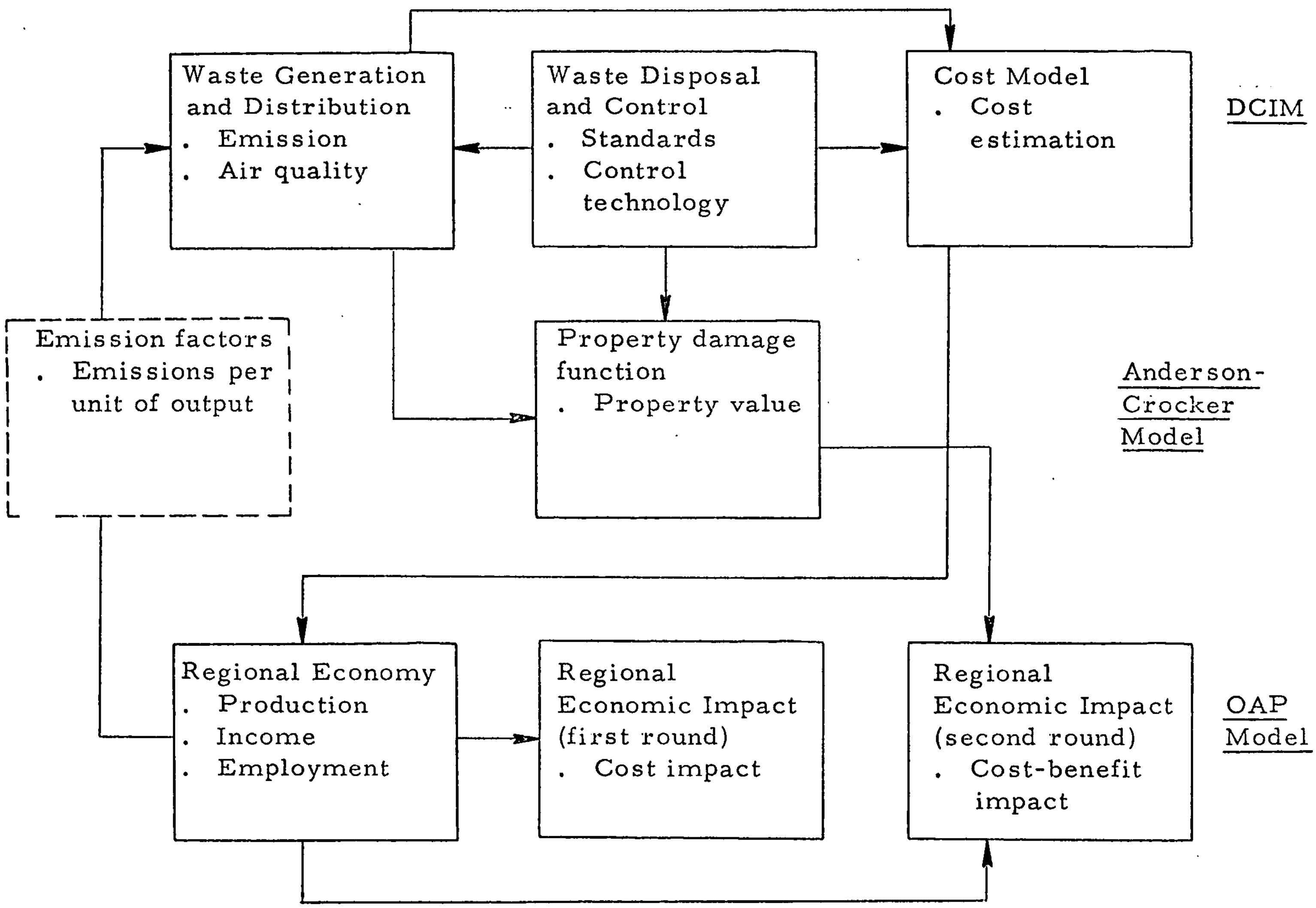
6.2 Improvement in Emissions and Air Quality Due to Control

The costs, emissions and air quality estimates presented here were obtained from simulations on the Direct Cost of Implementation Model (DCIM)* developed by CONSAD. DCIM is an eclectic assembly and refinement of three extant models into a cost-effectiveness model

---

*See CONSAD Research Corporation, Vol. I: Executive Summary; Vol. II: The Structure of DCIM, NEFM and REFM; Vol. III: NEFM and REFM Results; and Vol. IV: Users' Manual, prepared for the Environmental Protection Agency, February, 1972.

Figure 6.1
Interactions of DCIM, Anderson-Crocker Model and OAP Model: A Flow Chart



of air pollution control. Essentially, it comprises the Control Cost segment of the Implementation Planning Program* developed by TRW Systems Group, the SORTCON and INTCODE segments of the Ernst and Ernst cost-effectiveness model** and a SORTDEV routine with selected modification relevant to certain optimizing strategies. Figure 6.2 is a macro flow chart of the various component programs of DCIM.

The input data for the model, consisting of the four categories below, are of the type generally collected and used by air pollution control authorities:

- Emission Source Information,
- Regional Information,
- Control Device Information, and
- Meteorological Information.

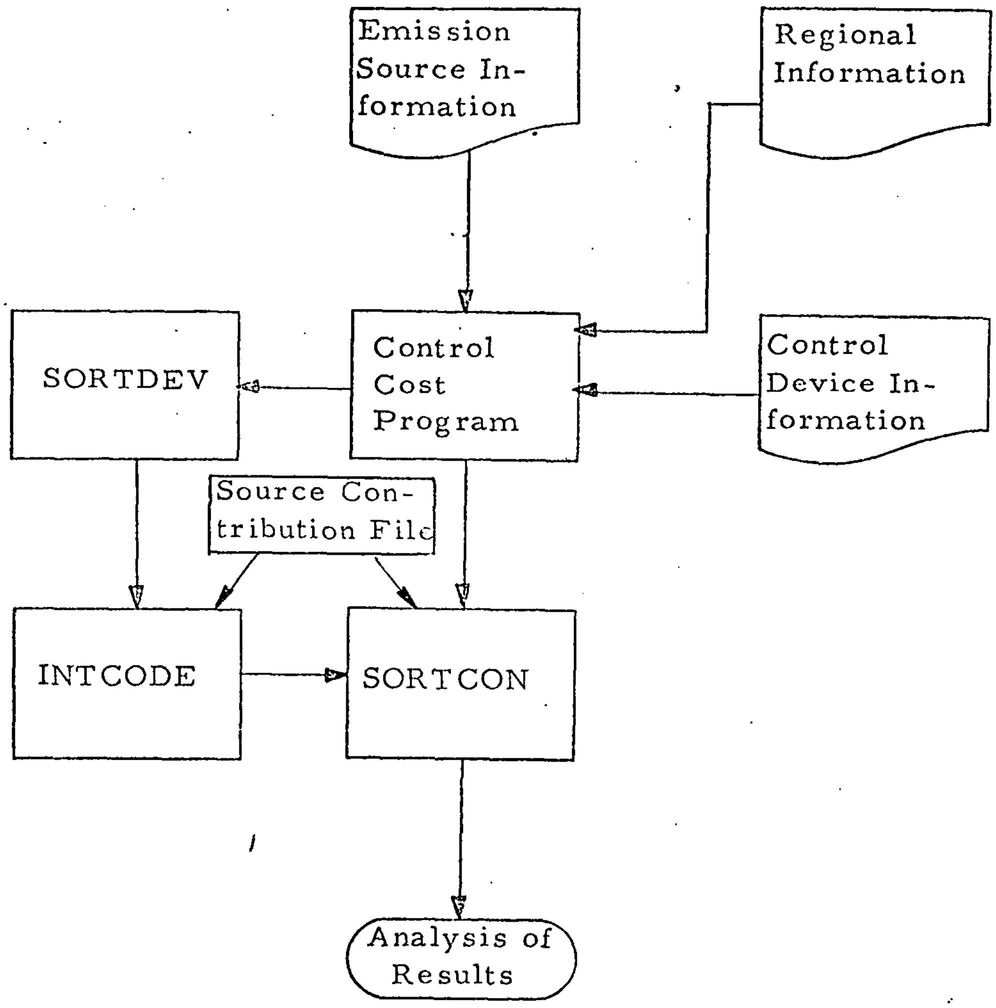
DCIM was simulated on data obtained for the New York and Philadelphia AQCRs. Emission source information was obtained from EPA in the form of a Source File. This file consists of a detailed history of all sources within the AQCR along with their emission rates, rate capacities, operating time, etc. Regional information consists of fuel costs

---

*TRW Systems Group, Air Quality Implementation Planning Program, Vols. I and II, prepared for the Environmental Protection Agency, National Air Pollution Control Administration, November 1970.

**Ernst and Ernst, Application of Cost-Effectiveness Analysis to Air Pollution Control, prepared for the Department of Health, Education and Welfare, Consumer Health Service, Consumer Protection and Environmental Health Service, April, 1970.

Figure 6.2
Structure of DCIM



and utility costs and was collected by CONSAD staff. The control device information is pre-set in the Control Cost program. Meteorological information was obtained from EPA as the Source Contribution File. This file is the output of the Air Pollution Concentration Segment* developed by TRW. It lists annual average air quality levels before control at selected receptor locations in the AQCR. For example, in the Philadelphia AQCR there are 270 such receptor locations. The file is really a matrix which details the number of sources and the amount of pollutants contributed by each to every receptor.

One of the strategies simulated for the Philadelphia AQCR was the least cost strategy which met emission standards laid down by the 312(a) amendment to the Clean Air Act of 1970.

The standards laid down by the Clean Air Act Amendment are as follows:

SIC Code	Process Code	Specified EMRAT (lb./hr.)	Rated Cap. (MBTU/hr.)
Any	X0	.6	≤ 10
	X0	$.4104 \cdot 10^{-4}$ (RATCAP) + .6004	$10 < \text{RATCAP} < 10^4$
	X0	.19	$\geq 10^4$
2819	02	.5 (Max. Process Rate)	
4953	01-05	4 (Max. Process Rate)	Max. Proc. Rate
Otherwise		$3.59\ (MPR)^{0.62}$	≤ 30 tons/hr.
		$17.31\ (MPR)^{0.16}$	> 30 tons/hr.

continued

*Ibid.

Any	X0	1.46 (RATCAP)
2819	02	6.5 (MPR)
Otherwise		10% of sulfur input to plant

Most of these standards are functions of the rated capacity of a plant and the maximum process rate that the plant can achieve. The rated capacity and maximum process rate are input variables and are a part of the emission source information input to the control cost segment.

For every source emission standards are calculated based on the above table. Four distinct possibilities can occur -- both SO_2 and particulate standards are met, both are not met or either SO_2 or particulate is met and the other is not. In the first case, the model will pick the device with the least total annual cost. In the other three cases, the model will pick the device that comes closest to meeting the standards. This will be done on the basis of total emissions (both SO_2 and particulate) being compared with total emissions required by the standards. It must be noted that the total annualized costs generated by DCIM consist of operating and maintenance costs and investment costs and are predicated upon the double declining method of depreciation over the estimated life of the control device.

Once appropriate devices have been selected for each source the model then calculates the resultant reduction in emissions, based on reduction efficiencies of each device, and the resultant air quality at each receptor. Since the outputs generated by DCIM can very easily be identified at the two-digit SIC level, the results can readily be used to perturb other regional econometric models in order to evaluate the effects of pollution control on regional economies.

Some of the results obtained for the 312(a) standard strategy for the Philadelphia AQCR are presented below. (Each number was obtained by combining all the 1033 point sources in Philadelphia).

1. Annual Emissions in Tons

	Pre-control	Post-control	% Reduction
SO_x	798,000	300,600	62.36
Particulate	141,180	25,410	82.00

2. Annual Average Air Quality in $mgms/m^3$

	Pre-control	Post-control	% Reduction
SO_x	52.58	12.89	75.53
Particulate	72.20	38.85	46.19

Figures 6.3 and 6.5 show the base year sulfur dioxide and particulate air quality. Figures 6.4 and 6.6 show the sulfur dioxide and particulate air quality after the implementation of Clean Air Act Amendment Standards. All distances shown along the axes in the figures are in kilometers, the numbering being in standard UTM coordinates.

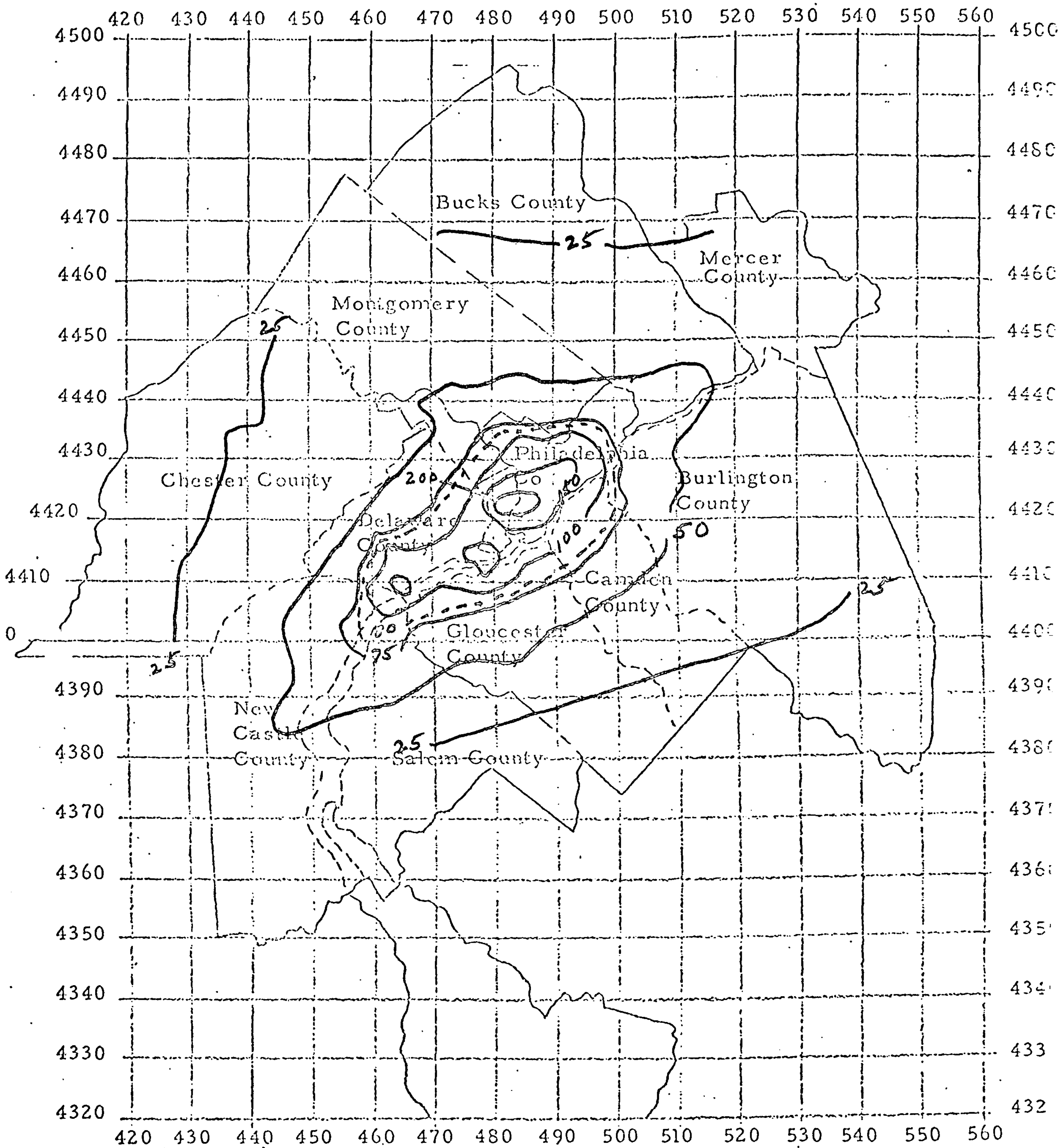


Figure 6.3
Philadelphia Air Quality Control Region
Sulfur Dioxide Air Quality Before Control (mgm/m^3)

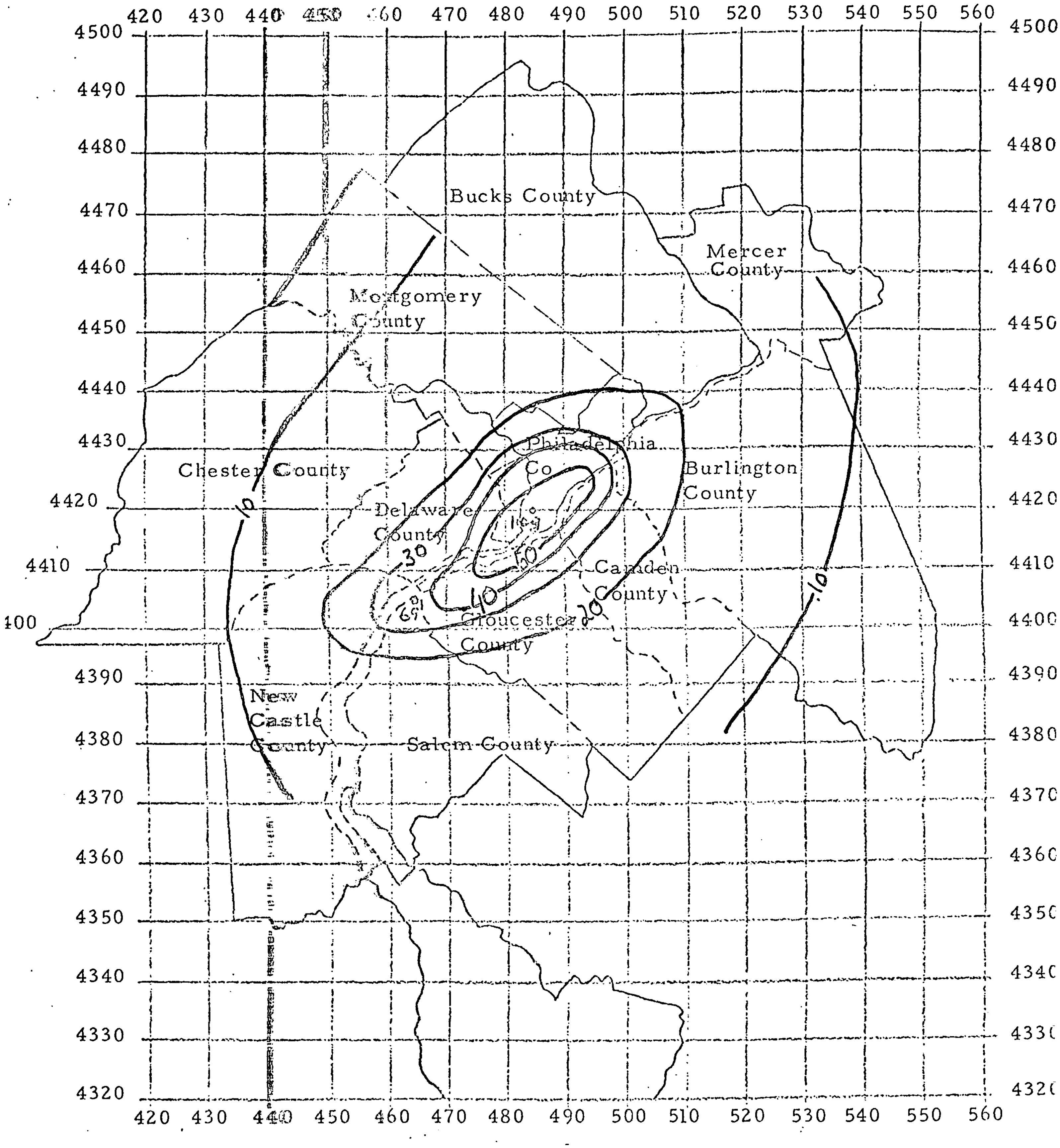


Figure 6.4
Philadelphia Air Quality Control Region
Sulfur Dioxide Air Quality After Implementation of Clean Air Act Amendment Standards (mgm/m^3)

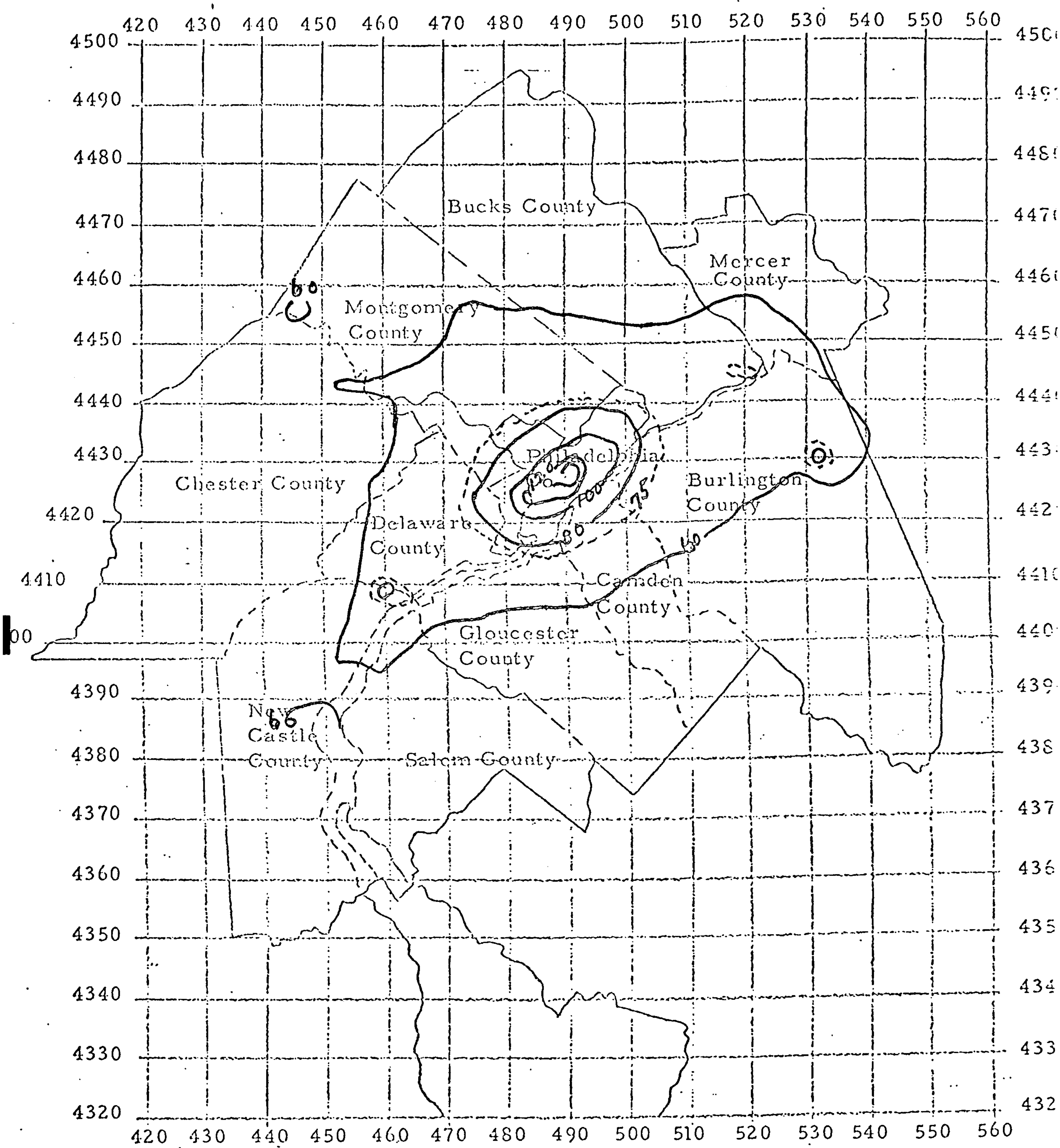


Figure 6.5
Philadelphia Air Quality Control Region
Particulate Air Quality Before Control (mgm/m^3)

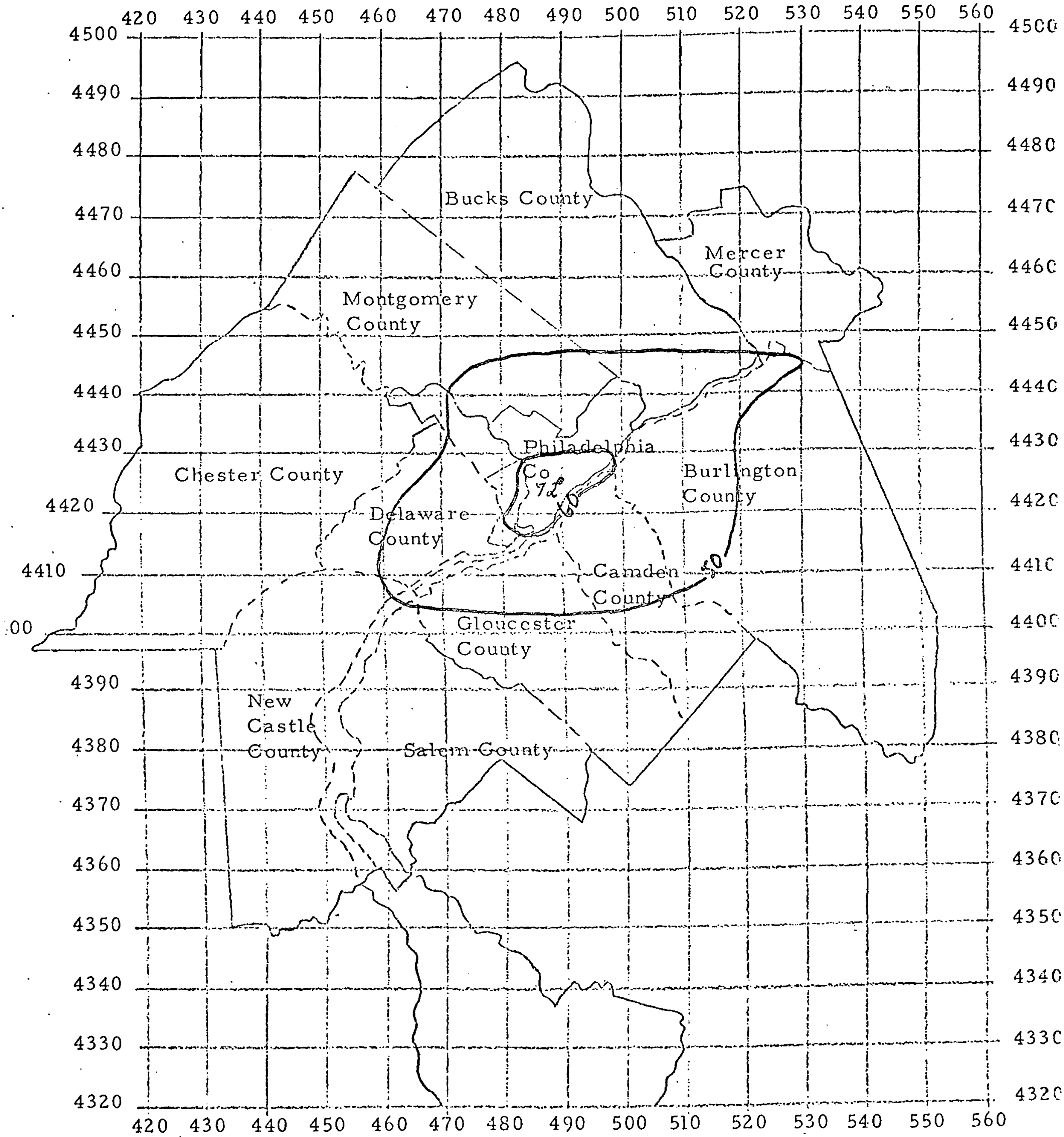


Figure 6.6
Philadelphia Air Quality Control Region
Particulate Air Quality After Implementation of Clean Air Act Amendment Standards (mgm/m^3)

6.3 Change of Property Values in Response to Change of Air Quality

The improvement in real estate values due to reduction of air pollution appears to be one of the best objective measures of the benefits of air pollution control. In recent quantitative studies on this topic, some statistically significant damage functions have been estimated relating pollution dosage and real estate values for different pollutants in different regions.* In this section, such a function will be applied to the simulated change in air quality due to control in Philadelphia to estimate the consequent improvement in property values and property tax assessments for that city.

Most of the damage functions have been estimated in a logarithmic form of regression equations.**

---

* Anderson, R.H., and T.D. Crocker, op. cit.
Crocker, T.D., "Some Economics of Air Pollution Control with Special Reference to Polk County, Florida," Report to the U.S. Public Health Service, 1968.

** Anderson, R.H., and T.D. Crocker, op. cit., p. 175.

Let A = Property value (sale price)

S = Dosage of SO_x

P = Dosage of Particulate

X_i = Other explanatory variables, $i = 1, 2, \ldots, V$*

Then the damage function is given

$$(1) \quad A = e^a S^{-\alpha} P^{-\beta} \prod_{i=1}^{V} X_i^{\gamma i}$$

Suppose change of air quality is presentented in the form,

quality with control = quality without control - improvement in quality due to control,

i. e., $S' = S - \Delta S;$

$P' = P - \Delta P$

Then the new value of property with air pollution control will be A', given by

$$(2) \quad A' = e^a (S - \Delta S)^{-\alpha} (P - \Delta P)^{-\beta} \prod_{i=1}^{V} X_i^{\gamma i}$$

Dividing (2) by (1)

$$(3) \quad \frac{A'}{A} = \left(\frac{S - \Delta S}{S}\right)^{-\alpha} \left(\frac{P - \Delta P}{P}\right)^{-\beta}$$

---

* The other variables are median family income, the percentage of property classed as dilapidated, the percentage of each tract's units more than 20 years old in 1959, the percentage of occupied housing each tract inhabited by non-whites, each tract's distance from the central business district and the median number of rooms in housing units.

The percentage increment of property value due to changes in SO_x and particulate concentrations, assuming other explanatory variables to remain the same, is given by $\frac{A' - A}{A} \times 100$, i.e., $\left(\frac{A'}{A} - 1\right) \times 100$.

The above result is applied to the data for Philadelphia AQCR as follows. From Section 6.2, the pre-control air quality measures of SO_x and particulate concentration are

$$S = 52.58 \text{ Mgm/m}^3$$

and $$P = 72.20 \text{ Mgm/m}^3.$$

The standards assumed in the Clean Air Act Amendment, 1970 (referred to as 312(a) Standard) will reduce the SO_x and particulates in Philadelphia AQCR to the levels of

$$S - \Delta S = 12.89 \text{ Mgm}^3$$

and $$P - \Delta P = 38.85 \text{ Mgm}^3$$

Consequently, $$\frac{S - \Delta S}{S} = 0.24488$$

and $$\frac{P - \Delta P}{P} = 0.5381$$

Substituting these and regression estimates of α and β * into (3)

$$\frac{A'}{A} = (.2449)^{-.0712} \quad (.5381)^{-.0610} = 1.06439$$

---

* The estimates of α, β for Washington, D.C., were adopted as substitutes for those of Philadelphia which are not available. The estimates are from Anderson, R.J., and T.D. Crocker, op. cit., p. 175, Type I equation.

From the calculation above, an increase of approximately 6.44 percent can be expected in the property value in Philadelphia AQCR due to the application of air pollution control to meet the standards of the 312(a) Amendment of the Clean Air Act, 1970. In dollar terms, the property value will rise from $9.2 billion before control to $9.8 billion after control, i.e., an increase of $593 million. If this is the case, this substantial increase in property value will lead to an increase of $29.6 million in property tax assessments in Philadelphia. This shows that the tax revenue of governmental bodies may increase substantially due to the application of pollution control measures. Thus the actual social cost of pollution control may be less than it looks at first sight. The results also suggest that the study of second-order effects in economic-environmental interactions can be a valuable addition to the present tools for policy decisions.

6.4 Economic-Environmental Interaction

It is almost impossible for any model system to give a complete coverage of the complexity of interdependencies between economic and environmental systems in reality. In this section, it merely utilizes the information provided from other models as described in Sections 6.2 and 6.3 to give a demonstration on how an integrated study can be conducted by the use of some existing modelling efforts.

By the use of the DCIM system the air qualities and the emission levels in Philadelphia AQCRs were obtained (Section 6.2).

Emissions are by-products of economic activities, in particular, from production processes of various industries that

$E_{ij} = f\,(Q_j, \text{process rate})$ $\qquad E_{ij} = f\,(Q_j,\ \text{process, etc.})$

where E_{ij} is type i emission from industry j

Q_j is level of production of industry j

Suppose emission E_{ij} is in proportion to the level of production

$$e_{ij} = \frac{E_{ij}}{Q_j}.$$

Where e_{ij} is type i emission per unit of output of industry j, or it may be called "emission factor" of industry j.

Upon the implementation of the air quality standards required by the law, emission reductions can be expected with corresponding improvement of the ambient air qualities. Thus, the emission per unit Q output with pollution control can be measured

$$e^*_{ij} = \frac{(E_{ij} - E'_{ij})}{Q_j}$$

where e^*_{ij} is type i emission per unit output of industry j with air pollution control,

E'_{ij} is type i emission reduction by industry j with implementation of air quality standards.

The DCIM system described in Section 6.2 also provides the emissions by Standard Industrial Code (SIC) 4-digit categories.

Emissions by two-digit SIC industries were estimated for the DCIM output (Table 6.1). Based on such information, emissions per unit of production by two-digit SIC industries can be estimated. Value of shipment and value-added were used for measurement of the production levels of each industry. Table 6.2 gives emissions per million dollar of value of shipment and value-added by two-digit SIC industries in Philadelphia AQCR. By the implementation of 312(a) standards, emissions per unit of output were considerably reduced as shown in Table 6.3.

The costs of the implementation of 312(a) standards were then introduced to the OAP Regional Econometric Model to measure the overall regional economic impact. The simulation results of Philadelphia AQCR in year 1976 are given in Table 6.4, column 2.

Table 6.1
SO_x and Particulate Emissions by Two-Digit SIC Industries in Philadelphia AQCR

(unit: tons/day)

Industry	SO_x	Particulate
SIC 20	12.754	3.176
22	4.998	4.819
26	11.481	.689
28	268.152	25.948
29	392.806	68.303
32	2.673	6.547
33	24.208	71.517
34	0	.020
37	4.089	.354
39	85.284	6.788
49	1,350.203	140.133
Other	29.782	58.526
TOTAL	2,186.43	386.82

Table 6.2
SOX and Particulate Emissions Per Unit of Output ($1 Million of Value of Shipment and Value-Added) by 2-Digit SIC Industries in Philadelphia AQCR Before Control

Industry SIC	SOx		Particulate	
	Tons per year per $1 million of value of shipment	Tons per year per $1 million of value-added	Tons per year per $1 million of value of shipment	Tons per year per $1 million of value-added
20	2.235	5.692	0.5566	1.4175
22	3.298	7.140	3.1796	6.884
26	5.425	10.218	0.3256	0.6132
28	56.112	72.195	5.4297	6.9861
29	95.240	348.333	16.5608	60.57
32	2.892	4.578	7.0826	11.214
33	7.241	13.034	21.3912	39.083
34	0	0	0.0065	0.0091
37	1.389	1.599	0.1202	0.1384
39	187.296	280.945	14.9075	22.361

Table 6.3
SOX and Particulate Emissions Per Unit of Output ($1 Million of Value of Shipment and Value-Added) by 2-Digit SIC Industries in Philadelphia AQCR After Control

Industry SIC	SOx		Particulate	
	Tons per year per $1 million of value of shipment	Tons per year per $1 million of value-added	Tons per year per $1 million of value of shipment	Tons per year per $1 million of value-added
20	0.842	2.144	0.1001	0.255
22	1.242	2.689	0.5723	1.239
26	2.043	3.848	0.0586	0.110
28	21.132	27.189	0.9773	1.257
29	35.867	131.182	2.9809	10.903
32	1.089	1.724	1.2748	2.019
33	2.727	4.909	3.8504	7.035
34	0	0	0.0011	0.002
37	0.523	0.602	0.0216	0.025
39	70.536	105.804	2.6833	4.025

Table 6.4
Percentage Changes of Major Economic Indicators in Philadelphia AQCR in Response to the Implementation of 312(a) Air Quality Standards by 1976

Variables	Percent Changes of Cost Impacts (first round)	Percent Changes of Cost Benefit Impacts (second round)
Manufacturing Industries		
Value added	- .43%	- .10%
Gross profit	-1.01	- .67
Investment	-6.24	-6.05
Capital stock	- .53	- .52
Employment	-1.00	1.62
Regional Income	- .23	.14
Regional Employment	- .27	.49
Local Tax Revenues	- .20	.96

However, the benefits such as changes in property value as described in Section 6.3 may have some positive economic impacts as the result of air pollution control. Assume a 6.4 percent property value increase in Philadelphia and introduce to the OAP Regional Econometric Model for a second-round simulation.* Some positive economic impacts can be expected in Philadelphia** as shown in column 3 of Table 6.4.

The changes in economic activities, such as manufacturing production, again, are expected to change the level of emissions and hence the corresponding air qualities in the Philadelphia AQCR. By using the emission factors, or emissions per unit of output, the regional emissions and air qualities can be projected.

---

*In the first-round simulation of the OAP Regional Econometric Model, taken as exogenous information, and then emissions and hence air quality changes lead to a change of the property value was introduced to the model for second-round simulated.

**Whether once the "damage is done," the property value damages can be recovered when the air is cleaner than before is a serious question. Therefore, this estimate may overstate the benefits that can be expected.

APPENDIX A
MANUFACTURING INVESTMENT FUNCTIONS: A CROSS-SECTION ESTIMATION WITH SMSA DATA

As indicated in Chapter 3, investment functions with Koyck's distribution were formulated in an earlier version both for gross investment or a net investment equation as follows:

$$(1) \qquad I_t = \lambda(I_{t-1} - \delta K_{t-1}) + \frac{\alpha_o}{C} \left[\Pi_t - \Pi_{t-1}\right] + \delta K_t$$

$$(2) \qquad (I_t - \delta K_t) = \lambda(I_{t-1} - \delta K_{t-1}) + \frac{\alpha_o}{C} (\Pi_t - \Pi_{t-1})$$

Besides Koyck's distribution, Almon's weights were also applied in the estimation.

Almon's Weights

Almon [1] used the Lagrangian interpolation polynominals to estimate lag distribution of manufacturing investment relations with quarterly data. In Almon's estimates, 90% or more investments were completed in eight quarters. By aggregating those quarterly weights into annual weights, we have, gross investment I_t as function of lagged changes of output and depreciation (δK_{t-1})

$$I_t = b \left[\lambda_1(X_t - X_{t-1}) + \lambda_2 (X_{t-1} - X_{t-2})\right] + \delta K_{t-1}$$

where λ_1 and λ_2 are Almon's annualized weights. This again is a formulation of a flexible accelerator model. By substituting gross profit Π for output X and introducing an error term u_t, we get

$$(3) \qquad I_t = \frac{b}{\beta} \left[\lambda_1 (\Pi_t - \Pi_{t-1}) + \lambda_2 (\Pi_{t-1} - \Pi_{t-2})\right] + \delta K_{t-1} + u_t$$

Data

Cross-section data for manufacturing industries by SMSA in years 1965, 1966 and 1967 were used. A maximum sample of 56 SMSA's is included; this is due to the fact that in years 1966 and 1965 data on the Annual Survey of Manufacturers includes only 56 out of 91 SMSA's under current study.

Some parameters used in the estimation need further explanation. Depreciation rates for all manufacturing industries and each of two-digit SIC industries were estimated from actual depreciation and gross book value of fixed assets of 1957 U.S. data.* Capital data were also estimated by using capital output ratios of U.S. applied to the value added by region by industries.**

Finally, Almon's weights were derived as described before. Her original estimation only included some two-digit SIC industries. Therefore, the parameters from non-durable or durable industries were applied to those two-digit SIC industries not inluded in her study.

- durables: SIC 24, 25, 32-39
  non-durables: SIC 20, 22, 23, 26-31

These parameters are summarized in Table 1.

---

* U.S. Department of Commerce. Bureau of the Census. 1958 Census of Manufacturers. Vol. 1, Summary Statistics. Section 9 "Selected Costs and Book Value of Fixed Assets."

** From the same source of data, capital-output ratios were estimated from value added and gross book value of fixed assets.

TABLE 1
SOME PRE-ESTIMATED PARAMETERS

Industry	Depreciation rate	Output-Capital ratio	Almon's Annualized Weights	
			λ_1	λ_2
All Manf.	.0662	1.271	.514	.406
SIC 20	.0674	1.394	.561	.401
22	.0525	1.043	.728	.269
23	.0906	6.032	.616	.291
24	.0915	1.126	.441	.490
25	.0737	2.415	.441	.490
26	.0539	.799	.557	.415
27	.0686	2.142	.616	.291
28	.0669	.952	.413	.519
29	.0614	.409	.845	.029
30	.0618	1.381	.480	.408
31	.0755	4.053	.616	.219
32	.0646	.966	.491	.462
33	.0560	.769	.441	.490
34	.0700	1.670	.441	.490
35	.0722	1.696	.541	.338
36	.0738	2.353	.429	.447
37	.0738	2.353	.429	.447
38	.0671	3.276	.441	.490
39	.0732	2.389	.441	.490

Results

Equations (1), (2) and (3) are estimated with ordinary least square regression method with cross-sectional data. In these equations t represents year 1967, and t-1 and t-2 are years 1966 and 1965 respectively.

The results are summarized in Tables 2, 3, and 4. In each table, the parentheses under each estimated coefficient shows the standard error, and followed by the regression coefficient R^2 and sample size in each estimation.

All three models seem to be superior to the previous estimates of the investment equations in the Regional Model both in theoretical formulation and empirical results.*

Equation (1) in Table 3 using gross investment by SMSA industry in 1967 as dependent variables and estimating the depreciation rate by the model gives a reasonably good fit; it shows a better fit then in Equations (2) and (3) (Tables 2 and 4)

---

* For previous investment functions see CONSAD Research Corporation An Economic Model System for the Assessment of Effects of Air Pollution Abatement prepared for Office of Air Program, EPA, May 15, 1971.

TABLE 2

EQUATION (2): Net Investment as Dependent Variable with Koyck Lag Structure

$$\left[I_t - \delta K_t\right] = b_1 \left[I_{t-1} - \delta K_{t-1}\right] + b_2 \left[\Pi_t - \Pi_{t-1}\right]$$

Industry	b_1 coefficient	b_2 coefficient	R^2	Sample Size
All Manf.	1.0202 (.0354)	.1225 (.0182)	.938	56
SIC 20	.9911 (.0804)	.0430 (.0469)	.768	49
22	.0779 (.0762)	.0750 (.0251)	.232	26
23	1.0086 (.0113)	.3945 (.0802)	.999	37
24	1.0113 (.1078)	.0655 (.0571)	.610	20
25	1.0242 (.0267)	.1279 (.0420)	.970	34
26	.6790 (.1059)	.3002 (.0816)	.530	41
27	1.0664 (.0219)	.0039 (.0582)	.989	47
28	.6571 (.0534)	.0390 (.0706)	.785	41
29	1.0629 (.1174)	.3618 (.1099)	.848	13
30	.0026 (.1460)	.2647 (.0995)	.136	25
31	1.0850 (.0282)	.0762 (.1027)	.992	15

TABLE 2 (continued)

Industry	b_1 coefficient	b_2 coefficient	R^2	Sample Size
SIC 32	.6621 (.0885)	-.0048 (.0546)	.396	46
33	1.0138 (.1099)	-.1392 (.0651)	.741	36
34	1.0499 (.087)	.0410 (.0282)	.905	51
35	1.0124 (.0507)	.1109 (.0420)	.850	47
36	1.1623 (.0331)	.2076 (.0575)	.960	37
37	1.1692 (.0354)	.0690 (.0207)	.975	35
38	1.1407 (.0270)	.2063 (.0156)	.995	22
39	1.0539 (.0126)	.0864 (.0032)	.995	30

TABLE 3

EQUATION (1): Gross Investment as Dependent Variable with Koyck Lag Structure

$$I_t = b_1 \left[I_{t-1} - \delta K_{t-1} \right] + b_2 \left[\Pi_t - \Pi_{t-1} \right] + b_3 K_t$$

Industry	b_1 coefficient	b_2 coefficient	b_3 coefficient	R^2
All Manf.	1.0753 (.0511)	.1204 (.0181)	.0680 (.0012)	.976
SIC 20	.6770 (.1444)	.0599 (.0449)	.0576 (.0038)	.888
22	.0872 (.0739)	.0991 (.0284)	.0483 (.0026)	.938
23	.0246 (.0178)	.0117 (.0111)	.0047 (.0016)	.992
24	.4425 (.0850)	.0697 (.0263)	.0551 (.0044)	.837
25	.3812 (.1959)	.1329 (.0367)	.353 (.0116)	.617
26	.3556 (.1314)	.1595 (.0824)	.0892 (.0102)	.845
27	.5701 (.1129)	.0540 (.0501)	.0440 (.0055)	.924
28	.6569 (.0565)	.0386 (.0786)	.0670 (.0045)	.907
29	.4198 (.3870)	.2175 (.1310)	.4201 (.2073)	.889
30	.0216 (.1491)	.2759 (.1141)	.0603 (.0068)	.694
31	-.2701 (.1235)	-.0963 (.0357)	-.0124 (.0080)	.807

TABLE 3 (continued)

Industry	b1 coefficient	b_2 coefficient	b_3 coefficient	R^2
SIC 32	.6447 (.1370)	-.0008 (.0601)	.0658 (.0069)	.805
33	.3376 (.1624)	.0428 (.0627)	.1346 (.0161)	.928
34	.2940 (.1107)	.1138 (.0223)	.0444 (.0036)	.972
35	.2178 (.1629)	.0157 (.0388)	.0459 (.0052)	.927
36	.4331 (.1102)	.0407 (.0455)	.0409 (.0049)	.900
37	.4392 (.1074)	.0284 (.0145)	.0439 (.0050)	.942
38	.1706 (.0994)	.0760 (.0148)	.0262 (.0042)	.992
39	.4529 (.0499)	.0906 (.0013)	.0369 (.0030)	.996

TABLE 4
EQUATION (3): Gross Investment as Dependent Variable with Almon's Annualized Weights

$$I_t = b_1 \left[\lambda_1 (\pi_t - \pi_{t-1}) + \lambda_2 (\pi_{t-1} - \pi_{t-2})\right] + b_2 K_t$$

Industry	b_1 coefficient	b_2 coefficient	R^2
All Manf.	.1964 (.0990)	.0471 (.0029)	.768
SIC 20	.0813 (.1076)	.0413 (.0027)	.839
22	.1430 (.0428)	.0498 (.0024)	.938
23	.0032 (.0149) =	.0025 (.0001)	.992
24	.1068 (.0197)	.0314 (.0029)	.823
25	.2258 (.0759)	.0105 (.0017)	.543
26	.2792 (.1854)	.1012 (.0117)	.819
27	.0429 (.0979)	.0168 (.0017)	.879
28	.9369 (.2073)	.0531 (.0095)	.726
29	.1700 (.1317)	.6343 (.0586)	.888
30	.0138 (.0376)	.0678 (.0066)	.631
31	-.1050 (.0465)	.0054 (.0007)	.784

TABLE 4 (continued)

Industry	b_1 coefficient	b_2 coefficient	R^2
SIC 32	-.2580 (.1674)	.0878 (.0052)	.719
33	-.0623 (.1146)	.1536 (.0071)	.918
34	.3390 (.0831)	.0298 (.0027)	.961
35	.0214 (.0852)	.0390 (.0016)	.926
36	-.2068 (.0792)	.0247 (.0014)	.877
37	-.0029 (.0267)	.0234 (.0013)	.913
38	.1606 (.0204	.0167 (.0003)	.992
39	.2118 (.0050)	.0076 (.0005)	.989

Both the pre-estimated depreciation rates in Table 1 and estimated depreciation rates with cross-section data seem to be higher than Jorgenson-Stephenson's estimates of 2 to 3 percents with time series data of 1947-1960.**

** Jorgenson, D.W. and J.A. Stephenson [8]

BIBLIOGRAPHY

[1] Almon, S., "The Distributed Lag between Capital Appropriations and Expenditures", Econometrica 33, 1965, pp. 178-196.

[2] Dhrymes, P.J., Econometrics: Statistical Foundations and Applications, Harper & Row, New York, 1970.

[3] ______________, Distributed Lags: Problems of Estimation and Formulation, Holden-Day, San Francisco, 1971.

[4] Evans, M.K., Macroeconomic Analysis, Theory, Forecasting, and Control, Harper & Row, New York, 1969.

[5] Jorgenson, D.W., "Capital Theory and Investment Behavior," American Economic Review, 33, 1963, pp. 247-259.

[6] ______________, "Anticipations and Investment Behavior," in The Brookings Quarterly Econometric Model of the United States, J. S. Duesenberry, G. Froman, L.R. Klien and E. Kuh (eds.), Rand McNally & Co., Chicago, 1965, pp. 35-94.

[7] ______________, "Econometric Studies of Investment Behavior: A Survey" Journal of Economic Literature, 15, 1971, pp. 1111-1147.

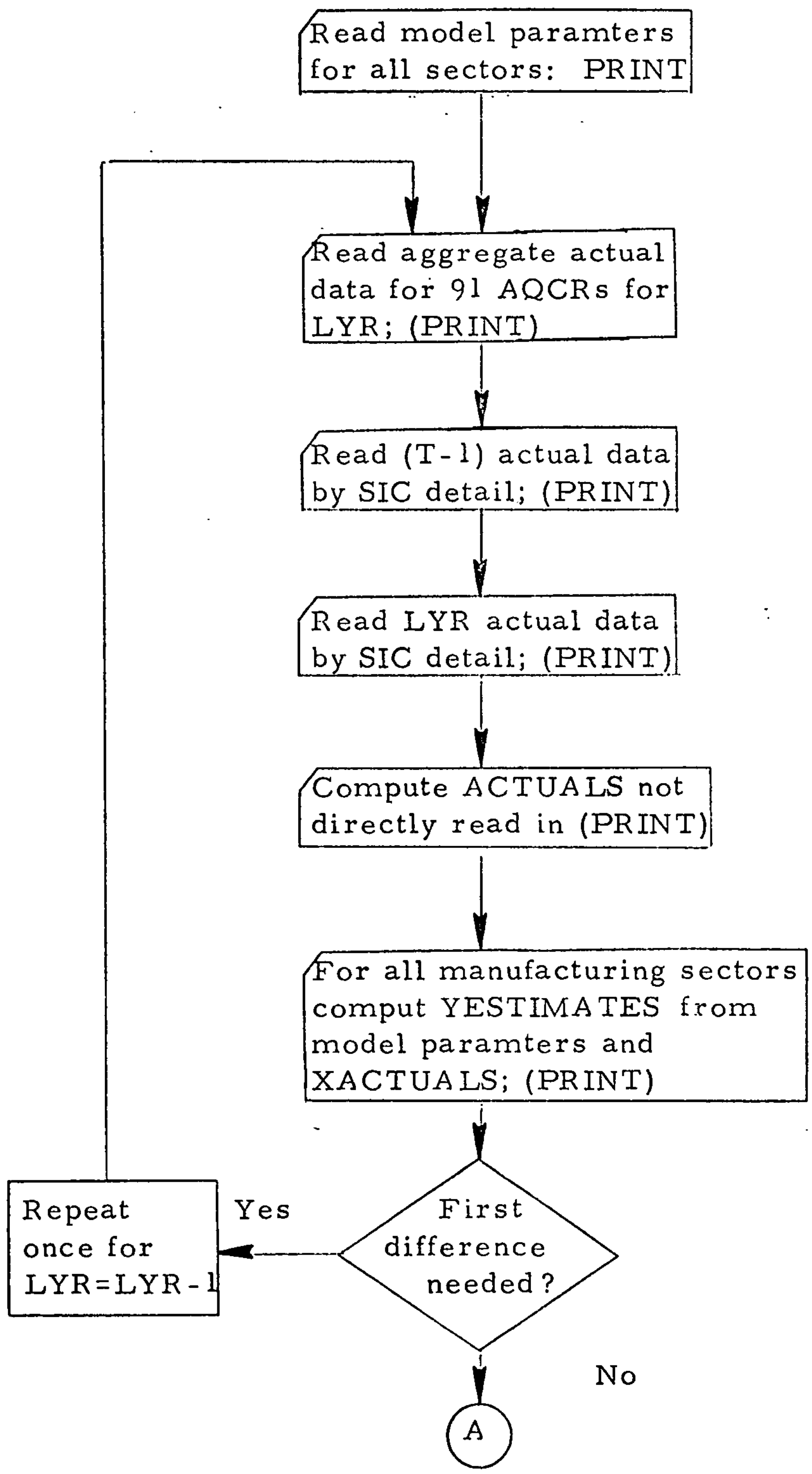
[8] ______________, and J.A. Stephenson, "The Time Structure of Investment Behavior in Uited States Manufacturing, 1947-1960," Review of Economics and Statistics, 49, 1967, pp. 16-27.

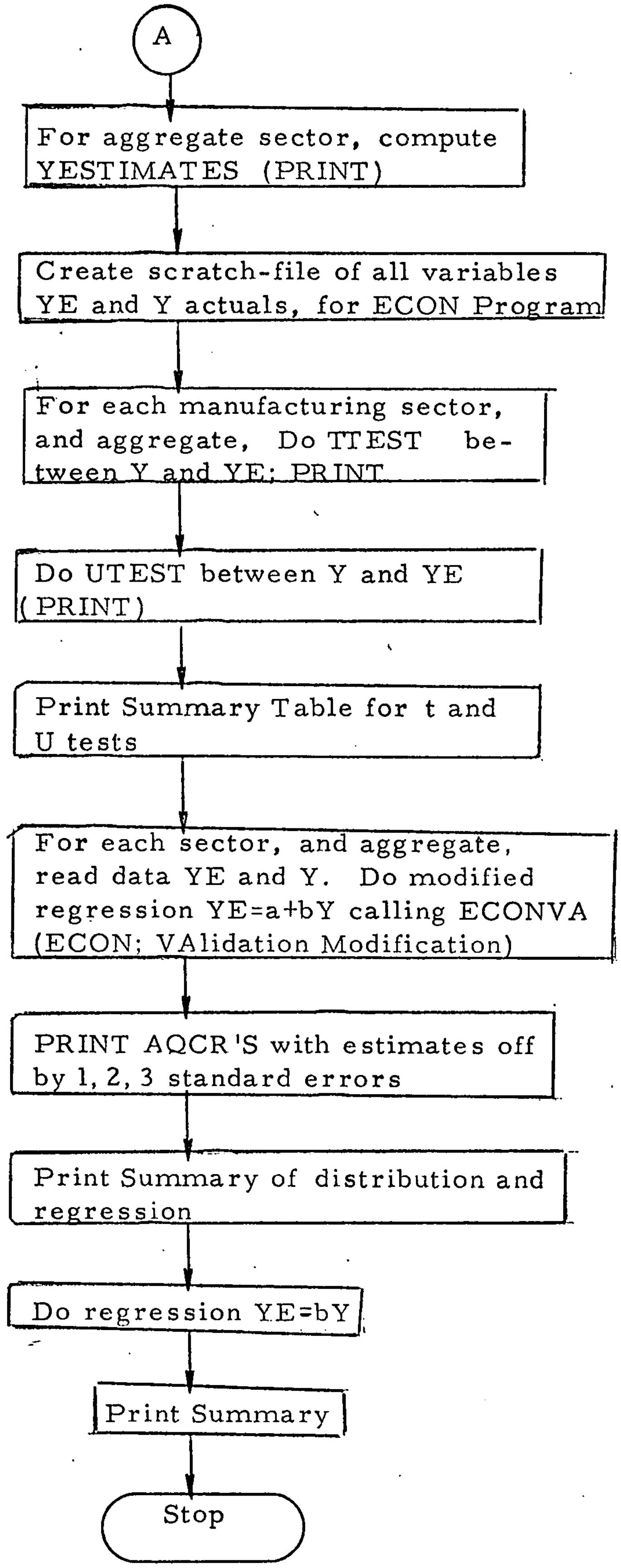
[9] Koyck, L.M., Distributed Lags and Investment Analysis, North-Holland Publishing Co., Amsterdam. 1954.

APPENDIX B

FLOWCHART OF VALIDATION PROGRAM KRVALTSC

FLOWCHART OF KRVALTSC PROGRAM:
ESSENTIAL ASPECTS




A
For aggregate sector, compute YESTIMATES (PRINT)
Create scratch-file of all variables YE and Y actuals, for ECON Program
For each manufacturing sector, and aggregate, Do TTEST between Y and YE; PRINT
Do UTEST between Y and YE (PRINT)
Print Summary Table for t and U tests
For each sector, and aggregate, read data YE and Y. Do modified regression YE=a+bY calling ECONVA (ECON; VAlidation Modification)
PRINT AQCR'S with estimates off by 1, 2, 3 standard errors
Print Summary of distribution and regression
Do regression YE=bY
Print Summary
Stop

APPENDIX C

EXTERNAL VALIDITY RESULTS FOR MANUFACTURING SECTOR BY TWO-DIGIT DETAIL FOR 1969 EXCEPT YE=bY

AGGREGATE OF ALL 19 SIC's

SIC 0	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.8488	172.361	208.589	.7947	23.755	59	33	49	55	133.440	1.1804	.9968
Value Added V	1.8273	2271.607	2811.880	.8972	236.775	59	27	43	49	107.763	1.2575	.9950
Investment I	.2987	144.361	149.817	.1716	31.035	59	51	57	59	64.099	1.0444	.9861
Gross Profit Π	.1211	1074.517	1090.382	.0645	202.526	59	51	56	57	57.519	1.0589	.9828
Wage Rate W	1.0899	6.667	6.841	1.1899	0.2936	59	38	56	59	32.870	0.7988	.9490
Capital Stock K	0.1588	1786.972	1774.311	.0306	31.507	59	38	54	57	270.372	.9887	.9992

FOOD AND KINDRED PRODUCTS

Sic 20	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.3580	13.333	15.812	.8127	2.535	54	37	46	53	85.933	1.1605	.9929
Value Added V	.8848	228.352	252.842	.4626	41.080	54	45	50	53	105.617	1.0829	.9953
Investment I	.4139	14.798	14.240	.1336	4.107	53	49	50	52	30.935	.7909	.9484
Gross Profit Π	.2028	144.355	137.148	.2297	19.229	54	44	51	52	78.561	.9402	.9915
Wage Rate W	.9647	6.026	6.160	.9070	.2872	54	43	52	54	28.025	.9045	.9367
Capital Stock K	.1422	165.086	163.848	.0333	4.628	53	38	46	51	160.737	1.0042	.9980

TEXTILE MILL PRODUCTS

Sic 22	Normal-ized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.0	11.100	13.507	.5259	.979	17	9	11	12	55.420	1.2245	.9948
Value Added V	.0	97.178	111.061	.3611	15.627	17	12	14	16	46.730	1.1406	.9927
Investment I	.0	6.012	5.845	.0749	1.944	17	14	17	17	24.514	.9127	.9740
Gross Profit Π	.0	46.027	40.708	.3311	7.228	17	12	14	17	40.492	.8738	.9903
Wage Rate W	.0	4.667	4.841	.8457	.210	17	11	17	17	18.075	1.0434	.9532
Capital Stock K	.0	93.199	92.117	.0319	1.912	17	9	13	14	76.801	.9755	.9973

APPAREL AND RELATED PRODUCTS

Sic 23	Normal-ized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.9568	17.235	19.649	.2320	9.510	37	35	36	36	262.358	1.1120	.9995
Value Added V	.8811	145.734	155.072	.0999	116.658	37	37	37	37	152.391	.9991	.9985
Investment I	.2929	3.778	2.740	.4547	2.372	36	31	34	35	64.318	.6527	.9916
Gross Profit Π	.0595	68.504	60.480	.1879	46.856	37	36	36	36	138.933	.8376	.9981
Wage Rate W	1.2270	4.142	4.305	.9264	.236	37	27	36	36	33.124	1.0061	.9682
Capital Stock K	.0338	24.664	24.706	.0027	2.455	36	36	36	36	1261.757	1.0039	.9999

LUMBER AND WOOD PRODUCTS

Sic 24	Normal-ized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.0	5.813	7.869	1.5096	.416	8	0	1	2	12.799	1.3194	.9588
Value Added V	.0	64.875	85.227	1.3447	3.401	8	0	1	2	11.480	1.2548	.9492
Investment I	.0	4.234	4.302	.0431	.543	8	2	6	6	7.220	.6046	.8796
Gross Profit Π	.0	30.712	27.779	.4906	1.546	8	3	4	6	11.211	.8732	.9468
Wage Rate W	.0	5.934	6.318	.8319	.306	8	2	8	8	17.330	1.0356	.9771
Capital Stock K	.0	57.625	55.212	.2068	.5415	8	0	0	1	73.663	.9960	.9987

FURNITURE AND FIXTURES

Sic 25	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.0	6.888	9.087	.7734	.833	17	4	11	13	42.144	1.2554	.9911
Value Added V	.0	73.171	89.437	.5287	8.300	17	4	14	14	52.282	1.1795	.9942
Investment I	.0	2.224	2.113	.1664	.754	17	15	17	17	15.737	1.0588	.9391
Gross Profit Π	.0	33.302	30.929	.1950	2.166	17	9	12	16	50.548	.9508	.9938
Wage Rate W	.0	5.633	5.587	.1947	.316	17	17	17	17	60.120	.8793	.9956
Capital Stock K	.0	30.296	29.396	.786	.7589	17	11	14	15	311.002	.9669	.9998

PAPER AND ALLIED PRODUCTS

Sic 26	Normalized U-Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.8941	7.8968	8.820	.4554	.747	31	19	26	27	81.001	1.1235	.9954
Value Added V	.7532	95.854	104.199	.3414	9.151	31	22	29	29	51.956	1.0673	.9890
Investment I	.5408	7.764	9.031	.6129	3.949	28	22	25	28	11.373	1.1562	.8262
Gross Profit Π	.0634	48.704	47.208	.1244	5.057	31	25	28	29	36.663	.9227	.9782
Wage Rate W	.2323	5.949	5.984	.2800	.218	31	30	31	31	46.775	.8364	.9865
Capital Stock K	.0328	124.125	124.453	.0101	3.9661	28	27	28	28	398.524	.9946	.9998

PRINTING AND PUBLICATION

SIC 27	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.0854	15.102	17.980	.4547	1.510	45	28	37	39	185.787	1.2093	.9987
Value Added V	.8191	204.383	211.639	.0792	97.854	45	44	44	45	98.492	.9165	.9955
Investment I	.5744	9.561	8.924	.1843	3.956	43	40	43	43	59.104	1.0208	.9881
Gross Profit Π	.2219	103.168	87.558	.3237	55.764	45	43	44	44	88.449	.7474	.9944
Wage Rate W	.5124	6.290	6.365	.5273	.256	45	41	45	45	58.675	.8616	.9874
Capital Stock K	.1771	98.658	99.021	.0078	4.0198	43	39	42	43	756.462	.9923	.9999

CHEMICALS AND ALLIED PRODUCTS

SIC 28	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.4193	11.340	16.271	1.4707	1.911	30	11	18	24	27.920	1.5082	.9641
Value Added V	1.6559	288.755	389.739	1.1857	43.969	30	8	17	24	51.081	1.2911	.9890
Investment I	.2099	23.675	24.966	.1339	7.647	29	27	29	29	61.083	1.0375	.9925
Gross Profit Π	.0591	208.142	202.792	.0992	17.505	30	21	27	28	54.446	.9149	.9903
Wage Rate W	.2366	6.975	7.010	.1959	.339	30	29	30	30	43.609	.8399	.9850
Capital Stock K	.1944	309.144	306.739	.0303	7.743	29	22	23	26	78.486	.9974	.9955

PETROLEUM AND COAL PRODUCTS

SIC 29	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval			t_b	b	R^2
							$\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$			
Variables (Manufacturing)												
Employment N	.0	7.667	14.466	2.6087	2.983	6	0	4	4	4.154	1.8098	.7648
Value Added V	.0	257.330	388.174	1.4806	53.544	6	0	3	4	12.184	1.2952	.9672
Investment I	.0	92.846	84.234	.2596	16.015	4	1	3	4	2.572	.7057	.6518
Gross Profit Π	.0	193.780	175.448	.3147	18.642	6	4	5	5	14.541	.7970	.9768
Wage Rate W	.0	8.206	8.430	.6209	.3108	6	4	6	6	6.588	.9892	.8945
Capital Stock K	.0	719.176	735.612	.0631	16.250	4	2	4	4	29.666	.9884	.9966

RUBBER AND PLASTICS PRODUCTS

SIC 30	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.0551	9.725	12.019	.7590	1.246	20	8	14	16	51.050	1.2381	.9928
Value Added V	1.0550	111.736	136.663	.7147	28.800	20	15	17	19	35.716	1.1957	.9853
Investment I	.0	9.687	9.355	.0894	4.582	13	10	13	13	9.628	.7801	.8843
Gross Profit Π	.0812	55.837	55.108	.0459	13.933	20	19	20	20	30.130	.9489	.9795
Wage Rate W	.2976	5.640	5.705	.2711	.361	20	19	20	20	47.217	.8133	.9915
Capital Stock K	.0	92.016	94.059	.0614	4.614	13	11	13	13	204.806	1.0190	.9997

LEATHER AND LEATHER PRODUCTS

SIC 31	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.0	8.318	9.741	.3326	.769	11	6	8	9	96.622	1.1805	.9989
Value Added V	.0	57.295	65.398	.2993	12.030	11	10	10	10	25.367	1.2016	.9847
Investment I	.0	1.279	1.137	.2954	.742	11	10	11	11	8.428	.7123	.8751
Gross Profit Π	.0	22.993	22.402	.0624	4.048	11	9	11	11	25.374	1.0066	.9847
Wage Rate W	.0	4.163	4.122	.1841	.370	11	11	11	11	59.648	.7689	.9972
Capital Stock K	.0	14.138	13.988	.0253	.7486	11	10	10	11	79.231	.9727	.9984

STONE, CLAY, AND GLASS PRODUCTS

SIC 32	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.5198	6.418	7.526	.8894	.933	33	20	27	30	58.287	1.1440	.9907
Value Added V	1.0708	97.841	111.384	.7165	14.159	33	24	28	32	49.760	1.1234	.9872
Investment I	.5707	7.769	8.259	.3074	3.026	33	29	32	33	16.523	.8850	.8947
Gross Profit Π	.1475	53.087	52.149	.0985	5.862	33	26	32	33	43.722	.9745	.9835
Wage Rate W	.0577	6.845	6.828	.0833	.338	33	32	33	33	57.195	.8752	.9903
Capital Stock K	.1603	101.233	100.236	.0546	3.056	33	27	32	33	165.744	.9920	.9988

C. 14

PRIMARY METAL INDUSTRIES

SIC 33	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y} \pm S$	$\hat{Y} \pm 2S$	$\hat{Y} \pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.3966	17.936	23.425	.9048	3.297	36	21	25	29	88.624	1.3105	.9956
Value Added V	1.1375	274.867	339.736	.7023	90.386	36	26	34	34	91.410	1.2025	.9958
Investment I	.5887	32.875	33.452	.0535	15.676	34	27	33	34	20.408	.9041	.9264
Gross Profit Π	.0113	131.396	124.817	.1661	48.810	36	34	36	36	54.607	.9129	.9884
Wage Rate W	.1577	7.661	7.654	.0412	.289	36	35	36	36	56.567	.8741	.9892
Capital Stock K	.0123	374.716	374.969	.0022	15.981	34	30	32	33	150.306	.9999	.9985

FABRICATED METAL PRODUCTS

SIC 34	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.3119	17.154	20.935	.7280	16.651	46	44	46	46	118.983	1.1979	.9968
Value Added V	1.1401	229.564	271.591	.6040	59.736	46	39	41	44	154.408	1.1738	.9981
Investment I	.1252	12.722	13.253	.1550	6.102	44	43	43	44	44.737	1.0767	.9790
Gross Profit Π	.4295	107.290	102.799	.1558	11.639	46	38	42	43	74.698	.9777	.9920
Wage Rate W	.9761	6.864	7.009	1.0414	.512	46	43	46	46	20.136	.7609	.8999
Capital Stock K	.0584	141.371	140.674	.0176	6.212	44	41	44	44	435.798	.9967	.9998

MACHINERY, EXCEPT ELECTRICAL

SIC 35	Normalized U - Statistic	Actual Mean $\bar{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval			t_b	b	R^2
							$\hat{Y} \pm S$	$\hat{Y} \pm 2S$	$\hat{Y} \pm 3S$			
Variables (Manufacturing)												
Employment N	1.4957	21.002	28.174	1.2494	3.029	49	18	30	37	69.028	1.2768	.9900
Value Added V	1.3606	314.556	400.480	.9812	44.507	49	21	33	42	95.858	1.2459	.9948
Investment I	.4877	17.467	19.552	.4434	5.395	47	42	45	46	68.975	1.1193	.9904
Gross Profit Π	.0533	149.463	140.827	.2447	16.478	49	35	42	45	46.882	.9545	.9786
Wage Rate W	.4725	7.398	7.489	.5110	.2828	49	46	49	49	77.864	.9155	.9921
Capital Stock K	.1096	188.958	188.497	.0097	5.628	47	30	41	44	194.829	1.0023	.9988

ELECTRICAL MACHINERY

Sic 36	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval			t_b	b	R^2
							$\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$			
Variables (Manufacturing)												
Employment N	.7745	24.338	27.956	.4620	5.723	39	35	36	38	61.524	1.1891	.9901
Value Added V	.7145	319.796	377.751	.5691	55.648	39	29	33	35	106.914	1.1836	.9967
Investment I	.0811	17.611	17.575	.0077	8.054	37	35	36	37	25.157	1.0114	.9461
Gross Profit Π	.1149	145.519	150.976	.1229	29.472	39	33	36	37	37.961	.9631	.9743
Wage Rate W	.1449	7.096	7.128	.1694	.300	39	38	39	39	71.975	.8841	.9927
Capital Stock K	.2649	141.840	144.854	.0728	8.268	37	35	35	36	235.058	1.0119	.9993

TRANSPORT EQUIPMENT

Sic 37	Normal-ized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.2980	27.674	38.229	.9416	12.538	35	27	32	33	60.500	1.3932	.9908
Value Added V	1.2040	435.426	559.231	.6923	135.587	35	24	32	33	52.252	1.1998	.9877
Investment I	.1840	27.061	26.128	.0846	16.927	34	33	34	34	69.874	.9096	.9933
Gross Profit Π	.3935	195.935	191.500	.0578	98.935	35	31	33	34	25.200	.8435	.9491
Wage Rate W	1.4154	7.962	7.783	.7980	.836	35	31	35	35	51.206	.5713	.9872
Capital Stock K	.0981	244.463	245.936	.0157	17.353	34	32	33	34	269.382	1.0177	.9995

INSTRUMENTS AND RELATED PRODUCTS

SIC 38	Normal-ized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval			t_b	b	R^2
							$\hat{Y} \pm S$	$\hat{Y} \pm 2S$	$\hat{Y} \pm 3S$			
Variables (Manufacturing)												
Employment N	.0	14.125	16.207	.3300	2.677	16	12	14	15	75.921	1.2130	.9974
Value Added V	.0	262.713	224.782	.2768	91.726	16	15	15	15	21.291	.6690	.9679
Investment I	.0	13.602	19.101	.4907	8.328	15	12	13	14	29.841	1.2260	.9845
Gross Profit Π	.0	153.511	119.534	.3600	56.776	16	14	15	15	41.496	.6499	.9914
Wage Rate W	.0	7.281	7.055	.8041	.486	16	15	16	16	16.191	.8025	.9457
Capital Stock K	.0	83.321	94.211	.1949	8.688	15	10	12	14	340.844	1.1393	.9999

MISCELLANEOUS PRODUCTS

SIC 39	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.6222	11.445	12.266	.1363	2.592	20	18	19	20	207.469	1.0691	.9996
Value Added V	.0271	122.536	120.617	.0323	29.344	20	20	20	20	93.621	1.0131	.9978
Investment I	.0	3.923	2.981	.5688	1.900	18	16	17	18	16.293	.8249	.9396
Gross Profit Π	.3787	59.861	54.577	.1940	10.291	20	16	19	20	80.702	.9334	.9971
Wage Rate W	.1082	5.558	5.510	.2906	.410	20	20	20	20	43.223	.8172	.9899
Capital Stock K	.0	49.014	47.857	.0442	1.929	18	15	16	17	193.208	.9724	.9995

1969

RESULT OF REGRESSION WITHOUT CONSTANT

$YE = bY + \epsilon$

	SIC 0 Aggregate of all 19 SICs			SIC 20 Food & Kindred Products			SIC 22 Textile Mill Products		
	t_b	b	R^2	t_b	b	R^2	t	b	R^2
Variables (Manufacturing)									
Employment N	165.355	1.1914	.9966	117.348	1.1722	.9928	78.956	1.2208	.9951
Value Added V	136.844	1.2499	.9950	139.776	1.0934	.9951	66.971	1.1417	.9932
Investment I	85.221	1.0416	.9863	35.082	.8399	.9367	34.038	.9398	.9738
Gross Profit Π	72.922	1.0407	.9824	105.259	.9444	.9916	57.888	.8789	.9909
Wage Rate W	208.834	1.0224	.8742	220.231	1.0203	.9223	155.329	1.0373	.9561
Capital Stock	347.967	.9903	.9992	211.421	.9992	.9980	108.899	.9817	.9974

1969

RESULT OF REGRESSION WITHOUT CONSTANT

$YE = bY + \epsilon$

	SIC 23 Apparel & Related Products			SIC 24 Lumber & Wood Products			SIC 25 Furniture and Fixtures		
	t_b	b	R^2	t_b	b	R^2	t	b	R^2
Variables (Manufacturing)									
Employment N	265.935	1.1161	.9994	40.400	1.3496	.9641	58.100	1.2865	.9904
Value Added V	143.695	1.0068	.9980	35.639	1.3063	.9546	70.828	1.1992	.9939
Investment I	64.850	.6600	.9906	9.267	.8464	.6526	22.938	.9934	.9369
Gross Profit Π	138.498	.8425	.9979	34.437	.9005	.9534	69.574	.9404	.9939
Wage Rate W	194.014	1.0384	.9681	134.202	1.0641	.9797	251.622	.9900	.9798
Capital Stock	1390.279	1.0036	1.000	148.134	.9629	.9976	429.855	.9684	.9998

1969

RESULT OF REGRESSION WITHOUT CONSTANT

$YE = bY + \epsilon$

	SIC 26 Paper & Allied Products			SIC 27 Printing and Publication			SIC 28 Chemicals & Allied Pro.		
	t_b	b	R^2	t_b	b	R^2	t_b	b	R^2
Variables (Manufacturing)									
Employment N	120.092	1.1200	.9956	210.152	1.2048	.9987	41.350	1.4664	.9640
Value Added V	76.740	1.0777	.9892	87.029	.9370	.9929	72.914	1.3213	.9883
Investment I	17.874	1.1602	.8326	63.315	.9970	.9864	74.835	1.0428	.9927
Gross Profit Π	52.816	.9462	.9776	81.163	.7616	.9920	72.291	.9438	.9886
Wage Rate W	322.539	1.0046	.9468	334.242	1.0100	.9579	264.182	1.0032	.9477
Capital Stock	535.289	.9988	.9998	736.044	.9943	.9999	114.801	.9947	.9956

1969
RESULT OF REGRESSION WITHOUT CONSTANT
$YE = bY + \epsilon$

	SIC 29 Petroleum & Coal Products			SIC 30 Rubber & Plastics Prod.			SIC 31 Leather & Leather Prod.		
	t_b	b	R^2	t_b	b	R^2	t	b	R^2
Variables (Manufacturing)									
Employment N	14.975	1.8789	.8105	80.927	1.2368	.9931	137.969	1.1760	.9990
Value Added V	27.117	1.4705	.9521	56.072	1.2113	.9858	36.104	1.1701	.9849
Investment I	8.096	.8693	.7170	14.128	.8707	.8692	13.035	.8055	.8587
Gross Profit Π	29.171	.8821	.9672	46.407	.9700	.9797	38.174	.9890	.9857
Wage Rate W	111.528	1.0271	.9143	147.034	1.0075	.9342	105.690	.9863	.9164
Capital Stock	76.255	1.0171	.9967	322.354	1.0208	.9997	116.103	.9814	.9984

C.25

1969
RESULT OF REGRESSION WITHOUT CONSTANT
$YE = bY + \epsilon$

	SIC 32 Stone, Clay, and Glass Products			SIC 33 Primary Metal Industries			SIC 34 Fabricated Metal Prod.		
	t_b	b	R^2	t_b	b	R^2	t	b	R^2
Variables (Manufacturing)									
Employment N	100.732	1.1628	.9906	116.342	1.3087	.9957	149.739	1.2062	.9968
Value Added V	86.556	1.1333	.9875	115.207	1.2153	.9957	195.397	1.1772	.9981
Investment I	26.372	.9885	.8769	25.839	.9433	.9236	57.643	1.0623	.9790
Gross Profit Π	76.051	.9797	.9840	68.872	.9265	.9881	94.073	.9703	.9920
Wage Rate W	310.636	.9958	.9715	414.171	.9981	.9695	179.418	1.0182	.7978
Capital Stock	286.655	.9908	.9989	196.565	1.0002	.9986	554.665	.9961	.9998

1969

RESULT OF REGRESSION WITHOUT CONSTANT

$YE = bY + \epsilon$

	SIC 35 Machinery, Except Electrical			SIC 36 Electrical Machinery			SIC 37 Transport Equipment		
Variables (Manufacturing)	t_b	b	R^2	t_b	b	R^2	t	b	R^2
Employment N	89.155	1.3043	.9892	76.552	1.1737	.9899	75.644	1.3891	.9910
Value Added V	124.623	1.2570	.9947	137.935	1.1827	.9968	61.080	1.2252	.9866
Investment I	90.382	1.1193	.9906	34.056	1.0054	.9475	77.800	.9236	.9925
Gross Profit Π	61.725	.9493	.9790	47.324	.9896	.9729	29.024	.8772	.9446
Wage Rate W	460.894	1.0108	.9814	363.075	1.0027	.9747	98.561	.9695	.4980
Capital Stock	254.636	1.0004	.9988	300.146	1.0156	.9993	311.474	1.0142	.9995

1969
RESULT OF REGRESSION WITHOUT CONSTANT
$YE = bY + \epsilon$

	SIC 38 Instruments & Related Prod.			SIC 39 Miscellaneous Products					
	t_b	b	R^2	t_b	b	R^2	t	b	R^2
Variables (Manufacturing)									
Employment N	83.356	1.1833	.9963	252.930	1.0698	.9996			
Value Added V	21.371	.7182	.9501	108.513	1.0041	.9977			
Investment I	31.439	1.2634	.9812	20.061	.8013	.9410			
Gross Profit Π	35.598	.6758	.9841	97.004	.9264	.9971			
Wage Rate W	131.547	.9668	.9091	229.115	.9898	.9460			
Capital Stock	386.732	1.1370	.9999	235.011	.9736	.9996			

APPENDIX D

INTERNAL VALIDITY RESULTS BY TWO-DIGIT DETAIL FOR 1967 FOR SIC 0, 24, 29, 31

VALIDATION WITH 1966-67 DATA

AGGREGATE OF ALL 19 SICs

SIC 0	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval			t_b	b	R^2
							$\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$			
Variables (Manufacturing)												
Employment N	1.0824	181.016	193.922	.2999	23.755	56	41	53	56	100.107	.9973	.9945
Value Added V	.9964	1552.367	1682.135	.3547	236.775	89	67	80	88	120.232	1.0287	.9939
Investment I	.0524	161.555	160.097	.0331	31.035	56	45	54	55	43.682	.9360	.9720
Gross Profit Π	.1498	736.784	745.148	.0499	202.526	89	80	86	87	71.893	1.0583	.9833
Wage Rate W	.3550	6.462	6.526	.4535	.293	56	39	55	56	19.779	.8431	.8765
Capital Stock K	.7274	1484.059	1602.636	.3694	327.348	56	45	50	54	50.670	1.1172	.9790

VALIDATION WITH 1966-67 DATA
WITHOUT CONSTANT $YE = bY + \epsilon$

AGGREGATE OF ALL 19 SICs

SIC 0	t_b	b	R^2
Variables (Manufacturing)			
Employment N	112.643	1.0263	.9925
Value Added V	137.175	1.0450	.9932
Investment I	60.302	.9628	.9708
Gross Profit Π	84.857	1.0433	.9828
Wage Rate W	174.870	1.0076	.8447
Capital Stock K	68.246	1.0997	.9789

Lumber and Wood Products, 1967

SIC 24	Normalized U-Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	1.4347	2.225	2.797	.9315	.4185	20	8	16	19	46.669	1.1875	.9913
Value Added V	8927	21.240	26.389	.8463	3.4006	20	13	15	17	27.916	1.2560	.9762
Investment I	0.0	.965	1.240	.9272	.5428	19	12	17	18	5.508	.8566	.6198
Gross Profit Π	.2976	9.744	9.095	-.2795	1.5459	20	17	18	20	25.942	.9517	.9725
Wage Rate W	.9468	5.067	5.298	.8522	.3064	20	9	18	19	9.583	1.0881	.8270
Capital Stock K	0.0	17.875	21.218	.6199	2.3088	19	10	14	16	32.723	1.1502	.9835

Petroleum and Coal Products, 1967

SIC 29	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.0	4.062	6.035	1.0611	2.9826	13	10	13	13	13.836	1.3243	.9407
Value Added V	.0	135.619	149.240	.2496	53.5436	13	9	13	13	10.382	.9367	.8990
Investment I	.0	30.955	25.885	.3944	16.0152	13	10	11	13	8.154	.6612	.8451
Gross Profit Π	.0	102.787	92.465	.2542	18.6418	13	12	12	12	31.422	.8585	.9880
Wage Rate W	.0	8.090	7.689	1.9358*	.3108	13	9	9	11	1.003	.2563	.0003
Capital Stock K	.0	244.489	273.045	.3115	40.6846	13	9	12	13	37.580	1.0771	.9916

Leather and Leather Products, 1967

SIC 31	Normalized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval $\hat{Y} \pm S$	$\hat{Y} \pm 2S$	$\hat{Y} \pm 3S$	t_b	b	R^2
Variables (Manufacturing)												
Employment N	.0	6.073	6.290	.0713	.7691	15	11	12	13	16.932	1.0219	.9533
Value Added V	.0	46.576	45.585	.0460	12.0298	15	13	15	15	38.350	.9298	.9906
Investment I	.0	.887	1.006	.2678	.7422	15	12	14	14	5.689	1.1967	.6921
Gross Profit Π	.0	20.485	18.211	.2414	4.0480	15	13	14	14	34.332	.8761	.9883
Wage Rate W	.0	4.162	6.759	.9260	.3702	15	13	14	14	.5431	3.1580	-.0530
Capital Stock K	.0	10.746	12.781	.4067	3.2176	15	12	15	15	54.220	1.2008	.9953

1967
RESULT OF REGRESSION WITHOUT CONSTANT

$$YE = bY + \epsilon$$

	SIC 24			SIC 29			SIC 31		
	t_b	b	R^2	t_b	b	R^2	t	b	R^2
Variables (Manufacturing)									
Employment N	72.335	1.2312	.9897	21.075	1.4102	.9382	22.297	1.027	.9566
Value Added V	46.532	1.2475	.9774	15.600	1.0191	.8934	48.910	.9486	.9902
Investment I	9.740	1.0954	.5514	11.469	.7351	.8327	7.856	1.1676	.7132
Gross Profit Π	43.775	.9400	.9737	44.518	.8783	.9879	45.327	.8815	.9890
Wage Rate W	63.732	1.0464	.8349	45.277	.9474	.5277	2.482	1.6456	.0170
Capital Stock	52.506	1.1719	.9838	57.811	1.0994	.9915	74.986	1.1957	.9956

APPENDIX E

INTERNAL VALIDITY RESULTS FOR TAX EQUATIONS 1967

TAXES AGGREGATE, 1967

	Normal-ized U - Statistic	Actual Mean $\overline{Y}$	Estimate Mean $\overline{YE}$	t-Stat.	Stand. Error of Est. Sy.	No. of ob. n	No. of observations Within Interval			t_b	b	R^2
							$\hat{Y}\pm S$	$\hat{Y}\pm 2S$	$\hat{Y}\pm 3S$			
Variables												
Total Local Revenue, T	0.2171	370.256	321.436	.4095	234.956	82	69	77	80	29.8511	.8894	.9166
Property Tax, TP	0.6610	148.186	158.138	.2110	76.632	82	70	76	79	35.0025	.9841	.9379
Other Taxes, TO	2.8185 *	32.532	30.787	.1139	50.962	82	74	79	80	16.8275	.7283	.7770
Federal and State Aid, TA	0.6512	189.536	132.510	.9168	257.531	82	62	78	81	12.0910	.8124	.6419

TAXES AGGREGATE, 1967
WITHOUT CONSTANT $YE = bY + \epsilon$

	t_b	b	R^2
Variable			
Total Local Revenue, T	33.0376	0.8855	0.9175
Property Tax, TP	39.5730	1.0006	0.9374
Other Taxes, TO	17.9185	0.7469	0.7737
Federal and State Aid, TA	13.1045	0.7911	0.6440

APPENDIX F

IDENTIFICATION OF AQCRs WITH ESTIMATES OFF BY MORE THAN 1, 2, 3, STANDARD ERRORS (AGGREGATE MANUFACTURING)

1969, AGGREGATE MANUFACTURING

Variable	AQCRs Off by 1 to 2 Standard Errors of Estimation
Employment	5 Detroit, Mich.
	6 San Francisco, Calif.
	8 Pittsburgh, Pa.
	12 Baltimore, Md.
	14 Minneapolis-St. Paul, Minn.
	16 Buffalo, N.Y.
	17 Milwaukee, Wis.
	18 Cincinnati, Ohio
	20 Dallas, Texas
	21 Seattle-Everett, Wash.
	22 Kansas City, Mo.
	25 Indianapolis, Ind.
	26 Miami, Fla.
	30 Providence-Pawtucket, R.I.
	40 Memphis, Tenn.
	74 Rochester, N.Y.
	AQCRs off by 2 to 3 standard errors of estimation
	7 Boston, Mass.
	9 St. Louis, Mo.
	11 Cleveland, Ohio
	15 Houston, Texas
	19 Louisville, Ky.
	67 Greensboro, N.C.
	AQCRs off by 3 or more standard errors of estimation
	1 New York, N.Y.
	2 Chicago, Ill.
	3 Los Angeles, Calif.
	4 Philadelphia, Pa.

1969, AGGREGATE MANUFACTURING

Variable	AQCRs off by 1 to 2 standard errors of estimation
Value Added	6 San Francisco, Calif. 18 Cincinnati, Ohio 21 Seattle-Everett, Wash. 22 Kansas City, Mo. 23 San Diego, Calif. 25 Indianapolis, Ind. 26 Miami, Fla. 29 Portland, Ore. 31 Phoenix, Ariz. 33 Columbus, Ohio 35 Dayton, Ohio 36 Birmingham, Ala. 61 Allentown-Bethlehem-Easton, Pa., N.J. 67 Greensboro, N.C. 76 Scranton/Wilkes Barre-Hazelton, Pa. 100 York, Pa.
	AQCRs off by 2 to 3 standard errors of estimation
	12 Baltimore, Md. 14 Minneapolis-St. Paul, Minn. 16 Buffalo, N.Y. 17 Milwaukee, Wis. 24 Atlanta, Ga. 30 Providence-Pawtucket, R.I.
	AQCRs off by 3 or more standard errors of estimation
	1 New York, N.Y. 2 Chicago, Ill. 3 Los Angeles, Calif. 4 Philadelphia, Pa. 5 Detroit, Mich. 7 Boston, Mass. 8 Pittsburgh, Pa. 9 St. Louis, Mo. 11 Cleveland, Ohio 20 Dallas, Texas

1969, AGGREGATE MANUFACTURING

Variable	AQCRs off by 1 to 2 standard errors of estimation
Investment	5 Detroit, Mich. 8 Pittsburgh, Pa. 12 Baltimore, Md. 15 Houston, Texas 19 Louisville, Ky. 21 Seattle-Everett, Wash.
	AQCRs off by 2 to 3 standard errors of estimation
	2 Chicago, Ill. 4 Philadelphia, Pa.
	AQCRs off by 3 or more standard errors of estimation

Variable	AQCRs off by 1 to 2 standard errors of estimation
Profit	3 Los Angeles, Calif. 8 Pittsburgh, Pa. 19 Louisville, Ky. 67 Greensboro, N.C. 74 Rochester, N.Y.
	AQCRs off by 2 to 3 standard errors of estimation
	15 Houston, Texas
	AQCRs off by 3 or more standard errors of estimation
	1 New York, N.Y. 5 Detroit, Mich.

1969, AGGREGATE MANUFACTURING

Variable	AQCRs off by 1 to 2 standard errors of estimation
Wage Rate	5 Detroit, Michigan
	22 Kansas City, Mo.
	26 Miami, Fla.
	28 New Orleans, La.
	30 Providence-Pawtucket, R.I.
	32 Tampa, Fla.
	39 Chattanooga, Tenn.
	40 Memphis, Tenn.
	49 Lawrence-Haverhill/Lowell, Mass.
	70 Knoxville, Tenn.
	71 Nashville, Tenn.
	73 Richmond, Va.
	74 Rochester, N.Y.
	76 Scranton/Wilkes Barre-Hazelton, Pa.
	90 Lancaster, Pa.
	98 Utica-Rome, N.Y.
	99 Wichita, Kan.
	100 York, Pa.
	AQCRs off by 2 to 3 standard errors of estimation
	15 Houston, Texas
	19 Louisville, Ky.
	67 Greensboro, N.C.
	AQCRs off by 3 or more standard errors of es estimation

Variable	AQCRs off by 1 to 2 standard errors of estimation
Capital Stock	2 Chicago, Ill.
	3 Los Angeles, Calif.
	4 Philadelphia, Pa.
	5 Detroit, Mich.
	7 Boston, Mass.
	9 St. Louis, Mo.
	12 Baltimore, Md.

1969, AGGREGATE MANUFACTURING

16 Buffalo, N.Y.
17 Milwaukee, Wis.
18 Cincinnati, Ohio
19 Louisville, Ky.
30 Providence-Pawtucket, R.I.
64 Davenport-Rock Island-Moline, Iowa, Ill.
67 Greensboro, N.C.
72 Peoria, Ill.
74 Rochester, N.Y.

AQCRs off by 2 to 3 standard errors of estimation

14 Minneapolis-St. Paul, Minn.
27 Denver, Colo.
95 Rockford, Ill.

AQCRs off by 3 or more standard errors of estimation

1 New York, N.Y.
15 Houston, Texas