ESTIMATING PRICE EFFECTS ON
INPUT-OUTPUT COEFFICIENTS

by
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ABSTRACT

Dissertation Topic: Estimating Price Effects on Input-Output Coefficients

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Forecasting the economy using input-output techniques requires accurate predictions of the matrix of input-output coefficients. The traditional approach has been to assume a constant matrix. Other approaches have moved the matrix forward using trend techniques. The object of this dissertation has been to take advantage of new techniques, new data on industry prices, and new data on input-output coefficients in the areas of energy and transportation, to determine the effects of price change on the input-output matrix.

In order to estimate the price effects, the Diewert or generalized Leontief cost function has been employed. This function makes input-output coefficients depend on relative prices in a way which has a number of useful properties for this work. First, the dependent variable of the estimated function is the input-output coefficient itself, unlike other production function specifications such as the translog or the CES. Second, the Diewert function is consistent with standard economic theories on the cost-minimizing behavior of the firm.

This behavior relates input-output coefficients of substitutes to one another. The property of price coefficient symmetry, which derives from that relationship, reduces the number of parameters to be estimated; this reduction is often important when working with a limited number of observations. Lastly, the assumption of separability is easily imposed on the Diewert specification. This assumption limits the cost minimizing decisions of the firm to appropriate groups of inputs only, so that a manageable number of variables can be included for estimation and still allow for a moderately high level of disaggregation of industry data.

In this study, the Diewert function was applied to two groups of input-output coefficients--energy and transportation. Each group presented a different challenge because of the type of data available. Therefore, two different approaches were taken. In the case of energy, cross-section data by state existed on four types of energy use for heat and power by two-digit Standard Industrial Classification (SIC) categories of manufacturing. The four energy types were oil, coal, natural gas, and electricity. By applying the Diewert function to the four energy categories and capital and labor, long run price effects on input-output coefficients were estimated for each two-digit manufacturing industry. Combining these long-run estimates with yearly data on coefficient change produced estimates of yearly input-output coefficient adjustments to price changes. In the case of transportation, a time-series of tonnage shipments, differentiated by commodity and mode, was available. Application of the Diewert function allowed the estimation of modal shares of tons shipped by commodity for two-digit SIC categories. The modal share estimates were then combined with estimates of total tons of commodity shipments and measures of distance hauled to create measures of transport service demanded by industry. Dividing these measures by industry output produced price sensitive input-output coefficients for the transportation rows of the input-output matrix. Other variables were considered in the specification of modal shares but few proved to be operational. Those that were operational added little to the estimating process.

This dissertation has demonstrated the feasibility of estimating the price sensitivity of rows of coefficients in an input-output matrix in order to project this matrix more accurately into the future in a world of rapidly changing prices. With the help of the Diewert cost function, industry data, and industry price forecasts, such modeling is now possible.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

Introduction

The purpose of this dissertation is to report on the development of a practical technique for applying economic theory to forecast more accurately the input-output (I/O) coefficients of an interindustry forecasting model. An equation to be used for forecasting will be presented which represents an improvement over existing forecasting techniques for I/O coefficients. This equation is an improvement because it is derived from production theory of the firm and takes into account, over and above the usual technological trend effects, the effects of changing relative prices of alternative inputs into production. Using this equation, changes in I/O coefficients are estimated and forecasted, with input price effects explicitly taken into account for a number of sectors of INFORUM, a multi-sector interindustry input-output model of the U.S. economy. These sectors are alternative inputs within the transportation and energy industries. Differing price scenarios are then used to examine substitution among alternative inputs into production resulting from relative price changes.

A statement of the problems involved in estimating and forecasting I/O coefficients will be presented in Chapter I. A summary of existing techniques in the literature for I/O coefficient estimation will follow in Chapter II. Chapter III will present the equation used for estimation in this study along with theoretical justifications for its use. This equation will then be used to estimate and forecast the I/O coefficients in the energy and transportation sectors of the INFORUM model in Chapters IV and V respectively. Chapter VI summarizes the findings.

Statement of the Problem

INFORUM is an input-output type forecasting model which forecasts industrial output in 200 sectors of the U.S. economy. The technique of forecasting industry output using input-output tables in the INFORUM model requires the solution of the following set of equations for future years:[1]

$$X_i = \sum_j a_{ij} X_j + F_i - M_i + N_i \qquad i = 1, 200 . \qquad (1.1)$$

where, X_i = output of each of the 200 industries. The following variables are known, forecasted prior to solution or estimated simultaneously with the above equation.

F_i = final demand for each sector; a summation of demands for investment equipment, structures, government and defense articles, exports, and personal consumption

M_i = imports of product i

N_i = inventory change of product i

a_{ij} = the amount of input i that is demanded to produce one unit of output j.

Redefining $d_i = F_i - M_i + N_i$ and using matrix notation, the above set of simultaneous equations can be rewritten as:

$$(I - A) x = d \tag{1.2}$$

where x and d are the output vector and final demand vector respectively; A is the matrix of input-output coefficients, a_{ij}; I is an identity matrix. Solving for x, (1.2) becomes,

$$x = (I - A)^{-1} d \quad . \tag{1.3}$$

While INFORUM does not in practice solve for x in quite this manner (preferring the Seidel method instead) the above equation shows the importance of accurate forecasts of A and d in order to estimate accurately the vector of industry output, x, for future years. The forecasting of the vector of final demands has been the preoccupation of the Maryland Interindustry Forecasting Project for many years and its progress is well documented elsewhere.[2] This paper will deal with the progress made in improving the estimation of an expected A matrix for future years.

Definition of the A Matrix

Since every industry's output goes either to final demand or to another industry as input, the economy is linked by a network of interconnected flow relationships between industries, including a sector for final demand. Wassily Leontief, the originator of I/O techniques, first defined the input structure of an industry as a set of technical coefficients representing the amount of each input absorbed by that industry from another industry per unit of its own output.[3] Industry flows are converted to technical coefficients by dividing input flows by industry output. These technical relationships were assumed to be fixed at any point in time, subject to some optimal mix of inputs for producing output. There exists, then, a matrix of technical relationships showing technical coefficients for each industry, across all industries.

INFORUM presently measures inputs and outputs in terms of their values at 1976 prices. The a_{ij} coefficient in INFORUM, therefore, represents the dollar value of input i needed to produce one dollar's worth of output j at 1976 prices, or

$$a_{ij} = X_{ij} / X_j \tag{1.4}$$

where,

X_{ij} = the value of the total amount of good i going to the production of good j, in 1976 dollars

X_j = value of the total output of good j in 1976 dollars.

Here, technical coefficients measured in physical units have been changed into relationships in value terms simply by weighting all technical coefficients going to an industry by a ratio of the price of input i to the price of output j in 1976. We are interested then, in structural coefficients, known from here on as I/O (input/output) coefficients, each coefficient showing the relative importance of an input in a 1976 dollar's worth of output. The matrix of these coefficients shows the technical linkages between all industries in the economy and is known as the A matrix.

These coefficients are assumed to be fixed at any point in time but, over time, we can expect them to change. Three reasons that have been cited for this change are: [4]

1. Technological Innovation

   Technological innovation deals with the change in the mix of technical inputs into the making of a product over time as new methods of production are developed and introduced. New capital equipment geared to the new technology will slowly replace outdated machinery as old methods of production become increasingly less productive. New ratios of factors of production will replace old ratios and input-output coefficients will change.

2. Changes in Product Mix

   The second reason for coefficient change deals with the problem of data aggregation where a number of products are aggregated under one industry heading. Given available data, flows generally cannot be disaggregated to lower than the industry level. As product demands change due to shifting consumer tastes or other influences, an industry's product mix will change even though the basic technical relationship between input mix and output of a particular product may be fixed. Only if each and every product within an industry has an identical technical input mix will a change in product mix have no effect on the relative amounts of inputs going to that industry. Otherwise, we can expect a change in I/O coefficients as an industry's product mix changes even with constant technical coefficients for the production of each product.

3. Price Induced Substitution

The third reason for coefficient change deals with the effect of changing relative prices of inputs into production for industries attempting to minimize the costs of production. As the price of an input increases relative to its alternative, firms will substitute away from the more expensive inputs in an attempt to keep the costs of production down. New capital equipment which uses the new cheaper input ratios, will replace older capital equipment as old methods of production become increasingly less cost effective.

Estimation

Prior to this dissertation, INFORUM, in its forecasting efforts, has tried to take into account these three causes of coefficient change in a general manner only. The total effect of these causes on coefficients is examined in the past and extrapolated into the future. The separation of product mix changes from technological changes has been studied on a case-by-case basis where the need warrants, but the lack of specific product data across all industries, over time, prohibits a general examination.[5] Price effects have not been taken explicitly into account because of the unavailability of an adequate price model to forecast industry prices for future years, as well as a lack of a theoretical approach for introducing price effects. Consequently, the majority of changing coefficients were forecast using a procedure known as "Logistic curve" estimation. This approach was applied to two types of data, (1) individual industry coefficients, and (2) coefficient rows of the A matrix using an "Across the Row" technique. A row shows the structural coefficients of one input to each of its intermediate users. Logistic curve estimation takes into account the effects of the three causes above, in total, on both types of data. Recently a price model, the result of the dissertation efforts of David Belzer, has been added to INFORUM, which forecasts prices yearly for 200 sectors.[6] The intention of this dissertation is to take the process of forecasting changing I/O coefficients one step further by explicitly taking into account price changes in a theoretically acceptable manner now that price forecasts are possible.

Across-the-Row Change

A consistent matrix of I/O coefficients for industries at a fairly high level of disaggregation (367 order level) exists only for 1963, 1967, and 1972[7] and consequently only a crude extrapolation for forecasting can be made for individual I/O coefficients on a general basis. However, the row totals of input flows of a product to intermediate users can be derived yearly and this information can be put to work to help complete the table for later years.[8] Starting with a series on product shipments for each year, we subtract out personal consumption expenditures, producer's durable equipment, inventory change, exports minus imports, and government demands. The residual in year t, defined as U(t), represents the actual flow of input to the 200 intermediate users in the INFORUM model. Also, a historical series is calculated which represents what the intermediate flow would have been if the row of I/O coefficients had remained constant at their 1969 levels. This series is calculated using the following equation:

$$I_i(t) = \sum_{j=1}^{200} a_{ij}^{(69)} X_j(t) + \sum_{j=1}^{28} c_{ij}^{(69)} S_j(t) \qquad (1.5)$$

where,

$I_i(t)$ = an "Indicator" for the amount of input i that would have been used in period t if the row coefficients for its use had remained unchanged over the history period

$S_j(t)$ = the demand for structures by industry j

$c_{ij}^{(69)}$ = the 1969 coefficient for the ratio of input i needed to produce a dollars worth of construction for industry j.

$a_{ij}^{(69)}$ = the 1969 I/O coefficient

A time series of the ratio U(t)/I(t), an intermediate use coefficient for each year over the historical period, shows the changing structural demand for input i over time by the total of intermediate users. INFORUM, then, forecasts future trends in intermediate use coefficients by fitting an "S" shaped logistic curve to the U/I coefficient trend and extending this curve into the future. The logistic curve is applied in order to place a ceiling or floor on the extrapolated trends. The percentage change in the intermediate use coefficient is then applied to all I/O coefficients in the row. The result of this technique is to forecast the change in an I/O coefficient for an input to one industry by moving it by the average change in the demand for that input by all intermediate users. A row of the A matrix, which shows the structural coefficients for one input to each of its intermediate users, changes, then, by the same percentage amount over time. Stated in this way, one of the implicit assumptions behind this technique becomes obvious; all industries behave in approximately the same way in matters of input demand per unit of output. All industries must change demands for an input per unit of output by the same percent in order for the Across-the-Row technique to be exactly correct.[9]

Individual Industry Change

A less stringent assumption is maintained when a time series of input demands is separately acquired for a particular industry, usually from the industry itself. This input data is divided by INFORUM-computed industry output to produce a series of I/O coefficients which will vary over time for all the reasons specified above. Future trends in individual coefficients for a single industry are forecasted once again, by fitting a logistic curve to the historical time series of I/O coefficients and extending it.

Both types of data still require another assumption, however, when the logistic curve estimation technique is used; each industry will follow in the future the same trends with respect to input demands per unit of output as have been evidenced in the past. As well, this technique does not take advantage of the assumption that coefficient change is interdependent between rows. When the share of the output dollar increases for one input it must necessarily decrease for another. Substitution will occur between inputs within an industry, and this interdependence should be taken into account in estimation.

An attempt is made in this study to improve upon these points. The study is carried out on an industry-by-industry basis allowing each industry to exhibit its own production function response to changing prices. Here, we improve on the "Across-the-Row" assumption above by estimating coefficient change on an industry-by-industry basis. The technique developed here for forecasting I/O coefficient change utilizes the Diewert or generalized Leontief equation which takes into account changing prices of alternative inputs in the production behavior of cost minimizing firms. The historical trend assumptions are improved upon by taking into account, over and above the extrapolated trends, the effects on I/O coefficients of changing input prices. As well, changing coefficients are estimated with their interdependence taken into account. These improvements are a natural progression of the advances made in estimating I/O coefficient change. A short review of the history of those advances follows.

CHAPTER II

Progress in Estimating Coefficient Change

In order to forecast coefficient change correctly, the reasons for coefficient change must be examined. Progress in explaining coefficient change has developed from two separate perspectives, each side focusing on different aspects of the problem. "Input-output" theorists have been interested in examining and explaining I/O tables while "production" theorists have been interested in investigating the production function relationship between inputs and output. The difference between them is characterized by the scope of their work. The former group has focused on the movement of the I/O coefficients of the disaggregated sectors of the A matrix. The majority of these represent intermediate flows between industries. The latter group has focused on the functional relationship of only a few aggregated coefficients; in particular, the basic resources, capital and labor. The production theorists have added intermediate inputs to their work to formulate better the capital-labor relationship. The result of the two approaches points up the importance of the theoretical content in the analysis of coefficient change, learned from the work of the production theorists, as well as attention to detail with respect to individual disaggregated coefficients, learned from the work of I/O theorists. Below is a review of the progress that has been made on both fronts.

Advances in I/O Techniques

One ot the major problems involved with the application of input-output techniques to solve current economic problems is the five year lag period in the production of an I/O coefficient table. Also, this task is only periodically carried out. The assumption that a five-year-old table reflects current basic technical relationships in production raises questions as to the stability of I/O coefficients. In particular, the problem of product mix may destabilize I/O coefficient tables even though technical relationships remain the same. The destabilizing effect of product mix on I/O coefficients is aggravated as more and more commodities are aggregated into columns of a table. A column represents the list of inputs needed to produce a dollars worth of one category of output. An opposite stabilizing effect is also created by aggregation. When rows of possible substitutes are aggregated, the resulting offsetting movements of coefficients caused by price or technology induced substitution will leave aggregate coefficients unchanged. In 1968, Vacarra found, for U.S. tables disaggregated to the 64 sectors of the two-digit SIC level, that coefficients within a row changed over time and did not all behave in the same way. While some coefficients decreased, others increased. It appeared that not all industries were substituting toward or away from inputs in the same manner. Because of a lack of data (since U.S. tables only existed for 1954, 1958, and 1961 at that time), she was unable to derive the separate causes responsible for individual coefficient change.[1] Stagen and Wessels (1971) evidenced individual coefficient change in I/O tables for 1954, 1958, and 1962 for West

Germany but, also, provided no functional explanatory equations.[2] Sevaldson (1968), investigating the stability of I/O coefficients, found trends in changing coefficients over time for I/O tables of Norway. Also, he observed that more aggregated tables produced more stability in coefficients. This result most likely reflects his attempt to aggregate, as much as possible, rows of substitutable inputs.[3]

From the work above, it appears that I/O coefficient tables exhibit changing individual coefficients over time, but not enough table data have been available to separate out the causes for these movements. Acknowledging the lack of consistent tables over time for many countries, Fontela (1968)[4] introduced a method for interpolating coefficients between tables that is a variation on the "RAS" technique of row and column balancing.[5] Using row controls, coefficients in a row of the table are adjusted to reflect the extent to which one input is substituted for another throughout the economy and, using column controls, coefficients in a column are adjusted to reflect "fabrication" as an industry absorbs a larger or smaller ratio of intermediate to primary inputs. (Capital and labor are considered primary inputs.) The substitution of one input for another is assumed to be identical across columns, and the absorption of an input by an industry is assumed to be identical for all intermediate inputs in the column. A series of iterations of column and row adjustments generally produce a table consistent with a vector of known row and column totals. Fontela points out that forecasted row and column controls can be used to update existing tables for future years.

The weaknesses of RAS balancing are exposed, however, when a second look is given to the homogeneity properties of substitution and fabrication processes across rows and columns. Both Vaccara (1968) and Peterson (1974)[6] point out that changing relative prices and technology effect coefficient change through the introduction of new technical processes resulting from investment. The heterogeneity of new capital equipment and the dissimilarity of its acquisition across industries, along with the industry specific aspects of technical innovation does not support the rationale that input substitution should be identical across industries adjusted only for different fabrication rates. Also the fabrication adjustment for each industry of all intermediate inputs as a group omits the possibilities of substitution between alternative intermediate inputs. As new capital equipment is introduced, these machines should reflect changing relative input prices in their input requirement mix as firms attempt to minimize the costs and maximize the efficiency of production. K.Sarma (1972) found that A matrices calculated by RAS between known I/O tables for 1959 and 1962 performed worse in simulation tests than interpolated coefficients between those same years. He concluded that the "errors in forecasts from interpolated I/O matrices are, in general, smaller than those obtained from the RAS method."[7]

Given the evidence that coefficients change, and lacking the data to divine the functional relationships to explain these changes for I/O coefficient tables, Fisher et. al. (1971)[8] and Aujac (1971)[9] propose acquiring updated technical data on production processes from industry technicians. Aujac, however, finds technical answers to be unsatisfactory for improving tables.

Forssell (1971) develops a regression equation to explain changing I/O coefficients where he takes into account explanatory variables and uses data on individual coefficients. Using data on Finland from 1954 to 1965, he considers proxy variables for the effects of technical development, changes in relative prices, and changes in output. Measures used for technical development are degrees of electrification and mechanization and a time trend. For prices, the ratio of material input price to output price is used. The problem of product mix arises when, in order to generate complete consistent sets of I/O tables over enough years for regression analysis, columns and rows must be aggregated. This problem is handled by Forssell by limiting the scope of his investigation to only four sectors: wood, furniture, paper, and printing, and these are subdivided into 21 industries. The inputs are limited to five specific types. Regression equation results exhibit a negative correlation between price and I/O coefficients for intermediate inputs and a positive correlation between technical change and I/O coefficients for labor inputs. The evidence showed that product mix, relative prices, and technical progress had a high correlation with changing coefficients.[10] While we see here an attempt to explain changing coefficients for one industry at a time, which reduces the problem of product mix and allows for individual industry responses, no consideration is taken of the interdependence between the I/O coefficients for alternative inputs into production. This work can be faulted for providing no theoretical justification for the functional form of the regression equation. No theoretical basis is provided for believing that the high correlation he observes is evidence of a cause-and-effect relationship.

Progress in Production Function Theory

Production theorists, on the other hand, have laid the theoretical groundwork for studying cause-and-effect relationships between relevant factors affecting production and input demand.

Parks (1971) uses the theory and funtional equations of Diewert (1971)[11] to estimate coefficient change where the input decisions by a cost-minimizing firm have been taken into account. (The theoretial justifications for Diewert's equations are presented in Chapter III of this dissertation.) Parks shows that the capital-labor elasticity of substitution generated from cost minimizing firms will be undervalued when intermediate inputs are neglected in the estimation of a firm's production function. This conclusion is drawn from the results of regression analysis on five aggregate inputs -- agriculture, transportation, imports, capital, and labor -- into manufacturing for a time series of Swedish manufacturing data from 1870 to 1950. Using Diewert's derived demand equations for inputs, Parks determines that the elasticity of substitution for many inputs is neither zero nor one, making both the Cobb-Douglas and Leontief fixed coefficient production functions inappropriate formulations for explaining coefficient change. Here, aggregation problems may arise from combining all manufacturing products into one category of output and dividing all inputs into only five groups. Again we see the necessity of aggregation in order to create a sufficiently long time series which incorporates all input-output relationships. Since the derived demand equations are the result of a firm's cost minimizing reactions only, the non-firm related problems of aggregation are not accounted for adequately in Parks analysis. Product mix effects may invalidate his production function conclusion.[12]

In 1974, Peterson took advantage of Diewert's derived demand equations for inputs to estimate the effects of prices on captial, labor, and productivity, where intermediate inputs are considered for the British engineering industry. An attempt is made to incorporate I/O table data by generating consistent tables between 1954 and 1968 for England using the RAS balancing technique and dividing inputs in the engineering industry into five categories -- labor, fuels, other materials, services, and investment goods. His statistical tests of the elasticity of substitution allow him to reject the assumption of fixed intermediate inputs. However, he qualifies this conclusion by acknowledging that other factors, such as product mix, may be at work when he aggregates 36 intermediate inputs into five groups.[13] Also, the assumptions underlying the RAS technique of data generation that he used may lead to incorrect results, as pointed out previously.

In an attempt to provide adequate I/O coefficient data for Diewert equation analysis, Humphrey in 1975 considered sixteen inputs into production. Sixteen equations are estimated, each equation having as the dependent variable the I/O coefficient for each input, and as independent variables, the ratio of the price of that input relative to:

(1) a price index of its closest substitutes, (2) a price index of all other intermediate goods, and (3) a price index of the value added items, capital and labor, along with a constant term. The data for regression are changes in I/O coefficients between the two years 1947 and 1958 for columns of U.S. I/O tables. He finds few cases where the elasticity of substitution is significantly different from zero, indicating that price has no effect on the stability of I/O coefficients.[14] We see here an attempt to test the effects of prices on I/O coefficients in I/O tables for a fairly disaggregated set of inputs in order to pick up substitution effects between alternative inputs. However, Humphrey's use of cross-section data across columns of the I/O table requires the assumption that the effect of prices on input substitution is identical for all columns. As pointed out by Vaccara, this assumption is questionable in light of the argument that input substitution is the result of unique capital investment decisions made by each industry.[15]

Using an alternative equation to the Diewert, the translog specification, Humphrey and Moroney (1975) try to estimate factor substitution elasticities but are able to make less heroic assumptions about the cross-section I/O data by limiting the scope of their investigation.[16] Here they are interested only in the price effects on substitution between three inputs: capital, labor, and an input aggregate of natural resources. By stipulating that natural resources are functionally separable[17] from other intermediate inputs, they are able to assume that the resulting estimated price elasticities are theoretially unbiased even though all inputs in production are not considered. Also, they assume that price effects on coefficient substitution are identical only for four-digit SIC industries within a two-digit category, but may differ between two-digit categories. Consequently, their data for estimation runs across four-digit industries within a two-digit category. They estimate price elasticities for twelve two-digit categories using the three inputs.[18] While disaggregated I/O table data is utilized across columns, here again, the aggregation of rows hides many intermediate substitution situations. Since the majority of inputs to production are intermediate, most price effects are left unestimated.

The translog specification is used by Halvorsen (1977) to estimate input demand functions and here the data is disaggregated by both rows and columns. The property of separability of groups of inputs in the production function of each industry is relied upon to limit the number of rows of alternative inputs without the need for aggregation. Halvorsen developes coefficients and prices for four fuel inputs used for heat and power in nineteen two-digit SIC categories, using two-digit SIC data across states for 1971.[19] Here, he assumes that the effects of fuel price changes will cause substitution only among oil, natural gas, electricity, and occasionally coal, holding total fuel demand constant. Price elasticities are estimated for these inputs where the problems of product mix and aggregation of substitute inputs are kept to a minimum, allowing for theoretically unbiased results. Questions may be raised however, about the assumption of separability of fuels from capital and labor inputs, leading to the conclusion that total energy demand will remain unchanged as fuel becomes relatively more expensive.

Synthesis

This history of investigations of I/O coefficient change points out the problems that exist with modeling coefficient change and the steps that have been taken to deal with these problems. The work of the former group of authors, labled I/O theorists, evidences the trade off that exists between the use of aggregated data in order to create a data series of sufficient length verses the increased complexity in modeling that is created by aggregation problems. In order to create consistent disaggregated I/O tables of data, such techniques as "RAS" balancing were introduced. No theoretically sound technique was developed, however, to explain the changing tables, a necessary prerequsite for accurately forecasting tables. On the other hand, the latter group of authors, labled "production theorists," applied techniques for estimating coefficient change that was consistent with the theory of the firm but glossed over the problems of aggregation. The earlier estimation attempts of this group suffers from problems of product mix.

The methodology of this dissertation represents an improvement over previous investigations of coefficient change in I/O tables because attention is paid to both detail and theory. A balance is struck between the approaches of the two groups for forecasting I/O coefficient change in the U.S. economy.

Detail

In this dissertation, coefficient change is estimated on an individual industry basis so that industry specific adjustments for changing price and technology can be accounted for with a minimum amount of product mix problems. Inputs are considered at a detailed level so that the effects on close substitutes can be examined. In order to attain this level of detail it was necessary to abandon the use of existing disaggregated I/O tables because too few actual tables exist for the U.S. Data from aggregated tables was dismissed because of the intractable problems of product mix and the aggregation of substitutable inputs. The use of tables derived from RAS balancing was also rejected because of the assumption of homogeneity of coefficient change across rows and columns. The RAS technique generates industry I/O coefficients without consideration of the industry specific interdependence between substitutable inputs.

In this study, the necessary level of detail is attained by applying the assumption of separability to industry production functions which allow inputs irrelevent to the cost minimizing mix of specific substitutable inputs to be disregarded. When irrelevent inputs are ignored, it is no longer necessary to obtain the comprehensive detail of I/O tables for estimation and data can be gathered for specific inputs into production which are consistent and of sufficient length to make estimation feasible. In particular, data is gathered for alternative fuels used for heat and power in manufacturing and for transportation services demanded by industry, differentiated by mode of shipping. By applying the assumption of separability, coefficient change can be estimated using detailed input data which avoids the problems of data aggregation and allows for a more accurate estimation of coefficient change.

Theory

The Diewert equation is used for estimation because of its theoretical basis. This equation takes into consideration the interdependence between alternative inputs resulting from the cost minimizing behavior of the firm. Also, this equation is prefered because of its ease of estimation. Input demands are simply a function of a series of additive terms representing the relative prices of alternative inputs and the dependent variable is the I/O coefficient itself, the variable to be modeled. In the following chapter, the implications of firm behavior on input demand are reviewed and the equations introduced by Diewert to model input demand are derived.

Chapter III

Developing An Equation for Estimation

What does economic theory tell us about the firm's responses to changing input prices? This chapter presents a standard cost minimization approach to firm behavior and derives the resulting conditions that this behavior implies. Second, a specification introduced by W. E. Diewert is presented which will be shown to be consistent with the derived cost minimization theory. This specification is then compared to an alternative, the translog function, which is sometimes used as an alternative for estimation.

Behavior of the Firm

Following the usual approach for deriving the conditions for cost minimization, a firm, facing fixed prices of inputs and having a production function with constant returns to scale, will attempt to minimize the unit costs of production, C, where

$$C = \sum p_i x_i \qquad i = 1, \ldots, n \qquad (3.1)$$

P_i = price of input i

x_i = amount of input i per unit of output

This cost minimization is subject to a production function, f, for producing one unit of output with constant returns to scale where,

$$f(x_1, \ldots, x_n) = 1 \quad . \tag{3.2}$$

This production function is assumed to be a continuous, twice differentiable function in inputs with first order partial derivatives, $\partial f / \partial x_i = f_i \geq 0$. The matrix of second order partials is assumed to be negative semi-definite so that the function is concave and has convex isoquants.

Cost minimization is accomplished by picking the optimal mix of inputs so as to minimize total costs for any given set of input prices. The minimization of (3.1) with respect to a production function for producing one unit of output, (3.2) is represented by the following Lagrangian problem,

$$L = \sum p_i x_i - \lambda [f(x_1, \ldots, x_n) - 1]$$

where λ is a Lagrangian multiplier. The first order conditions for the minimization of this function produce,

$$p_i = \lambda \frac{\partial f}{\partial x_i}(x_1 . . . x_n) \qquad i = 1, . . . n \quad . \tag{3.3}$$

The optimal amount of each input is purchased so that, defining

$$f_i = \frac{\partial f}{\partial x_i} \quad ,$$

$$\frac{f_1}{p_1} = \frac{f_2}{p_2} = ... \frac{f_n}{p_n} \tag{3.4}$$

From this it can be seen that, for a cost-minimizing firm experiencing constant returns to scale, the demand for input i per unit of output, x_i' , is a function of all input prices involved in the cost minimizing process or,

$$x_i' = g_i(p_1 . . . p_n) \tag{3.5}$$

The minimum cost of producing a unit of output is then,

$$C(p_1 . . . p_n) = \sum p_i \; x_i' \tag{3.1'}$$

where the x_i' s represent the minimum cost input bundle.

Input demand functions such as (3.5) possess a useful condition of symmetry. To make it evident, we first write the first order conditions for cost minimization derived from equation (3.3),

$$\frac{\partial L}{\partial x_i} = p_i - \lambda \frac{\partial f}{\partial x_i} = 0 \qquad i = 1, \ldots, n$$

$$\frac{\partial L}{\partial \lambda} = 1 - f(x_1, \ldots, x_n) = 0. \tag{3.6}$$

From (3.5), we can see that the inputs are a function of prices. Consequently, the substitution of (3.5) for x in (3.6) demonstrates that these functions are identically zero as functions of prices. Thus, the partial derivative of (3.6) with respect to one of the prices, p_1, must also equal zero, or,

$$1 - \sum_{j=1}^{n} \lambda f_{1j} \frac{\partial x_j}{\partial p_1} - f_1 \frac{\partial \lambda}{\partial p_1} = 0$$

$$- \sum_{j=1}^{n} \lambda f_{ij} \frac{\partial x_j}{\partial p_1} - f_i \frac{\partial \lambda}{\partial p_1} = 0 \qquad i = 2, \ldots, n$$

$$- \sum_{j=1}^{n} \lambda f_j \frac{\partial x_j}{\partial p_1} = 0$$

These equations may be written in matrix notation as,

$$\begin{vmatrix} \lambda f_{11} & \lambda f_{12} & \cdots & f_1 \\ \lambda f_{12} & \lambda f_{22} & \cdots & f_2 \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ f_1 & f_2 & \cdots & 0 \end{vmatrix} \begin{vmatrix} \frac{\partial x_1}{\partial p_1} \\ \frac{\partial x_2}{\partial p_1} \\ \\ \\ \\ \frac{\partial \lambda}{\partial p_1} \end{vmatrix} = \begin{vmatrix} 1 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \end{vmatrix} \qquad (3.7)$$

and solving for $\frac{\partial x_i}{\partial p_1}$ produces, $\frac{\partial x_i}{\partial p_1} = S_{i1}$, where S represents the inverse of the elements of the above matrix.[1] Had we differentiated with respect to P_j, the matrix on the left of equation (3.7) would be unchanged but the 1 in the vector on the right would be in row j.

Therefore, $\frac{\partial x_i}{\partial p_j} = S_{ij}$. Since the above matrix is symmetric, then $S_{ij} = S_{ji}$; thus,

$$\frac{\partial x_i}{\partial p_j} = \frac{\partial x_j}{\partial p_i} \quad . \text{ (condition of symmetry)} \qquad (3.8)$$

Also, solving for the demand for input i with respect to its own price, we can see that, $\frac{\partial x_i}{\partial p_i} = S_{ii}$, which can be shown to be ≤ 0.[2] This condition states that only negatively sloped demand curves exist for inputs purchased by a cost minimizing firm.

What implications do these results have for I/O coefficients? Viewing x_i as an I/O coefficient, we see from (3.5) that the optimal I/O coefficient is a function of the relative prices of alternative inputs into the production of a firm's output. A column of the I/O matrix shows the amounts of alternative inputs in production per dollar of output for a single industry. Assuming all firms in the industry have approximately the same production function, we see from equation (3.5) that each coefficient in the column is sensitive to the relative prices of alternative inputs in the column. Since the price of an input enters the demand functions of alternative inputs, a change in one price will affect the demands for a number of inputs. The condition of symmetry, (3.8), also assures that the changes in the demands for alternative inputs are linked. I/O coefficients in the column of the matrix are, therefore, related and must be dealt with on a column-by-column basis taking into consideration changing relative prices in order to be consistent with standard cost minimizing theories of the firm.

Equation for Estimation

The cost function derived by Diewert is used to estimate relative price effects on I/O coefficients because the function takes advantage of the Shephard duality theorem which defines input demand in terms of a cost function derived from the cost minimizing behavior of the firm and a regular production function such as the one described by (3.2). Shephard's Lemma, (also derived by Samuelson[3] and others) is defined as,

$$\frac{\partial C\,(p_1, \ldots, p_n)}{\partial p_k} = g_k\,(p_1, \ldots, p_n)\ .^4 \qquad (3.9)$$

This equation states that the derivative of the cost of producing one unit of output with respect to the price of an input is equal to the demand for that input.

To prove this we differentiate (3.1') with respect to p_k,

$$\frac{\partial C}{\partial p_k} = x_k + \sum_i p_i \frac{\partial x_i}{\partial p_k} \qquad (3.10)$$

Using (3.3), the conditions for cost minimization by the firm, equation (3.10) becomes,

$$\frac{\partial C}{\partial p_k} = x_k + \lambda \sum_i \frac{\partial f}{\partial x_i} \cdot \frac{\partial x_i}{\partial p_k} = x_k + \frac{\partial f}{\partial p_k}$$

Since $f(x_1, . . . , x_n)$, from (3.2), is a constant, $\frac{\partial f}{\partial p_k} = 0$.

Consequently,

$$\frac{\partial C}{\partial p_k} = x_k$$

which is Shephard's result.

Diewert makes use of this lemma to specify a cost function which is a generalization of the Leontief cost function and produces a system of derived demand equations that can attain any set of partial elasticities of substitution using a minimal number of parameters.[5]

The cost function is,

$$C(p) = \sum_i \sum_j b_{ij} \, p_i^{1/2} \, p_j^{1/2} \tag{3.11}$$

where

$b_{ij} = b_{ji}$ for all $i \neq j$.

Differentiating (3.11) with respect to p_k we have

$$\frac{\partial c}{\partial p_k} = \sum_i b_{ik} \left(\frac{p_i}{p_k}\right)^{1/2}$$

which, using (3.9), becomes

$$x_k = \sum_i b_{ik} \left(\frac{p_i}{p_k}\right)^{1/2} . \tag{3.12}$$

This equation can be estimated using a data series of I/O coefficients for the dependent variable on the lefthand side and a series of prices for substitutable inputs on the right. This is the basic equation used in this dissertation for estimating coefficient change.

The appearance of the square root in (3.12) at first seems arbitrary. A natural generalization of (3.12) would be

$$x_k = \sum_i b_{ik} \left(\frac{p_i}{p_k}\right)^{B} \tag{3.13}$$

However, only with B = 1/2 can (3.13) represent the behavior of a cost-minimizing firm. For, from (3.13) the demand for input k with respect to a change in p_i is

$$\frac{\partial x_k}{\partial p_i} = B\, b_{ik}\, p_i^{B-1}\, p_k^{-B},$$

and the symmetry of cross-partials for a cost-minimizing firm, equation (3.8), requires that

$$B\, b_{ik}\, p_i^{B-1}\, p_k^{-B} = B\, b_{ki}\, p_k^{B-1}\, p_i^{-B}.$$

For $B \neq 0$, this condition will hold for all $p = 1$ if, and only if, $b_{ik} = b_{ki}$. With $b_{ik} = b_{ki}$ and $p_i \neq p_k$, this equation will hold if, and only if, $B = 1/2$.

The Translog Function

An alternative specification of a unit cost function used for estimation by many[6] is the translog developed by Christensen, Jorgenson, and Lau[7]. The specification is,

$$\ln C = a_o + \sum_i a_i \ln p_i + 1/2 \sum_i \sum_j b_{ij} \ln p_i \ln p_j \tag{3.14}$$

where $\sum_i a_i = 1$, $b_{ij} = b_{ji}$, and $\sum_j b_{ij} = 0$ for $i, j = 1, n$.

To produce a demand function for estimation we first calculate the change in the cost function with respect to input prices,

$$\frac{\partial \ln C}{\partial \ln p_i} = a_i + \sum_j b_{ij} \ln p_j$$

which by definition becomes,

$$\frac{\partial C}{\partial p_i} \cdot \frac{p_i}{C} = a_i + \sum_j b_{ij} \ln p_j \tag{3.15}$$

Applying Shephard's lemma, $\frac{\partial C}{\partial p_i} = x_i$, to the first term on the left and moving the second term to the righthand side produces a demand function for input i, but this function is difficult to estimate because it is nonlinear in the parameters. However, since $C = \sum p_i x_i$, equation (3.15) can be translated into,

$$M_i = \frac{x_i p_i}{\sum_j x_j p_j} = a_i + \sum_j b_{ij} \ln p_j \tag{3.16}$$

where M_i is the share of the total cost going to input i. Since this function is linear in prices, it is estimable with simple regression techniques. We see here, however, that, unlike the Diewert function, the I/O coefficient is not estimated directly.

Another characteristic of the translog function is that, if all $b_{ij} = 0$, the cost function collapses to a Cobb-Douglas form with an elasticity of substitution, σ, equal to one. To see this we simply note that with all b_{ij}'s = 0, equation (3.16) would reduce to,

$$\frac{x_i\, p_i}{\sum x_j\, p_j} = a_i \quad .$$

Since a_i is a constant we can see from this that the factor share is always constant regardless of the p's. This condition is the normal result derived from a production function with unitary elasticity of substitution. The consequence of this property with respect to estimation is that poor fits of equation (3.16) to the data lowers values of the b_{ij}'s and consequently biases the elasticity of substitution between inputs toward one. On the other hand, poor fits of the Diewert equation do not allow a rejection of $\sigma = 0$. To see this one need only note from (3.12) that poor fits on the data push all b_{ij}'s for $i \neq j$ to zero, leaving only the constant term b_{ii} to be estimated. Consequently, for poor fits, the demand for an input, x_k, will equal to a constant, indicating zero elasticity of substitution. Since zero substitution has been the standard implicit assumption of I/O modeling, it seems inappropriate to allow $\sigma = 1$ to be the null hypothesis for the estimation of price effects. The intent of this study is to test for the alternative assumption that price sensitivity exists with the default value being zero, and for this work the Diewert function is best suited.

CHAPTER IV

I/O Coefficients for Energy

Fuels used for heat and power enter into the production function of nearly every commodity. Consequently, the fuel rows of the INFORUM A matrix contain more entries than almost any other row, and accurate estimation of the changes in these coefficients is essential to accurate forecasting. While fuel consumption is ubiquitous, the extent of the use of various fuels in industry production functions varies significantly over time and among industries. For the manufacturing sectors, which consume approximately 25 per cent of the total energy requirements of the economy, the demands for coal, oil, natural gas, and electricity used for heat and power have changed appreciably in the last twelve years. Between 1967 and 1975, coal use declined from 19 percent to ten percent of total energy consumed for heat and power in manufacturing. Residual oil use increased from seven to ten percent and distillate fuel, from four percent to five percent. Natural gas declined from 53 to 52 percent, while electricity increased the most from 12 percent in 1967 to 17 percent by 1975. Since 1975 these trends have changed somewhat. While residual fuel oil and natural gas use trends have continued on their old paths, electric energy and coal use trends have started to turn around. In 1977, electric energy use, as a percent of total energy use by all manufacturing industries, remained approximately at the same level as in 1975, after increasing six percentage points in the preceding eight years. Coal use, after dropping to 10 percent of total energy use in 1975, increased to 11 percent by

1977. Distillate fuel oil consumption, as a percentage of total fuel consumption, remained flat during the 1975 to 1977 period. Also, a large disparity in use exists among industries. For the 20 two-digit SIC manufacturing industries in 1975, the amount of energy consumption varied from a high of 814.7 billion kilowatt hours (kwh) for the sector "Chemicals"[1] to 6.6 billion for the sector "Leather and Leather Products," where all energy sources have been converted into kilowatt equivalents. Energy intensity also varies widely among industries. The most energy intensive two-digit industry in 1975 was "Stone, Clay, and Glass Products," with 12.3 kwh consumed per dollar of industry shipments. The least energy intensive was "Apparel and Other Textile Products" with .52 kwh per dollar of industry shipments.[2] Clearly, energy demand is diverse and must be modeled on an industry-by-industry basis in order to model faithfully this changing demand structure.

The Diewert equation is applied to the 20 two-digit SIC commodity groups in manufacturing in order to estimate the role which changing energy prices have played in determining energy-use intensities for the major fuels: oil, coal, natural gas, and electricity. In order to take into account the heterogeneity of energy demand, a separate set of Diewert equations is estimated for each sector. The price effects are estimated using cross-sectional data across states for 1975. While no industry was fully adjusted to the increases in fuel prices in 1975, the energy price differentials between states due to transport costs should be fully incorporated into the firm's energy input decisions. Using this data, the Diewert equation, therefore, estimates the firm's long-run response to price differentials for alternative fuels. Since no firm can be expected to make instantaneous adjustments to "desired" energy coefficients as energy prices change through time, an adjustment lag function is also estimated to determine the yearly adjustment towards desired coefficients. For this function actual coefficients are gathered from an eight year series of data and desired coefficients are calculated from the Diewert cross-section estimations. The resulting equations produce, for columns of the A matrix, forecasts of fuel I/O coefficients which are sensitive to energy price changes.

Step 1, then, is to estimate the long run price effects from cross-section data. In Step 2 these results are reconciled with time series data in order to calculate the yearly adjustment process toward desired fuel coefficients. The final step incorporates the projected fuel coefficients into the INFORUM A matrix and tests their price sensitivity. These steps follow.

Step 1: Cross-Section Estimation

Included with the four fuels in the Diewert equation are variables for capital (K) and labor (L). In a similar work by Halvorsen[3] in which he estimates price effects on fuels using U.S. manufacturing data for 1971, the possibility of substitution of energy for K and L is neglected. This omission leads to the untenable result that an equal increase in all fuel prices will lead to no change in the demand for energy. Here, K and L have been included as arguments in the estimating equation to take into account energy conservation in the face of rising energy prices. The following empirical studies reinforce this approach.

Berndt and Wood review studies where attempts have been made to measure capital-energy (K-E) substitutability . Their own study and the studies by Fuss, Swain and Friede, and Magnus find some evidence of K-E complementarity. Others by Griffen and Gregory, Pendyck, and Halvorsen and Ford, note K-E substitution.[4] As to labor, Fuss also finds some evidence of energy-labor substitutability in his work.[5] Considering these results, it appears that demands for energy, capital and labor are interdependent and so are considered in the estimations here.

As in the Halvorsen work, it is assumed here that changes in the price of other intermediate goods have no impact on the demand for energy and so an intermediate input term is left out of the equation. Fuss again provides evidence to substantiate this assumption. He finds that the cross-elasticity between energy and other material inputs is not significantly different from zero. This conclusion is derived using aggregate manufacturing data for Canada.[6]

Including capital and labor along with the four fuels in the Diewert function produces a demand equation which lists input demands as a function of the ratios of their prices relative to the input prices of their alternatives.

Data

In order to obtain energy information which is rich in detail both in type of user and type of fuel used, cross-section data is used which varies across states for manufacturing industries in 1975. The use of cross-section data is advantageous for a number of reasons. First, since the data covers only a single period in time, it can be assumed that technological change is held constant and the level of technology is identical across states. No explicit consideration need be made in estimation for changing technology. Second, data across states provides many observations. The accuracy of estimation is, consequently, improved. Third, while some energy prices have been controlled, we should see price differentials between states which represent transportation and other location specific cost differences. The variation in energy prices and quantities consumed across states can be used to estimate energy price effects through the Diewert equation.

The use of cross-section data also poses some limitations. Some state data is misleading. For example, the price differential between price controlled interstate natural gas and uncontrolled intrastate natural gas produces an incorrect picture of price effects on natural gas demand where large portions of the gas supply is intrastate; the states with large intrastate supplies would show large gas use and high prices. The reason for this is that, previous to gas price controls, the local availability and abundance of this energy source would have made these states attractive for plant location. Once in place such plants would have to accept the relatively higher prices generated in 1975. A second problem is that, for many states, specific industry fuel use data is unreported because of government rules covering disclosure of firm data.[7] Another drawback is the possible upward bias of price sensitivity due to locational responses within a diverse industry. The location of plants which produce highly energy intensive products within an industry will be sensitive to energy price differentials. Such firms will be located in a state where an energy source is cheap. The less energy intensive plants will be more ambivalent to high energy prices. Consequently, the industry will display, across states, a high sensitivity to energy prices in its energy demands as a result of product diversity. However, changing energy prices through time would not lead to changing product mix for a single plant and, consequently, responsiveness to energy price changes would be lower. These problems are dealt with in a number of ways and will be discussed in the following sections starting with the selection and collection of data.

The _Annual Survey of Manufacturers, 1975_ provides information on the quantities consumed and revenues paid for oil, coal, natural gas, and electricity as well as man-hours, wages, and the value of industry shipments for 20 two-digit SIC manufacturing industries across states in 1975.[8] These industries are listed in Table 4.1. The last columns of Appendix A show the four-digit classification of the INFORUM sectors that match these two-digit industries. While some data also exists for a more disaggregated industrial breakdown, disclosure problems prevented the availability of a complete set. For estimation of the Diewert equation, the "unit" of measurement for the inputs: labor, oil, coal, natural gas, and electricity, is defined as one 1975 dollar's worth, calculated at the national average price. Prices for these inputs are calculated as the ratio of the state price for each industry divided by the national average price. For fuels, the state price is generated by calculating a ratio of revenues paid, divided by quantities consumed by each industry in each state; for labor, wages are divided by man-hours.

Table 4.1

Energy Consuming
Manufacturing Sectors
Standard Industrial Classifications

2-Digit SIC Code	
20	Food Products
21	Tobacco Products
22	Textile Mill Products
23	Apparel, Other Textiles
24	Lumber and Wood Products
25	Furniture and Fixtures
26	Paper, Allied Products
27	Printing and Publishing
28	Chemicals, Allied Products
29	Petroleum, Coal Products
30	Rubber, Miscellaneous Plastic Products
31	Leather, Leather Products
32	Stone, Clay, Glass Products
33	Primary Metal Industries
34	Fabricated Metal Products
35	Machinery, except electrical
36	Electric, Electronic Equipment
37	Transportation Equipment
38	Instruments, Related Products
39	Toys, Sports, Misc. Manufacturing

Designating the above defined input units and nationally indexed prices by C_{is} and P_{is}, respectively, for the i input used by an industry in state s, the Diewert equation for estimation is,

$$\frac{C_{is}}{Q_s} = \sum_j b_{ij} \left(\frac{P_{js}}{P_{is}}\right)^{1/2} \tag{4.1}$$

i = labor, oil, coal, natural gas, electricity

j = capital, labor, oil, coal, natural gas, electricity

s = 1 , 48

Q_s = value of shipments in 1975 for an industry in state s.

Since no state data was available for capital, no capital equation was estimated and the prices for capital are assumed to be constant across states. Five equations for the remaining five inputs are estimated simultaneously for each of the 20 two-digit manufacturing industries. It would appear that there are six coefficients to estimate for each input, times five inputs, which equals 30 coefficients for each equation. However, taking advantage of the symmetry property, $b_{ij} = b_{ji}$, and stacking the equations for all five inputs in one simultaneous equation system, the number of coefficients reduces to 20. Each off-diagonal coefficient, b_{ij}, enters two equations. An example of the reduction in coefficients for estimation implied by the property of symmetry can be observed in the data set-up in Appendix B for a three input Diewert function.

If no fuel price could be calculated because data was missing, the average price for that fuel in that state is used. Where the amount of fuel consumed was non-zero but was not reported because of disclosure problems, the observation is dropped; where the fuel use was reported as zero the observation is used. Data on energy, labor, and output are used for 48 states only. Texas and Louisiana are dropped because of non-typical intrastate natural gas pricing and supply.

An adjustment was made to the data in order to correct for estimation problems associated with heteroscedastic error terms where fuel coefficients are estimated simultaneously with labor coefficients. Since the labor input into production is often on the order of ten times larger than the fuel inputs, the error terms of the labor observations around the regression fit are significantly larger than the rest of the data. Consequently, too much weight is given to minimizing the size of the labor residual error to the detriment of the estimation of the fuel use coefficients. More formally stated, the variance of the disturbance term is not constant for all observations. This nonconstancy produces results which are unbiased but not efficient. To improve efficiency, a "weighted least squares" heteroscedasticity correction technique is applied to the data.[9] For this process, it is assumed that the variance of the error term, e_{is}, for state s and input i, is constant and equal to σ_i^2 for each i. Also, it is assumed that across inputs i,

$$\sigma_i^2 = (\overline{C_{is} / Q_s})^2 \cdot k \qquad (4.2)$$

where the first term on the right hand side is the square of the average input cost per dollar of output across states for each i, and k is a constant across all inputs. This condition implies that the variance of the disturbance term is proportional to the squared value of the average of the dependent variable of equation (4.1) for each input. Consequently, dividing both the dependent and independent observations of the Diewert equation by this average for each input produces an error term, $e_{is}/(\overline{C_{is}/Q_s})$, whose variance,

$$\text{var} [e_{is} / (\overline{C_{is} / Q_s})] = 1 / (\overline{C_{is} / Q_s})^2 \cdot \sigma_i^2 = k \qquad (4.3)$$

which is constant across all observations. For these transformed observations, then, all disturbance terms have an equal weight in estimation.

Results

The results of the Diewert equations appear in Appendix C. Table 4.2 presents an example of these results for a fairly typical energy user, the paper industry. Here the top panel shows the actual regression coefficients and the second panel shows the implied elasticities at the national average price and use levels. Each row represents an equation of the form (4.1) with the dependent variable

Table 4.2

Energy
Diewert Estimations

```
26  PAPER, ALLIED PRODUCTS       DIEWERT COEFS(MULTIPLIED BY 1000)

                          1        2        3        4        5        6
                       CAPITAL   LABOR     OIL     COAL     N GAS    ELEC
                      ---------------------------------------------------
      2  LABOR !       143.2   -101.3       .0       .0     24.7     53.3 !
      3  OIL   !       109.6       .0   -113.3      9.1       .0     12.2 !
      4  COAL  !          .0       .0      9.1     -3.2       .0       .0 !
      5  N GAS !          .0     24.7       .0       .0    -18.1       .0 !
      6  ELEC  !       -31.9     53.3     12.2       .0       .0    -17.7 !
                      ---------------------------------------------------

26  PAPER, ALLIED PRODUCTS       PRICE ELASTICITIES

                          1        2        3        4        5        6
                       CAPITAL   LABOR     OIL     COAL     N GAS    ELEC
                      ---------------------------------------------------
      2  LABOR !          .6      -.9       .0       .0       .1       .2 !
      3  OIL   !         2.0       .0     -2.4       .2       .0       .2 !
      4  COAL  !          .0       .0       .7      -.7       .0       .0 !
      5  N GAS !          .0      1.5       .0       .0     -1.5       .0 !
      6  ELEC  !         -.9      1.5       .3       .0       .0      -.9 !
                      ---------------------------------------------------
```

names listed down the left hand column and the names of the various input prices along the top. Due to a limited number of producing states and a substantial number of disclosure problems, too few observations existed to permit the estimation of Sector 21: Tobacco Products, 29: Petroleum and Coal Products, and 31: Leather and Leather Products. For the seventeen remaining sectors, the Diewert equations show all own-price elasticities to be negative or zero and all cross elasticities to be positive except for the cross-partial between capital and electricity. The negative own elasticities indicate that normal cost minimizing demand curves, which are downward sloping, exist for all inputs and the positive cross elasticities indicate that substitution occurs between alternative fuels. Indeed, the only place where complementarity might exist is between capital and electricity where cheaper electricity may cause more capital equipment such as air conditioners to be purchased. These results, which conform to economic theory, were derived by a constrained quadratic estimation technique which permitted no wrong signs on the cross partials. Where substitution was assumed to exist, the off diagonal b's were permitted to be only greater than or equal to zero. Without this constraint the data would have produced many wrong signs. At least one out of the fifteen cross partials for each equation turned out negative when using an OLS regression technique. While firms may be attempting to minimize costs at any point in time, across states, not all industries may be at their desired fuel use levels. This may result in some cross elasticities taking on the wrong sign. While own-price elasticities were permitted to be zero, only eleven zeros turned up out of ninety coefficients. Here t statistics were omitted since they are not applicable to constrained regression estimation.

In a few instances, own-price elasticities appeared to be unreasonably large and were adjusted down. This adjustment occured in two cases out of ninety. For example, Table 4.2 shows an oil own-elasticity of -2.4 for 26: Paper and Allied Products, but this is an adjusted value. The original value was -6.5, which seemed clearly excessive. As was pointed out earlier,such very high elasticities most probably stem from diversity within the industry. The _Survey of Manufacturing_ data shows that the more energy intensive plants within this sector, such as Papermills, tend to locate in energy cheap states, while less intensive plants, such as those making miscellaneous converted paper products, appear to be less influenced by energy costs in their location decisions. For example,the ratio of state wide energy consumption by paper products plants to energy consumption by papermills (measured in killowatt-hour equivalents) is significantly higher in energy-expensive states than in energy-cheap states. This ratio is 16 percent for Connecticut, 32 percent for Vermont, 31 percent for New Jersey, and 5.9 percent for New Hampshire. These states represent the top four in energy-expensiveness that produce both products. The four energy cheapest states that produce both products are Louisiana, Texas, North Carolina and Arkansas with energy consumption ratios of paper products plants to papermills of 1 percent, 9 percent, four percent, and 2 percent respectively.[10] Such industry diversification as is evidenced here, consequently, shows up as a huge price elasticity in our equation. Clearly this elasticity cannot be used as a guide to show how fuel inputs would change if prices change. The fact that we are dealing here with a spurious elasticity is further indicated by the fact that the principle substitute for oil appears to be not some other energy source, but capital. Since there is no capital equation, the capital coefficient appears only as a term in the other equations. The regression does not get the usual two shots at estimating the coefficient as is true for the other coefficients. The own-price elasticity for oil is made more reasonable by limiting the cross elasticity with respect to capial to no greater than 2.0. Because the elasticities must sum to zero across any row, the negative own price elasticity was raised by the amount that the positive cross elasticity had to be reduced to bring it down to 2.0. In the case of oil use by paper firms, the own-price elasticity came down to -2.4. In total, only two of the nineteen oil demand equations had to be adjusted. The other sector besides paper was 24: Lumber and Wood Products.

Comparison With Unconstrained Estimates

How reasonable are the price elasticity estimates? Here, coefficients have been guided by a firm hand to fall within bounds of price effect expectations derived from economic theory and common sense. Do these results have anything to offer over standard OLS regression estimates for forecasting purposes? Applying an unconstrained OLS regression technique to equation (4.1) produces alternative coefficient estimates which can be used for forecasting. For purposes of comparison, forecasts of two energy price scenarios are generated using the INFORUM "price" model and fed into the constrained quadratic and OLS price coefficient estimates. The first scenario, called "base," has the price of domestic crude oil increasing at the rate of the wholesale price index from 1978 to 1985. An alternative "deregulation" scenario increases the prices of domestic crude to approximately the price of foreign crude by 1985. Also the price of natural gas is allowed to increase at the same rate as the price of fuel oil in order to simulate natural gas supply restrictions. The differences in oil prices between the two are:

Crude Oil Price

(dollars per barrel)

	1978	1980	1985
Base-Domestic	9.12	12.29	19.21
Deregulation-Domestic	9.12	14.34	23.63[11]
Foreign-both scenarios	15.39	18.00	24.26

The deregulated crude oil price pushes up the price of coal and electricity by approximately one percent and the price of fuel oil by six percent over the base scenario by 1985. The natural gas price is made to follow the fuel oil increase.

Table 4.3 presents for each estimation technique, designated "Quad" and "OLS," a comparison of the desired fuel coefficients generated from the two price scenarios. Listed are the forecasted 1985 fuel coefficients as defined in the equation (4.1) for both the base and deregulation scenarios. In each column are the coefficients for oil, coal, natural gas, electricity and lastly total fuel demand for each of the seventeen two-digit industry categories. The third column under each estimation technique shows the percentage change in the coefficient resulting from the higher fuel prices.

Results show the following:

1. The increase in the price of fuel oil, which is as large or larger than the other energy price increases, leads to an <u>increase</u> in the use of oil under OLS for eight of the seventeen forecasted oil coefficients. Quad shows all oil coefficients decreasing as a result of the oil price increase.
2. Looking at total energy consumption, the increase in energy prices caused the total energy coefficients to <u>increase</u> under OLS for eight out of the seventeen sectors. All Quad total energy coefficients decreased or stayed constant as a result of higher prices.

We see here then, that for many sectors, OLS leads to untenable results where firms increase the use of oil as oil becomes relatively more expensive, and increase the use of energy in general as higher crude prices lead to a higher aggregate energy price. On the other hand, Quad holds forecasts within the bounds of economic theory by permitting only downward sloping oil demand curves and total energy conservation in the face of higher crude oil prices.

Table 4.3

FUEL COEFFICIENT FORECAST - 1985

		QUAD			OLS		
		BASE	DEREG	% CHG	BASE	DEREG	% CHG
20 FOOD PRODUCTS							
	OIL	.00325	.00302	-7.0	.00302	.00283	-6.2
	COAL	.00056	.00056	-.4	.00076	.00077	1.7
	N GAS	.00179	.00184	3.0	.00179	.00182	2.0
	ELEC	.00487	.00501	2.8	.00417	.00432	3.5
	TOTAL	.01047	.01043	-.4	.00973	.00974	.1
22 TEXTILE MILL PRODUCTS							
	OIL	.00753	.00733	-2.7	.00988	.00991	.3
	COAL	.00088	.00088	.0	.00039	.00037	-3.9
	N GAS	.00222	.00238	7.1	.00254	.00279	8.7
	ELEC	-.00079	-.00099	-24.0	.01482	.01494	.8
	TOTAL	.00983	.00959	-2.4	.02763	.02801	1.4
23 APPAREL,OTH TEXTILES							
	OIL	.00046	.00045	-1.3	-.00062	-.00063	-1.9
	COAL	.00001	.00001	.0	.00000	.00000	.0
	N GAS	.00053	.00053	.6	.00053	.00053	1.7
	ELEC	.00629	.00629	-.0	.00509	.00492	-3.5
	TOTAL	.00729	.00728	-.1	.00500	.00482	-3.7
24 LUMBER AND WOOD PRODUCTS							
	OIL	.00342	.00282	-17.7	-.00072	-.00238	-230.2
	COAL	.00005	.00005	4.2	.00005	.00008	40.0
	N GAS	.00085	.00070	-18.0	.00008	-.00009	-214.6
	ELEC	.04942	.04933	-.2	.00552	.00474	-14.1
	TOTAL	.05374	.05289	-1.8	.00484	.00234	-52.6
25 FURNITURE AND FIXTURES							
	OIL	.00176	.00166	-6.2	.00187	.00188	.4
	COAL	.00018	.00019	.6	.00006	.00010	59.4
	N GAS	.00111	.00112	.5	.00174	.00181	4.1
	ELEC	.00806	.00813	.8	.00545	.00564	3.5
	TOTAL	.01111	.01108	-.3	.00912	.00943	3.4
26 PAPER, ALLIED PRODUCTS							
	OIL	.01659	.01285	-22.5	.01132	.00082	-92.8
	COAL	.00576	.00602	4.6	.01104	.01172	6.1
	N GAS	.00649	.00600	-7.5	.01073	.01037	-3.4
	ELEC	.02217	.02242	1.1	.02115	.02127	.5
	TOTAL	.05101	.04729	-7.3	.05424	.04417	-18.6
27 PRINTING AND PUBLISHING							
	OIL	.00076	.00074	-2.2	.00097	.00100	3.1
	COAL	.00027	.00022	-18.8	.00500	.00494	-1.1
	N GAS	.00082	.00083	1.3	.00110	.00113	2.8
	ELEC	.00558	.00556	-.1	.00528	.00527	-.2
	TOTAL	.00742	.00736	-.8	.01236	.01236	-.0
28 CHEMICALS,ALLIED PROD							
	OIL	.01010	.00713	-29.4	.00964	.00684	-29.1
	COAL	.00590	.00590	-.1	.01071	.01104	3.1
	N GAS	.00811	.00735	-9.4	.00921	.00831	-9.8
	ELEC	.01570	.01610	2.5	.02195	.02228	1.5
	TOTAL	.03982	.03647	-8.4	.05151	.04847	-5.9
30 RUBBER MISC PLASTIC PROD							
	OIL	.00470	.00431	-8.1	.00476	.00438	-8.0
	COAL	.00050	.00049	-.2	.00166	.00167	.4
	N GAS	.00202	.00197	-2.6	.00241	.00237	-1.4
	ELEC	.02508	.02530	.9	.01281	.01303	1.7
	TOTAL	.03229	.03208	-.7	.02163	.02144	-.9

Table 4.3 (continued)

FUEL COEFFICIENT FORECAST - 1985

		QUAD			OLS		
		BASE	DEREG	% CHG	BASE	DEREG	% CHG
32 STONE,CLAY,GLASS PROD							
	OIL	.01385	.01153	-16.8	.01267	.01038	-18.0
	COAL	.01877	.01897	1.0	.01732	.01757	1.5
	N GAS	.02080	.01980	-4.8	.02245	.02136	-4.9
	ELEC	.02152	.02199	2.2	.01829	.01867	2.1
	TOTAL	.07494	.07229	-3.5	.07073	.06799	-3.9
33 PRIMARY METAL INDUSTRIES							
	OIL	.00893	.00799	-10.6	.00979	.00947	-3.2
	COAL	.00158	.00158	-.1	.00463	.00466	.5
	N GAS	.00813	.00808	-.4	.00811	.00819	1.0
	ELEC	.02579	.02562	-.7	.02112	.02075	-1.8
	TOTAL	.04443	.04328	-2.6	.04366	.04307	-1.4
34 FABRICATED METAL PRODS							
	OIL	.00167	.00164	-2.0	.00202	.00207	2.6
	COAL	.00009	.00009	.0	.00023	.00022	-3.0
	N GAS	.00197	.00197	.3	.00269	.00268	-.3
	ELEC	.00732	.00734	.2	.00749	.00774	3.4
	TOTAL	.01105	.01104	-.1	.01243	.01272	2.3
35 MACHINERY EXCEPT ELEC							
	OIL	.00180	.00175	-2.8	.00117	.00122	4.6
	COAL	.00016	.00016	.0	.00043	.00041	-4.0
	N GAS	.00036	.00035	-2.5	.00138	.00138	.1
	ELEC	.02323	.02321	-.1	.00575	.00582	1.2
	TOTAL	.02554	.02547	-.3	.00872	.00883	1.3
36 ELECTRIC,ELECTRONIC EQ							
	OIL	.00111	.00100	-10.2	.00126	.00131	3.8
	COAL	.00009	.00009	.0	.00033	.00032	-1.5
	N GAS	.00140	.00138	-.9	.00134	.00136	.9
	ELEC	.00838	.00848	1.2	.00677	.00688	1.7
	TOTAL	.01098	.01095	-.2	.00970	.00987	1.7
37 TRANSPORTATION EQUIPMENT							
	OIL	.00150	.00147	-1.6	.00168	.00202	19.8
	COAL	.00019	.00019	.0	.00044	.00050	14.3
	N GAS	.00102	.00099	-3.3	.00105	.00104	-.7
	ELEC	.00601	.00603	.3	.00492	.00485	-1.5
	TOTAL	.00872	.00868	-.4	.00810	.00842	3.9
38 INSTRUMENTS,RELATED PROD							
	OIL	.00095	.00082	-13.5	.00123	.00127	2.9
	COAL	-.00000	-.00000	.0	-.00068	-.00070	-2.3
	N GAS	.00066	.00068	1.8	.00082	.00087	6.3
	ELEC	.00674	.00682	1.2	.00512	.00526	2.6
	TOTAL	.00835	.00831	-.4	.00649	.00670	3.2
39 TOYS,SPORTS,MISC MANUF							
	OIL	.00148	.00116	-21.7	.00296	.00284	-4.1
	COAL	.00004	.00005	4.5	.00008	.00008	.0
	N GAS	.00121	.00121	-.2	.00200	.00197	-1.4
	ELEC	.00725	.00740	2.1	.00539	.00550	2.0
	TOTAL	.00999	.00981	-1.7	.01044	.01039	-.4

Step 2: Time Series Reconciliation

While we cannot expect a firm to be fully adjusted to energy price changes in 1975, fuel price differentials between states due to transport costs should be fully incorporated into the firm's production function. Consequently, the price effect estimations from the cross-section data indicate desired longrun adjustments to energy price changes. In order to forecast fuel coefficients through time, however, it is necessary to know the yearly adjustment in fuel coefficients toward their desired levels. To this end, a time series of fuel coefficient observations was combined with a time series of "desired" fuel coefficients generated from the cross-section estimates above in order to estimate the change in fuel coefficients through time.

Data Setup

The time series of actual data on two-digit manufacturing fuel use for the four fuels was gathered from the Census of Manufactures and Survey of Manufactures for the years 1954, 1958, 1962, 1967, 1971, 1974, 1975, and 1976.[12] From this series a constant dollar measure of fuel use for each fuel type and sector was calculated. Dividing this by INFORUM constant dollar output for each sector produced a constant dollar time series of fuel I/O coefficients, C_t, for the eight time periods, t. Seperately, indexing energy prices to equal one in 1975 and feeding a time series of these numbers into the cross section Quad-estimated demand functions produced a time series of "desired" fuel coefficients for the corresponding years. Denoting the desired coefficients as C^*_t, we assume that the actual coefficient is,

$$c_t = (1 - \lambda) \sum_{i=0}^{\infty} \lambda^i \; c^*_{t-i} \qquad 0 < \lambda < 1 \qquad (4.4)$$

where λ is estimated by regression analysis.

While it would seem that eight data points would be sufficient to estimate λ, in practice it was not. Other factors entered into fuel consumption decisions over the history period. In particular, between 1954 and 1967, oil and coal inputs into most industries were both falling sharply without much change in prices. Here it appears that firms were simply becoming more efficient in energy use. After 1967, coal inputs continued to drop, but oil consumption per unit of output began to rise rapidly. Likewise, natural gas coefficients rose between 1967 and 1971 in nearly every two-digit manufacturing industry. Here it appears that pollution control replaced economy as the dominant motive. A look at government policy during the period illuminates this impetus.

Between 1961 and 1965 the number of state, local, and regional air pollution agencies went from 44 to 93. By 1969 that number had more than doubled again, to 191. In 1961 the Federal government supplied no funds to these agencies. The total funding from other sources was $9 million. By 1969, non-federal sources supplied $30 million; the Federal government, $21 million for a total of $51 million. State laws and regulations multiplied during this period as well. Before 1965, thirteen states had air standards laws; by 1968 that number was up to 46.[13] Clearly government forces were in motion to persuade firms to consider cleaner fuels such as oil and natural gas.

Between 1971 and 1976, while oil use continued to rise, a regulation-induced natural gas shortage developed. Limited supplies of natural gas were distributed among competing users through a national gas curtailment system under the authority of the Federal Power Commission. This system was established as early as 1969 and was in full force by 1971[14].

To account for these developments, two trend variables have been introduced. One runs from 1954 onwards to account for increased energy efficiency in general. The other starts in 1967 to account for environmental considerations. As well, to handle the natural gas shortage, a shadow price for natural gas was introduced after 1971 which rises approximately at the rate of oil prices, its closest substitute. The assumption here is that ease of substitution between these close alternative fuels would have held their relative prices approximately constant had the equilibrating mechanism of the market been allowed to work. With the introduction of the trends, the values of λ along with our two new variables become rather difficult to estimate from eight data points. However, taking advantage of the fact that λ, the adjustment factor between actual and desired coefficients, is related for all fuels used by an industry as fuels are substituted for each other it is assumed here that λ for each fuel is the same. The data can then be grouped across fuels to estimate a single λ for each industry.

The equation for estimation is,

$$C_{ft} - [(1-\lambda)\sum_{i=0}^{\infty}\lambda^{i} C^{*}_{f,t-i}] = b_{0f} + b_{1f}\,T + b_{2f}\,(T-13)^{+} \qquad (4.5)$$

$f = 1, \ldots, 4 \qquad t = 1, \ldots, 8$

where f and t are indices representing the four fuels and the eight data points, respectively.

T = (Y-1953), a time trend starting with 1 in the first year of the data 1954. Y is the year of the data; 1954, 1958, 1962, 1967, 1971, 1974, 1975, and 1976.

$$(T-13)^{+} = \begin{cases} T-13 \text{ when this is positive} \\ 0 \text{ when } T-13 \text{ is non-positive.} \end{cases}$$

The regression matrix has a total of 12 parameters for estimation and 4 x 8 = 32 data points. Equation (4.5) was estimated for different values of λ between zero and .95 until the λ value was found that minimized the sum of squared errors.

Table 4.4 represents the results of this estimation. The "best fit" λ's are listed in the first column and measures of the coefficients associated with the constant term, the conservation trend, and the pollution trend for each fuel follow. The trend terms presented here are defined as the b's estimated in equation (4.5), divided by the average I/O coefficient for each fuel. Presented in this way, the terms indicate approximately the percentage change in fuel use per dollar of

Table 4.4

Adjustment Estimations From Time Series

SECTOR		LAMBDA	OIL CON(1)	COAL CON(2)	N GAS CON(3)	ELEC CON(4)	OIL T(1)	COAL T(2)	N GAS T(3)	ELEC T(4)	OIL T-13(1)	COAL T-13(2)	N GAS T-13(3)	ELEC T-13(4)	RSQ
20 FOOD PRODUCTS															
	COEF	.95	.224	1.929	.158	-.022	-.074	-.125	.012	.027	.109	.070	-.008	-.001	
	T		1.86	8.50	1.72	.33	5.62	5.02	1.16	3.84	3.96	1.34	.40	.06	.96
22 TEXTILE MILL PRODUCTS															
	COEF	.95	.946	2.579	-1.703	.943	-.084	-.155	.088	-.029	.110	.112	-.080	.030	
	T		7.12	14.83	6.46	19.73	5.79	8.00	3.03	5.61	3.62	2.79	1.49	2.72	.99
23 APPAREL,OTH TEXTILES															
	COEF	.30	-.340	.100	-1.653	-1.445	.089	.221	.120	.041	-.175	-.570	-.141	.026	
	T		.75	.06	3.17	27.25	1.51	.99	1.78	7.13	1.35	1.15	.94	2.13	.99
24 LUMBER AND WOOD PRODUCTS															
	COEF	.95	-1.663	2.898	-2.993	-5.395	-.073	-.178	.074	-.013	.172	.160	-.013	.105	
	T		9.31	3.72	12.63	71.68	3.73	2.09	2.87	1.55	4.23	.90	.24	6.13	.97
25 FURNITURE AND FIXTURES															
	COEF	.60	-.150	2.739	-.671	-.472	-.081	-.158	-.009	.025	.225	.109	.134	-.002	
	T		.37	8.50	1.93	6.25	1.84	4.47	.22	2.98	2.46	1.48	1.70	.10	.97
26 PAPER, ALLIED PRODUCTS															
	COEF	.95	-1.734	1.379	-.288	.431	-.034	-.048	.038	.019	.131	-.023	-.071	-.008	
	T		22.14	12.21	1.92	4.35	3.94	3.89	2.52	1.73	7.33	.88	2.24	.35	.94
27 PRINTING AND PUBLISHING															
	COEF	.10	1.179	.000	-2.928	-.009	-.019	.000	.037	.007	.002	.000	.000	.000	
	T		.40	.00	.11	6.22	.32	.00	.08	3.93	.20	.00	.19	.01	.97
28 CHEMICALS,ALLIED PROD															
	COEF	.95	-3.353	1.705	.052	.938	-.154	-.099	-.004	-.031	.310	.039	-.001	.013	
	T		9.38	7.46	.34	10.18	3.93	3.96	.25	3.09	3.81	.75	.03	.61	.94
30 RUBBER MISC PLASTIC PROD															
	COEF	.95	.058	2.507	-.450	-.537	-.074	-.138	.023	.010	.128	.070	-.020	.011	
	T		.42	17.84	2.37	13.59	4.78	8.82	1.11	2.25	3.89	2.19	.47	1.27	.99
32 STONE,CLAY,GLASS PROD															
	COEF	.95	-1.651	.392	-.193	-.069	-.095	-.100	.008	.024	.185	.086	-.043	-.012	
	T		13.21	4.40	4.02	.97	8.93	10.27	1.51	3.08	6.50	4.23	3.91	.73	.97
33 PRIMARY METAL INDUSTRIES															
	COEF	.95	.882	1.287	.298	-.580	-.087	-.026	.015	.014	.101	-.058	-.040	.026	
	T		9.22	7.00	4.54	13.60	8.27	1.32	2.15	2.98	4.64	1.40	2.67	2.72	.99
34 FABRICATED METAL PRODS															
	COEF	.85	1.293	2.398	-.170	-.241	-.081	-.128	.020	.027	.090	.078	.029	.020	
	T		7.09	4.82	1.51	5.18	4.04	2.35	1.59	5.18	2.17	.67	1.11	1.89	.99
35 MACHINERY EXCEPT ELEC															
	COEF	.00	.788	2.318	.023	-3.581	-.062	-.132	.019	.042	.047	.090	.038	.013	
	T		2.00	3.54	.07	34.15	1.44	1.85	.53	3.69	.53	.60	.52	.55	.95
36 ELECTRIC,ELECTRONIC EQ															
	COEF	.55	.420	2.825	-.334	-.745	-.103	-.182	-.004	.079	.200	.168	.059	-.111	
	T		.68	2.85	.68	8.18	1.47	1.68	.06	5.97	1.38	.75	.51	4.03	.93
37 TRANSPORTATION EQUIPMENT															
	COEF	.95	.240	1.876	-.379	-.157	-.058	-.075	.022	.021	.055	.007	-.014	-.022	
	T		1.16	11.95	2.38	3.86	2.47	4.38	1.24	4.78	1.16	.18	.39	2.40	.99
38 INSTRUMENTS,RELATED PROD															
	COEF	.50	.284	.000	-2.184	-.020	.002	.000	.314	.007	-.112	.000	.000	.000	
	T		.60	.00	.09	3.38	1.53	.00	.04	2.29	2.12	.00	.26	1.12	.93
39 TOYS,SPORTS,MISC MANUF															
	COEF	.40	1.354	3.208	.310	.289	-.157	-.215	.031	.046	.273	.197	-.115	-.154	
	T		2.54	1.84	.42	1.80	2.06	.86	.30	2.64	1.61	.38	.49	4.22	.90

output. In the last column, under "RSQ", is the coefficient of determination, R^2, for the explanatory power of the whole equation including C^*.

The results of the value of λ show the large energy users such as paper, chemicals, primary metals, transportation equipment, stone, glass, lumber, textile mills, and food products, to be slow in adapting to energy price changes. The λ for these industries are equal to .95, the slowest adjustment value allowed. We see faster adjustments for less energy intensive industries such as apparel, furniture, printing, fabricated metals, machinery, electronics, instruments, and miscellaneous manufacturing.

Looking at the measures for the b_1 coefficients we see that the oil and coal terms show a trend towards energy conservation, (b_1 less than zero), for practically all industries between 1954 and 1967. The coefficients for the pollution control trend, ($b_1 + b_2$), show that after 1967 the downward trend in oil use reverses for most industries and is rendered negligible for the rest. These trend terms also show coal use continuing to drop during the latter period. Electricity use over the whole period follows a slow climb in most sectors. The fits for these equations produce R^2's that are .90 or above for all of them. The estimated parameters are used to forecast changing energy I/O coefficients. Future coefficients are calculated by adding forecasted fuel prices to the estimated Diewert equation (4.1) and putting the resulting C^* along with trends into equation (4.5).

To measure the sensitivity of these equations to changing fuel prices the two oil price scenario forecasts used in the previous sector were applied. Table 4.5 shows the forecasted fuel I/O coefficients in 1985 for both the base and deregulation price runs described above. This table is similar to Table 4.3 in that the percentage change in the coefficients resulting from domestic oil price deregulation is shown in column three. These tables differ, however, in that the earlier one shows desired fuel coefficients resulting only from price effects. On the other hand, Table 4.5 forecasts actual fuel I/O coefficients where account is taken of existing trends in fuel use as well as the yearly adjustment of fuel use to desired levels as the result of changing fuel prices. Here, once again, we see that the increase in oil prices leads to either constant oil use (one sector) or decreasing oil use (remaining sixteen sectors). Also, the increase in energy prices in general leads to energy conservation as evidenced by the decreasing total energy coefficients for all sectors.

Step 3: Application to the A Matrix

The forecasted fuel coefficients in Table 4.5 are added to the INFORUM model by adjusting, to the above growth rates, the I/O coefficients for all INFORUM manufacturing sectors that fall under the seventeen two-digit SIC categories. The I/O coefficients are adjusted in the oil, coal, natural gas, and electricity rows of the A matrix. In all, 130 INFORUM sectors are made sensitive to changing energy prices.

Table 4.5

FUEL COEFFICIENT FORECAST - 1985

		PRICE AND TRENDS		
		BASE	DEREG	% CHG
20 FOOD PRODUCTS				
	OIL	.00198	.00189	-4.4
	COAL	.00000	.00000	.0
	N GAS	.00379	.00382	.7
	ELEC	.00810	.00815	.6
	TOTAL	.01387	.01386	-.1
22 TEXTILE MILL PRODUCTS				
	OIL	.00536	.00526	-1.8
	COAL	.00005	.00005	.0
	N GAS	.00236	.00244	3.5
	ELEC	.01084	.01078	-.6
	TOTAL	.01880	.01853	-.4
23 APPAREL,OTH TEXTILES				
	OIL	.00046	.00045	-1.5
	COAL	.00000	.00000	.0
	N GAS	.00041	.00041	.7
	ELEC	.00668	.00668	-.0
	TOTAL	.00755	.00755	-.1
24 LUMBER AND WOOD PRODUCTS				
	OIL	.00119	.00098	-17.8
	COAL	.00016	.00016	.6
	N GAS	.00159	.00155	-2.1
	ELEC	.01506	.01503	-.2
	TOTAL	.01799	.01772	-1.5
25 FURNITURE AND FIXTURES				
	OIL	.00213	.00201	-5.7
	COAL	.00000	.00000	.0
	N GAS	.00272	.00274	.8
	ELEC	.00947	.00954	.7
	TOTAL	.01433	.01430	-.2
26 PAPER, ALLIED PRODUCTS				
	OIL	.01413	.01286	-9.0
	COAL	.00069	.00078	13.3
	N GAS	.00742	.00729	-1.9
	ELEC	.03119	.03127	.2
	TOTAL	.05343	.05218	-2.3
27 PRINTING AND PUBLISHING				
	OIL	.00059	.00057	-3.1
	COAL	.00023	.00017	-27.1
	N GAS	.00126	.00128	1.0
	ELEC	.00881	.00881	-.0
	TOTAL	.01088	.01082	-.7
28 CHEMICALS,ALLIED PROD				
	OIL	.00000	.00000	.0
	COAL	.00000	.00000	.0
	N GAS	.01368	.01347	-1.5
	ELEC	.02450	.02464	.6
	TOTAL	.03817	.03811	-.2
30 RUBBER MISC PLASTIC PROD				
	OIL	.00364	.00350	-3.8
	COAL	.00000	.00000	.0
	N GAS	.00287	.00287	-.2
	ELEC	.02271	.02279	.3
	TOTAL	.02922	.02916	-.2

Table 4.5

FUEL COEFFICIENT FORECAST - 1985

		PRICE AND TRENDS		
		BASE	DEREG	% CHG
32 STONE,CLAY,GLASS PROD	OIL	.00075	.00000	-100.0
	COAL	.00281	.00285	1.4
	N GAS	.01151	.01125	-2.3
	ELEC	.03021	.03037	.5
	TOTAL	.04528	.04447	-1.8
33 PRIMARY METAL INDUSTRIES	OIL	.00634	.00601	-5.1
	COAL	.00000	.00000	.0
	N GAS	.01227	.01227	.0
	ELEC	.03567	.03561	-.2
	TOTAL	.05427	.05389	-.7
34 FABRICATED METAL PRODS	OIL	.00175	.00172	-1.8
	COAL	.00000	.00000	.0
	N GAS	.00517	.00518	.3
	ELEC	.01439	.01439	.0
	TOTAL	.02130	.02129	-.0
35 MACHINERY EXCEPT ELEC	OIL	.00114	.00109	-4.4
	COAL	.00001	.00001	.0
	N GAS	.00280	.00259	-.3
	ELEC	.00962	.00961	-.2
	TOTAL	.01337	.01330	-.6
36 ELECTRIC,ELECTRONIC EQ	OIL	.00107	.00095	-11.3
	COAL	.00017	.00017	.0
	N GAS	.00219	.00218	-.3
	ELEC	.00759	.00769	1.4
	TOTAL	.01101	.01099	-.2
37 TRANSPORTATION EQUIPMENT	OIL	.00073	.00072	-1.2
	COAL	.00000	.00000	.0
	N GAS	.00147	.00147	-.5
	ELEC	.00668	.00668	.1
	TOTAL	.00888	.00887	-.1
38 INSTRUMENTS,RELATED PROD	OIL	.00220	.00206	-6.3
	COAL	.00000	.00000	.0
	N GAS	.00142	.00144	1.2
	ELEC	.00679	.00697	1.3
	TOTAL	.01041	.01037	-.3
39 TOYS,SPORTS,MISC MANUF	OIL	.00238	.00204	-14.3
	COAL	.00000	.00000	.0
	N GAS	.00000	.00000	.0
	ELEC	.00013	.00029	118.1
	TOTAL	.00251	.00233	-7.2

How is total energy use affected by the addition of energy price sensitivity to the manufacturing sectors? To answer this question the INFORUM model was run with and without the price adjusted fuel I/O coefficients for both the base and the deregulated oil price scenarios. The difference in fuel demand from these two runs indicates the extent of the impact of the estimated Diewert equations on energy use by the economy.

Domestic crude oil price deregulation, as observed before, raises the price of coal and electricity by approximately one percent and the price of fuel oil by six percent over the base scenario by 1985. Again, the natural gas price was made to rise to follow the fuel oil increase. Where the INFORUM model was run with the deregulated or high oil price scenario and no fuel coefficient adjustment was made, the resulting impact on energy use would be solely the result of changes in consumer purchases through the INFORUM Personal Consumption Expenditure equations. Adding the Diewert price adjusted energy coefficients for the manufacturing sectors produces an impact on total fuel use over and above consumer responses. To clearly differentiate these impacts, three forecasts were run: a base oil price run (BASE), a high oil price run with only personal consumption responses (ALTPCE), and a high oil price run with both consumption responses and a changed A matrix, adjusted by the Diewert equations for energy use in manufacturing (ALTDIEWERT). The difference between BASE and ALTDIEWERT shows the total impact of both PCE and manufacturing demand changes for energy and is called ALL. The differences between ALTPCE and ALTDIEWERT demonstrates the impact on total energy use resulting solely from changes in demand by the manufacturing sectors and is called MFG. Table 4.6 lists the results of these comparisons. The four columns show the absolute difference and percentage difference in fuel demand (measured in 1976 dollars) from the baseline for ALL and MFG in 1985.

By 1985 we see that total oil use decreased by $247 million as a result of higher oil prices. This represented approximately a one percent decrease in total oil use. Of this, $39 million, or .17 percent of total oil use was the result of substitution away from fuel oil by the manufacturing sectors. Natural gas demand by manufacturing was down but by less -- only .06 percent -- due to the higher gas prices which were linked to the higher oil prices. Of the total natural gas drop of $387 million, $38 million came from a decrease in manufacturing demand. Coal use by ALL was down $23 million which represented a decrease of only .12 percent of total coal use as the result of increased energy prices. This drop would have been greater had manufacturing demand not led to an increase of $9 million. Coal became more attractive to manufacturers as its price became relatively cheaper. Electricity also showed increased manufacturing sector demands as it became a relatively cheaper energy input. The total drop of $90 million worth of electricity consumption would have been $149 million lower had manufacturing not increased demand by $59 million. The result is that total electricity decreased only .1 percent as the result of higher energy prices. Looking at the net result across all fuels, total energy use decreased by $747 million, only $9 million of which was caused by energy conservation in manufacturing. However, manufacturing energy substitution led to significant movements away from the consumption of

Table 4.6

Energy Demand in 1985: Difference from Baseline (measured in 1976 dollars)

	ALL		MFG	
	Million $	Percent	Million $	Percent
Coal	-23	-.12	+9	+.05
Oil	-247	-1.05	-39	-.17
Natural Gas	-387	-.66	-38	-.06
Electricity	-90	-.10	+59	+.07
	-----		-----	
Net	-747		-9	

scarce fossil fuels such as oil and natural gas as the result of relatively higher prices. Oil and natural gas use by manufacturing decreased by $77 million by 1985.

CHAPTER V

I/O Coefficients for Transportation Services

The demand for freight hauling by industry is a derived demand stemming from the requirements for shipping industrial outputs. As such, the demand for transportation services need not be distinguished from the demand for other inputs into industry production. Using the production function theory outlined in Chapter III, we can hypothesize that for each dollar of output there is at any time a demand for a given level of transport services just as there is a fixed demand for other inputs. This input-output relationship between transport services and industry output can be regarded as an I/O coefficient in the A matrix. Since for many industries the modal choice decision for shipping output is affected by the costs of transportation, it is important to see how changing prices of alternative modes affect modal choice and ultimately the I/O coefficients in the transportation rows of the matrix. If it is assumed that firms are motivated to minimize the costs of production, it is clear from the production theory outlined in Chapter 3 that firms will be responsive to changes in the relative prices of alternative inputs where inputs such as transport services are substitutable. As the price of a transport mode rises, firms will substitute away from that mode toward a relatively cheaper alternative in order to minimize costs. This substitution effect shows the interdependence between alternative modes. When the cost share of the transportation dollar increases for one mode, it must necessarily decrease for another. The

Diewert function is used to specify this relationship because it allows for price responsive input substitution in production where both the behavior of the firm and the interdependence between modal shares are considered.

Theoretical Approach

Since nearly all production must be shipped in order to be sold, we should see a constant I/O coefficient ratio between output shipped and output produced and imported (minus inventory buildup). This ratio should remain constant regardless of decisions about the optimal cost minimizing amounts of non-transport inputs into production. Consequently, the firm's production function can be considered separable into two parts; the cost minimizing mix of non-transport inputs and the cost minimizing mix of transport services needed to meet total transport demands. With this assumption, the relative prices and amounts of non-transport inputs need not be considered in the Diewert equation for the determination of the demand for transport services by mode. Previous writers, in attempting to specify the full production function relationship for estimation where all inputs are considered, found it necessary to aggregate groups of inputs in order to generate sufficient consistent data. This aggregation led to problems of product mix. With the assumption of separability, it is possible to estimate price effects where substitutable transport inputs are considered at a fairly disaggregated level of detail, since it is generally easier to obtain consistent data for just a few key inputs such as transport services in the production process than for a comprehensive list.

Data

The data used for estimation, gathered by Jack Faucett Associates (JFA), measures intercity tons shipped yearly from 1965 to 1974 for 45 commodities and by five modes; rail, water, commercial truck, private truck, and pipelines.[1] A list of the 200 INFORUM sectors appears in Appendix A and the Faucett-sector INFORUM-sector matchup appears in the first two columns of Table 5.1. This time series data is unique in that it represents a fairly high level of disaggregation of alternative inputs for a detailed number of purchasers. This detail minimizes the problems of product mix. Also, having a time series of data for individual industries allows for the estimation of transport price sensitivity by product shipped.

For estimation purposes, we might be interested in ton-miles as a measure of the amount of modal transport services demanded per unit of output. However, a consistent time series of the data does not exist. As well, while ton-miles are the units that are purchased, miles will not necessarily be a function of the level of production since distance of shipments is determined by changing locational requirements. However, taking advantage of the fact that all tons produced must eventually be shipped, there is a straight-forward derived demand relationship for transport services measured in tons as a function of the level of output. Consequently, tons is the measure used for estimation.

Table 5.1

Faucett Data

Faucett Commodity Classification	Matching INFORUM Sectors	Shipments (1974 Millions of Tons)	Total Tons Market Quotient Yearly Percentage Change	Total Tons Market Quotient Avg. Absolute Percentage Error
1 Grains	5	245	1.5	7.8
2 Forestry & Fishery Products	9	25	-6.5	6.4
3 Iron Ores	11	197	1.2	2.7
4 Copper Ore	12	13	-3.6	6.6
5 Coal	14	603	-1.4	1.1
6 Crude Petro. & Natural Gas	15	669	-0.6	3.5
7 Stone & Clay Materials	17	353	0.4	1.3
8 Chemial Fertilizer Materials	18	89	-0.3	4.3
9 Logs	43	270	2.0	3.9
10 Lumber	44	41	-1.1	3.4
11 Pulp, Paper & Paperboard	50,51	63	1.1	1.2
12 Industrial Chemicals	64	129	-1.5	2.7
13 Misc. Petroleum Products	76	643	0.6	2.0
14 Fuel Oil	77	393	1.6	1.7
15 Cement	89	113	-1.6	3.7
16 Steel	91	155	0.2	3.7
17 Motor Vehicles	144,145	65	-0.7	2.0

Table 5.1 (continued)

Faucett Commodity Classification	Matching INFORUM Sectors	Shipments (1974 Millions of Tons)	Total Tons Market Quotient Yearly Percentage Change	Total Tons Market Quotient Avg. Absolute Percentage Error
18 Metal Scrap	91,92,93,94, 95,96,97,98, 99	47	2.5	4.1
19 Livestock & Poultry	1,2,3	46	5.0	2.5
20 Other Agricultural Products	4,6,7	105	-1.5	5.2
21 Other Non-Ferrous Ores	13	14	-0.5	7.7
22 Food & Tobacco Products	24,25,26,27, 28,29,30,31, 32,33,34,35	282	0.4	1.5
23 Textiles & Leather Products	36,37,38,39, 83,84,85	17	0.2	5.4
24 Apparel	40,41,42	6	0.9	2.1
25 Paper Products excepting Containers	52,53	18	-0.3	3.0
26 Printed Matter & Paperboard Containers	54,55,56,57 58,59,60	28	2.1	2.0
27 Other Chemicals	65,66,67	53	-2.2	4.2
28 Plastics	68,69,70,71	27	2.6	1.4
29 Drugs & Paints	72,73,74	19	-4.2	2.1
30 Paving Materials	78	28	-2.8	7.2
31 Rubber Products	80,81,82	17	-0.6	3.4
32 Other Wood Products	45,46,47	31	0.2	2.8
33 Furniture - Misc. Manufactured Products	48,49,163, 164,165,166	17	-1.0	4.3

Table 5.1 (continued)

Faucett Commodity Classification	Matching INFORUM Sectors	Shipments (1974 Millions of Tons)	Total Tons Market Quotient	
			Yearly Percentage Change	Avg. Absolute Percentage Error
34 Glass Products	86	18	0.1	3.4
35 Stone & Clay Products	87,88,90	75	-0.5	4.6
36 Primary Nonferrous Metal Products	92,93,94,95, 96,97,98,99	28	1.0	2.8
37 Fabricated Structural Metal Products	102,103,104	22	-3.3	6.3
38 Ordnance & Misc. Fabricated Metal Products	21,22,23,100, 101,105,106, 107,108,109, 110	21	0.1	7.7
39 Metal Working Machinery & Equipment	115,116,117, 118,119,120, 121,122	8	-1.4	6.7
40 Other Machinery except Electrical	111,112,113, 114,123,123, 125,126	17	-5.4	2.5
41 Communication Equipment	136,137,138 139	2	-3.9	3.6
42 Electrical Machinery & Equipment	129,130,131, 132,133,134, 135,140,141, 142	12	-2.0	2.4
43 Other Transportation Equipment	147,148,149, 150,151,152, 153	9	5.0	7.7
44 Instruments, etc.	156,157,158 159,160,162	1	-1.9	5.5
45 Other Scrap	39,53	28	2.1	4.9

Though all tons produced must eventually be shipped, the ratio of total tons shipped divided by output measured in constant dollars may change. Explanations for trends in this ratio, called the "total tons market quotient," [2] are: (1), a change in the physical weight of the product shipped, and (2), remaining product mix problems-- changes in the product mix of commodites shipped under one aggregated Faucett commodity heading. Changes in the total tons market quotient could also come from the double counting of shipments involved in inter-modal transfers. However, we feel that this is not an important source of change for our data.[3]

Procedure

Taking advantage of the Faucett data on commodity tons shipped by each mode, the following equation is used to estimate I/O coefficients for transportation rows in the A matrix:

$$\frac{TM_i}{Q} = \frac{T}{Q} \cdot S_i \cdot M_i \tag{5.1}$$

where,

TM_i = transport services measured in ton-miles of output shipped by mode i

Q = output measured in 1976 dollars

S_i = T_i/T , the portion of total tonnage shipped by mode i; a modal share. T_i is the tons shipped by mode i and T is total tons-shipped by all modes where $T = \Sigma T_i$

T/Q = total tons market quotient

M_i = average distance hauled by mode i.

The ratio on the lefthand side of this equation is a measure of transport services by mode shipped per dollar of output. By assuming that a fixed relationship exists between this ratio and modal transport expenditures per dollar of output (all measured in 1976 dollars) which is the INFORUM I/O coefficient, the 1976 A matrix transport coefficients can be moved by the forecasted transport services to output ratio calculated in equation (5.1).

The procedure for estimating price effects on transport coefficients involves three steps. The first is the estimation of the trend in the total tons market quotient for each commodity, T/Q; the second, the estimation of modal shares of total tons shipped, S_i, as a function of relative modal prices using the Diewert equation; and the third, the estimation of modal transport service coefficients as a function of S_i and T/Q adjusted for changes in distance hauled. These coefficients are then used to move the INFORUM transportation rows.

Step One: Total Tons Market Quotient

In order to determine the trends in the total tons market quotient, the ratio of total tons shipped of each of the 45 commodities divided by the aggregate output measured in 1976 dollars of the matching INFORUM sectors was calculated for the 1965 to 1974 period. Imports were added to industry outputs, but inventory adjustments were taken into account only for the commodity group "grains" which often carries large inventories. Other inventories were neglected because of a lack of satisfactory inventory data. However, since inventories are small for most sectors, this neglect should not significantly influence the results. The trend in the quotient time-series was estimated by fitting a logistic curve through the observed data so as to minimize the sum of the squared errors around the curve. A logistic curve was used in order to put a ceiling or floor on any projection of these trends so that quotients can never be projected to be too large or less than zero.[4] Columns four and five of Table 5.1 list respectively the yearly percentage change in the estimated logistic curves and the average absolute percentage error (AAPE) of the fitted curve to the actual quotients.

Consistency Check of Faucett Data

The quality of the Faucett tons data can also be checked using the total tons market quotients. Besides inventory changes, the only explanation for fluctuations of the total tons quotient around its trend are a mismatch between INFORUM and Faucett commodity groups, product mix shifts, and errors in the measurement of tons of shipments. To check for these fluctuations, the fits of the actual quotients around the logistic curve trends were studied for the 45 industries.

By counting the trends with yearly changes of one percent or less in column four of Table 5.1, it can be seen that the total-tons market quotient is approximately constant for 18 out of 45 sectors, or 40 percent. These 18 show the pattern of shipping to be approximately a constant function of total output produced. Of these, however, three show large fluctuations which are reflected in high AAPE values. They are Other Non-ferrous Ores, Textiles and Leather Products, and Ordnance and Miscellaneous Fabricated Metal Products. An AAPE value above five percent is assumed here to show substantial variation of the actual quotients around the curve. All three ship relatively small amounts ranging between 14 and 21 million tons in 1974. The total tons shipped in 1974 by each industry is listed in column three of Table 5.1 in millions of tons.

The remaining 27 industries show some appreciable trend in their market quotients for total tons shipped. The yearly percentage change for these sectors are above one percent. Of the trended quotients, 11 trends went up and 16 went down. There seems to be no general bias toward shipping more or less weight per constant dollar of output across industries for the period 1965 to 1974. The variation of the data around the predicted trends for the 27 trended quotients shows AAPE values less than five percent for 18 of them. The lowest AAPE value of 1.1 percent occurred for coal, one of the largest transportation service demanders. The low AAPE's for these 18 give evidence that definitive trends as opposed to random errors in the market quotients do occur for many industries. Whatever the reason for change, the trends in the total tons market quotients seem to be stable over time for approximately 67 percent of the trended market quotients. For these sectors, the Faucett tons shipped data appears to be fairly accurate since changes in tons shipped must move coincidentally with changes in tons in order to produce AAPE's as low as were found.

The remaining 12 sectors with AAPE's above five percent are now given special attention since they exhibit wide fluctuations around their trended quotients or constant quotients. The problems with these sectors fit into six categories:

1. Anomalous Events

   A labor strike in the copper industry affecting production and destabilizing the market quotient ratio of shipments to output for 1967 and 1968 worsens an otherwise good fit to an AAPE of 6.6 percent.

2. Inventories

   Tonnage flows of Grains even though adjusted for inventory change still seems to suffer from a flow problem between production and shipments in a given year which points up possibly still more inventory adjustment problems.

3. Product Mix and Mismatch

   Where many INFORUM product sectors are aggregated to form one Faucett category, a changing mix over time of heavier and lighter products hauled within this category will cause total Faucett tons to vary separately from changes in the level of output. For example, the Faucett category Ordnance and Miscellaneous Fabricated Metal Products is made up of eleven INFORUM sectors. A change in its product mix over time could destablize the total tons market quotients and produce the rather high AAPE of 7.7 percent. As well, any product mismatch between the products in the INFORUM sectors and the products under the one Faucett heading will cause tons shipped and output levels to diverge. The output for the Faucett category Forestry and Fishery Products varies extensively due to cyclical timber demand. However, since the output of the Forestry industry is standing timber just before it is cut, the Faucett tons shipped for Forestry and Fishery Products reflect mostly the waterborne shipments of freshly caught fish. Here we see a mismatch between the major good being shipped and the major good being produced due to the aggregation of the data by Faucett. To improve on this situation, only Fishery output was used with the Faucett Forestry and Fishery tons data. This realinement lowered the AAPE from over 13 percent to 6.7 percent. Sector 37: Fabricated Structural Metal Products appears to suffer from this problem as well since it includes as the largest component of output the nebulous commodity group Other Metal Products.

4. Data Jumps

For Metal Working Machinery and Equipment, the total tons market quotient drops precipitously in 1970 due to a drop in rail tons shipped in that year to one-third of their 1969 value. This drastic change was not compensated by an increase in the use of another mode. Also, it appears that tons shipped by truck are significantly different in 1965 from the rest of the truck data. These data inconsistencies contributed to the high AAPE of 6.7 percent for this sector. ~~The AAPE~~ fit of the total tons market quotient for Textiles and Leather Products suffers from a large upward jump in the data in 1974 for tons shipped by truck, when, in fact, output in that year dropped. This again could be the result of product mix problems resulting from the aggregation of seven fairly heterogeneous INFORUM sectors.

5. Interpolated Data

Since a consistent time series of data does not exist for private truck, Faucett Associates had to interpolate between the known census years of data, 1963, 1967, and 1972, from the *U.S. Census of Transportation* in order to produce the missing numbers. However, where output levels fluctuate over time, interpolated private truck points will not lead to stable market quotients. The result is poor data fits to a total tons market quotient trend and high AAPE's if the private truck share is a significant portion of the total. The private truck shares of the total tons shipped for Other Agricultural Products, Paving Materials, and Other Transportation Equipment is 47 percent, 69 percent, and 41 percent respectively in 1974. Such high shares may indicate that the high AAPE values for these sectors could be the result of the interpolated private truck data.

6. Small Sectors

For Instruments the AAPE value of 5.5 percent is most likely the result of errors in data collection due to the smallness of the numbers since this sector demands a relatively insignificant amount of transport services--one million tons in 1974 compared to an industry average of 112 million tons.)

Overall, how does the Faucett data hold up? The total-tons shipped to output ratios are fairly constant, showing no trend, for 18 out of the 45 industries with only three of these showing wide fluctuations. Of the remaining 27 sectors showing some trend in their ratios, 18 show good fits of the data around their trends and nine show some fluctuations. Counting the 15 good constant coefficient fits and the 18 good trend fits, a total of 33 of the 45 sectors show the Faucett tons data doing a creditable job of tracking industry output. These 33 sectors represent approximately 90 percent of total tons shipped in 1974. The remaining 12 sectors, making up ten percent of total tons shipped, appear to suffer from inventory problems, poor data for private trucks and some bad data points.

Step Two: Estimation of Modal Shares

By applying the condition of separability discussed above to separate the transport cost minimizing decision from the production cost minimizing decision for non-transport inputs, we may write the demand function for tons transported by mode i as,

$$T_i = d_i\,(T, P_1, \ldots, P_k)$$

where tonnage, T_i, shipped by mode i is a function, d_i, of total tons for which shipping services are demanded, T, and the prices, P, of k alternative modes of transport. By assuming the demand function is linearly homogeneous in T, the modal share demand function can be written as,

$$S_i = T_i / T = d_i(P_i, \ldots, P_k) \qquad (5.2)$$

If we now assume the d_i function to be the Diewert equation, this equation for transport inputs becomes,

$$S_i = \sum_{j=1}^{4} b_{ij} \left(\frac{P_j}{P_i}\right)^{1/2} \qquad i = 1, \ldots, 4 \qquad (5.3)$$

i = Modes: Rail, Water, Truck, Pipeline. Since no price data exists for Private Truck, it is assumed here that its implicit price is approximately the same as commercial truck and the two modes were combined.

Thirty-nine commodity groups drawn from the Faucett data for the years 1965 to 1974 were used for estimating equation (5.3).[5] Again, taking advantage of the symmetry property, $b_{ij} = b_{ji}$, the simultaneous estimation of (5.3) for all modes requires the estimation of only ten coefficients. The data setup would be similar to the example for the inputs in Appendix B. This estimation technique assures consistency of substitution between modes by retaining their interdependence through simultaneous estimating. Relative price coefficients estimated in this way will cause substitution between modes while maintaining expected levels of total tons shipped.

Independent Variables

The independent variables of equation (5.3) are relative prices. A weighted price term was calculated for each mode where the importance of transport revenues collected for each commodity shipped is taken into account. Calculated in this manner, the total transport price for each mode is free of the bias introduced by high prices on shipments where transport services are dying out. For example, it may be the case that, over time, a decreasing amount of freight is being shipped of a commodity whose transport rate is high. At the same time an increasing amount of freight is being hauled of a commodity whose rate for the same mode is low. A total modal price, unweighted by individual commodity transport revenues would register this situation as a drop in the modal transport price when, in fact, only freight substitution has occurred. To account for this substitution, commodity shipment costs were weighted by their changing importance in the provision of total transport services by each mode.

It might seem appropriate to use transport tariffs by commodity shipped as the price term, however, this approach was not possible because: (1) consistent rates are available only at too disaggregated a level, (2) rates vary by location and commodity shipped, and (3) rates are non-linear in distance. Since the tons data is at the national level, correct specification would require comprehensive aggregation of rates for all modes over time, a heroic task since the only comprehensive consistent data comes from the Interstate Commerce Commission which governs 100 percent of rail shipments but only 84 percent for Pipelines, 44 percent for Trucks, and 20 percent for Water Carriers.[6] The lack of comprehensive rates by commodity necessitates the use of modal prices which are not differentiated by commodity hauled.

The following equation was used for calculating modal prices where the diversity of transport rates and changing transport demands by commodity shipped are considered. A transport price index, P , for each mode was calculated using,

$$P = \frac{TR^t}{TR_c^t}$$

where,

$$TR_c^t = \sum_j \left(R_j^{72} \cdot \frac{T_j^t}{T_j^{72}} \cdot \frac{M_j^t}{M_j^{72}} \right) \qquad (5.4)$$

TR^t = total revenue collected in year t for all commodity shipments by a single mode

TR_c^t = total Revenue collected in year t for all commodity shipments by a single mode, measured in constant 1972 dollars

R_j^{72} = revenues collected for shipping commodity j by a single mode in 1972

T_j^t = tons shipped of commodity j by a single mode in year t; T_j^{72} measures tons shipped in 1972

M_j^t = miles shipped of commodity j by a single mode in year t; M_j^{72} measures tons shipped in 1972.

The righthand term in (5.4) shows what total revenues would have been in year t had rates per ton-mile for each commodity been constant at their 1972 values. It is calculated as an index, measured in tons, miles, and 1972 shipment revenues, for the change in transport services provided for each commodity. Dividing the total revenue by this index for all commodities removes real changes in transport services from the equation and leaves only the change in the transport price.

To estimate this equation, data from a number of sources had to be combined. Data on 1972 revenues by commodity shipped for each mode came from further transport data built from the 1972 Census, compiled only for 1972 by JFA. Tons by commodity shipped for each mode came from the JFA tons data described at the beginning of this chapter. Since, as was mentioned previously, no time series exists for commodity miles, a series had to be concocted. To do this, it was first assumed that a trend exists in the miles per ton ratio for each commodity over time. The three years of data (1963, 1967, 1972) on tons and ton-miles from the *U.S. Census of Transportation* was used to estimate that trend.[7] Multiplying the JFA tons data, T_{JFA}, by the ton-mile trend produced the following estimated miles in year t for commodity j, for each mode:

$$M_j^t = \widehat{\left(\frac{M_j}{T_j}\right)}^t \cdot T_{JFA,j}^t \qquad t = 1965 \text{ to } 1974 \qquad (5.5)$$

The first term on the right was estimated by a linear trend regression on the three Census data points. All trend fits with AAPE's above 20 were dropped from the calculations. This accounted for two of the commodities shipped by water, four by truck, and none by rail. The *Census of Transportation* does not report data for pipelines and so a total pipeline rate was used for the three sectors that use pipeline services. This rate is the average revenue per ton mile, reported yearly to the Interstate Commerce Commission.[8]

A time series of rates by commodity shipped does exist for Rail only, and this data has been incorporated into the transport price calculations. The Bureau of Labor Statistics has published, since 1969, quarterly price indexes for eleven selected commodities of railroad freight as well as an aggregate freight price index.[9] A ratio of the individual prices to the aggregate price index was used to adjust the rail price index derived from equation (5.4). The eleven BLS commodity price indexes were disaggregated to 31 of the JFA commodity classifications shown in Table 5.1. To calculate values for the period from 1965 to 1968, when there was no individual data, the ratio of individual prices to the BLS aggregate price index for all rail freight was estimated by OLS using a time trend on the existing data. The trend of this ratio was then backcast to 1965. The addition of these sectoral rail prices changed the results only marginally from the estimates that were obtained using the weighted rail price calculated from equation (5.4). The sectoral rail prices proved to have little impact on the results because the individual prices all moved in approximately the same manner.

To take into account lags between price changes and modal shifts, the price term is a composite of present and one year previous prices, equally weighted. This scheme was picked as the best after a number of alternatives were tried.

Results

Appendix D presents the estimation results of the Diewert equation for the 39 commodity categories. The results for two of these, 13: Fuel Oil and 14: Cement, are presented in Table 5.2. The top panel for each commodity shows the regression coefficients and, for some sectors such as Cement, the corresponding t statistics. Each row represents an equation of the form of equation (5.3) above with the dependent variable names listed down the lefthand column and the names of the various modal prices along the top. The second panel for each commodity shows the implied own and cross price elasticities which are calculated from the Diewert equation for 1972 when all prices are indexed to equal one.

Of the 39 commodity groups, 23 produced estimates where all coefficients show substitution between alternative modes, a result consistent with cost minimizing behavior of the firm. These are marked with an asterisk beside their names. Below the coefficients in the row designated "T" are the associated t statistics. Only 4 of the 23 show coefficients with t statistics below the significant range using a one-tailed test at the five percent level of the test. The remaining 16 sectors have at least one negative off diagonal ($i \neq j$) relative price term -- twenty terms in all. These coefficients are perverse in that a decrease in the price of one mode relative to another is associated with an increased demand for the mode which has experienced the relative increase in price. Three of these sectors can be discounted, however, since, upon inspection, they show essentially no change in modal shares through the history period. They are , 10: Paper, 20: Textiles and

Table 5.2

Transportation Diewert Estimations

```
13        FUEL OIL             DIEWERT COEFS (MULTIPLIED BY 1000)

                             1        2         3         4
                           RAIL    WATER     TRUCK      PIPE
                     ------------------------------------------

         1  RAIL   !       .00      .00       .00       .00 !
         2  WATER  !       .00   483.90      #.00       .00 !
         3  TRUCK  !       .00     #.00    164.30     41.00 !
         4  PIPE   !       .00      .00     41.00    247.20 !
                     ------------------------------------------
13        FUEL OIL                   PRICE ELASTICITIES

                             1        2         3         4
                           RAIL    WATER     TRUCK      PIPE
                     ------------------------------------------

         1  RAIL   !                                        !
         2  WATER  !                          .00       .00 !
         3  TRUCK  !                .00      -.10       .10 !
         4  PIPE   !                .00       .07      -.07 !
                     ------------------------------------------


14   *   CEMENT                DIEWERT COEFS (MULTIPLIED BY 1000)

                             1        2         3         4
                           RAIL    WATER     TRUCK      PIPE
                     ------------------------------------------

         1  RAIL   !   -368.10      .00    672.10       .00 !
            T      !      3.36      .00      6.37       .00 !

         2  WATER  !       .00      .00       .00       .00 !
            T      !       .00      .00       .00       .00 !

         3  TRUCK  !    672.10      .00    -74.30       .00 !
            T      !      6.37      .00       .72       .00 !

         4  PIPE   !       .00      .00       .00       .00 !
            T      !       .00      .00       .00       .00 !
                     ------------------------------------------
14        CEMENT                     PRICE ELASTICITIES

                             1        2         3         4
                           RAIL    WATER     TRUCK      PIPE
                     ------------------------------------------

         1  RAIL   !     -1.17               1.17           !
         2  WATER  !                                        !
         3  TRUCK  !       .55               -.55           !
         4  PIPE   !                                        !
                     ------------------------------------------
```

Leather Products, and 36: Communication Equipment. Accordingly, the t statistics associated with the coefficients for these sectors are insignificant. Of the 17 remaining negative coefficients, t statistics show that 14 appear to be significantly less than zero using a one-tailed test at the five percent level of the test. These are marked with a # next to their coefficients which appear mostly as zeros. (Because each Diewert coefficient appears twice in the panels due to the symmetry property of coefficients, each negative coefficient is marked in two places with the # .) One of the significantly negative coefficients can be observed for Fuel Oil in Table 5.2. Four of the 14 significantly negative coefficients show price effects between 2) Water, and 3) Truck. Four are between 1) Rail, and 3) Truck, and six are between 1) Rail, and 2) Water.

The explanation for these terms most probably is that they are picking up the movement of modal shares caused by factors that have not been considered in the regression. Although the double accounting of tons created by inter-modal transfers might at first appear to lead to complementarity which would create negative terms, this argument is rejected because, as pointed out earlier, inter-modal transfers make up an insignificant proportion of the Faucett intercity shipment data. Consequently, complementarity is rejected as an explanation of negative relative price coefficients resulting from the Faucett data.

In order to pick up price effects which are consistent with the normal cost minimization theory of the firm laid out in the previous section, a quadratic programming regression technique is used which does not permit wrong signs on relative price terms. Market quotient data which creates perverse price effects is chalked up to the effects of omitted variables and is essentially ignored in the estimation of Diewert price sensitive equations. Constraints on the values of the relative price coefficients move the twenty negative coefficients to zero. Since the adjustment of the twenty coefficients is the result of a constrained estimation technique, the usual t statistics for the sixteen constrained equations are inappropriate measures of the statistical significance of the equations and have been deleted. The true test of the explanatory power of these equations rests with their ability to forecast well. This topic will be taken up later in this chapter.

Other Variables Considered

A literature search of other variables that might explain price perverse changes in modal shares produced many theoretical possibilities but few operational measures. Factors, other than modal price, often cited in the determintion of modal choice by an individual demander of modal services are inventory costs, ordering costs, transit time, carrier reliability, handling and packaging costs, and loss and damage in transit claims.[10] Most studies of modal choice that have tried to take these factors into account have had to work with either time-series data of aggregated commodity shipments, or cross-section data across commodities for only a few time periods.[11] The problems of product mix inherent in the aggregated time-series data have already been discussed. Researchers, attempting to estimate modal price elasticities from data across commodities, have found it necessary to stratify the data by commodity characteristics in order to specify completely the modal choice decision. Commodity characteristics theorized to explain the other factors in the modal choice decision besides price are commodity size, density, value per pound, perishability, ease of handling, susceptability to theft, and fragility. The acquisition of data measuring these characteristics has been generally unsuccessful.[12] Ann Friedlander, for example, notes that data constraints limit her to defining commodity characteristics, in terms of length of haul, value, density, and average load size in order to estimate price effects on truck and rail shares for eight aggregate commodity groups. "No data was available on reliability and the use of loss and damage claims added nothing to the analysis."[13] This technique of product characteristic differentiation is necessary in order to explain the level of modal shares by commodity, but the rather restrictive implicit assumption here is that transport price effects on modal choice are identical across commodities. This assumption need not be made when time-series data by commodity exists such as the Faucett data. By using the Faucett data for regression analysis, the importance of the transport price in the total modal choice decision for each commodity will be reflected in the regression estimation of price sensitivity since regressions are estimated on a commodity basis. Since estimation is by commodity, commodity characteristics have already been taken into account.

Where price effects appear perverse for the fourteen significantly negative coefficients, the explantion could entail a change in the the product characteristics leading to a change in the modal choice decision. The use of average load and distance of shipments to help explain modal choice has been used by some. However, the use of changes in these measures over time to explain changing modal shares is a questionable procedure due to reverse causation. The Census of Transportation, published by the U.S. Census Bureau, is the major source on the size of shipments and the length of haul by commodity shipped. The Bureau reports that some of its statistics come from bills of lading which designate shipments by weight of the load in a railcar or trailer, rather than the weight of the total shipment. Consequently, in many cases the mode determines the size of the reported shipment rather than the reverse. The change through time in reported shipment size, therefore, often reflects rather than determines the mode and is inappropriate as an explanatory variable. As to the length of haul, it has been shown that rail has a cost advantage in shipping long distances, and truck, in shipping short distances.[14] However, it is not clear whether changing average length of haul indicates increased or decreased demand for a particular mode. For example, if the average haul by Rail increases, it is not clear whether this will cause increased Rail use due to the cost advantage or whether this is the result of inroads made by Truck into Rail's shorter hauls leaving fewer but longer hauls for Rail.

Other Variables Included

In this study two variables besides price have been considered for inclusion in the Diewert modal share equation. An attempt is made to use commodity value and commodity weight to explain factors other than transport costs in the modal choice decision. Each variable is included by adding extra terms along with prices to equation (5.3). When an extra explanatory term, Z, is considered, the expanded equation for estimation is,

$$S_i = \sum_j b_{ij} \left(\frac{P_j}{P_i}\right)^{1/2} + a_i \ Z \qquad i = 1, \ldots, n \text{ modes} \quad (5.6)$$

subject to $\sum_i a_i = 0$.

Since

$$\sum_i S_i = \sum_i \sum_j b_{ij} \left(\frac{P_j}{P_i}\right)^{1/2} = 1 \quad ,$$

the added explanatory term is estimated across all modes to insure that the a's sum to zero across all shares.

Commodity Value

Commodity value has been used as an explanatory term in the modal choice decision in a number of the cross-sectional data studies.[15] Roberts[16] has postulated that commodity value impacts on inventory costs and spoilage costs, which are arguments in the modal choice function determining the most economic mode. Commodity value also affects the costs of running out of stock. The costs incurred by running out of stock determine the importance in the modal choice decision of modal attributes such as speed and reliability. To consider commodity value, a price was created for each Faucett commodity category. This measure was an average of the prices of the INFORUM sectors making up that group. Each INFORUM sector price was weighted by the size of the sector's output in order to calculate its importance in the total group price. The Faucett group price was then deflated by a wholesale price index for all industrial commodities in order to determine the relative increase or decrease in the commodity group's value through time. A 1965 to 1974 time-series of these commodity prices was added as the extra variable to equation (5.4). The results of this estimation showed significant t values for the commodity price term and improved fits of the equation for five sectors. They are, 4: Coal, 24: Plastics, 29: Glass Products, 30: Stone and Clay Products and 34: Metal Working Machinery. Though none of these sectors are among the group that had significantly negative modal price coefficients under OLS estimation, the modal share response to commodity price changes seems quite plausible for these five. For coal, the shift away from water services to rail services could be explained by the observed increase in coal prices from 1945 to 1974. For the remaining four, which represent processed commodities, changing value could indicate significant product, quality, or packaging changes requiring modal services with different transport attributes. Moreover, it is observed that the truck share of transport services is <u>positively</u> related to the commodity value term in every one of these four sectors. This result is consistent with existing theories that relate high value goods with the demand for generally higher quality truck services. The resulting modal price coefficients and elasticities are listed in Appendix D for the five sectors.

Weight

Roberts, in the same paper, also theorized that shipment size and density affects ordering, handling, and storage costs, all variables in the modal choice decision.[17] Rail appears to have a cost advantage when shipping high bulk low-cost commodities.[18] An attempt is made here to consider changes in the weight-to-value ratio as an additional explanatory variable in equation (5.4) in order to take into account changing commodity weight. Given the attractiveness of rail service for heavier products, increases in commodity weight should lead to increased rail shipments. A measure considered is total tons shipped, derived from the Faucett data, divided by INFORUM constant dollar output. However, because the Faucett tonnage data is used directly as an independent variable, the fact that errors in measurement of this variable are a linear function of the errors in measurement of the dependent variable can lead to biased regression estimates.[19] To sidestep this issue, a trend is used as a proxy for changes in the output-to-tons-shipped ratio. In addition to the price terms, using a time trend in equation (5.4), as a proxy for a weight trend, significantly increased the R^2 for 2: Iron Ore, 23: Other Chemicals, and 37: Electrical Machinery and Equipment. For these sectors, trend coefficients entered with t statistics above 2.0 indicating that there seems to be significant trends in the modal shares. With the addition of the extra variable, the rail-truck price coefficient for Other Chemicals, which had been significantly negative when estimated with price alone, turns significantly positive with a t value above 2.0. For Iron Ore, which also had shown a significantly negative price term, the addition of the time trend brings the t associated with the price term into the negative but non-significant range. The price coefficient for Electrical Machinery had been negative but non-significant. Here, the trend variable enters with a t of 3.8 and pulls the price coefficient positive but in the non-significant range.

How accurate a proxy for changes in product weight is the time trend for these three sectors? Table 5.1 shows total-tons--market-quotients which are measures of the output weight ratios considered here, and a look at that table confirms that all three of these sectors have significant weight trends. For the two sectors Other Chemicals and Electrical Machinery, it is possible that these sectors are experiencing a weight change as particular products are being substituted for others within the commodity group. However, an inspection of the data shows weight decreasing over time while the rail share is increasing. While this is contrary to the usual weight arguement for increased rail demand the trend may be picking up other changes in product characteristics leading to increased rail demand. For Iron Ore, the total-tons-market-quotients indicate that iron ore is becoming lighter, a possible result of the shipment of more concentrated ores.

We see here, then, that for some sectors, significant trends are evident in modal substitution which apparently are industry specific and unrelated to the usual commodity weight argument. For Other Chemicals and Electric Machinery, we could be observing the effects of changing modal demands as the result of a change in the commodity mix of products with modal specific transport requirements. Within the chemicals group, for example, there has been a ten percent increase in the output of INFORUM sector 66: Pesticides and Agricultural Chemicals, and an eleven percent decrease in the output of INFORUM sector 67: Miscellaneous Chemical Products, over the 1965 to 1974 period. Whatever the explanations for the trends in the modal shares for these three sectors, the estimated trend coefficients are retained as alternative explanatory variables in the Diewert function, for comparison with alternative estimation techniques presented in the next section.

Summing up, we see that modal price effects are estimable for most sectors. Of the original 45 Faucett sectors, six were found to have only one major mode of transport and, therefore, were inappropriate for estimation with the Diewert equation. The Diewert equations were estimated for the remaining 39 sectors. Five of these were improved upon by a consideration of commodity value in explaining modal shares. Three were improved by adding a time trend to explain commodity mix or weight changes. Nine sectors remained with one or more significantly negative off-diagonal modal price coefficients. These were constrained by a quadratic estimation technique to permit no wrong signs.

Comparison

How well do the estimated Diewert equations work in predicting tons shipped? By multiplying the predicted modal shares calculated from the Diewert equation (5.3) times the total tons market quotient trends estimated in Step One, it is possible to predict tons shipped by mode of each commodity. These predictions can be compared to the actual Faucett data for the period 1965-1974. In order to make a comparison with the Diewert technique, the "skirt" method of forecasting tons shipped is applied to the Faucett data. This method, the one currently used in INFORUM for forecasting coefficient change, attempts to add to the existing INFORUM matrix of I/O coefficients additional rows which define tons of modal transport services demanded per unit of output of various INFORUM sectors. These tons-to-output ratios skirt the border of the existing matrix to form a submodel of I/O coefficients which can then be multiplied by industry outputs to predict freight demands by mode shipped, for each industry. The forecasting of the modal tons-to-output ratio using the INFORUM skirt routine involves the extrapolation of a trend estimated by fitting a logistic curve trend through the history series of Faucett tons-to-output ratios for each mode. For comparison with the Diewert predictions for the 1965-1974 period, the skirt-predicted tons shipped are estimated by multiplying the trend in the individual modal tons-to-output ratio times the actual industry output.[20]

Simulation: Historical Period

Table 5.3 shows the results of the comparison between the Diewert and skirt techniques of estimating tons. Listed are the average absolute percentage errors (AAPE) of predicted tons around the Faucett data points for the years 1965 to 1974 for both the Diewert technique and the logistic skirt technique. Each number in the table represents the average amount of error of the predictions compared to the size of the actual tonnage numbers. The lower the AAPE number the better the fit of the predicted points around the actual. The "AAPE's" are listed for each mode for 38 Faucett sectors.[21] The last column shows the AAPE fits of tons shipped by all modes for each sector. At the end of the table, listed in the row labled "All fits - Faucett tons," are the average absolute percentage errors across all industries for each mode and all modes together. A quick glance at the AAPE's for all modes in the last column shows the Diewert and logistic errors to be identical. The AAPE's in this column are equal because the logistic curve estimates have been adjusted to compensate for a theoretical bias towards a better total tons shipped by all modes fit for the Diewert equation and better individual modal fits for the logistic curve. The following describes the method of adjustment.

The better Diewert "total" fits are the result of the interdependence assumptions implicit in the Diewert technique where all modal coefficients are estimated simultaneously. The Diewert equation tries to minimize the sum of squared errors over all modes at the same time while the logistic predictions come from ordinary least squares

Table 5.3

SUMMARY TABLE
AVERAGE ABSOLUTE PERCENTAGE ERROR

FITS OF PRICE PREDICTED AND LOGISTIC PREDICTED POINTS AROUND ACTUAL

			RAIL	WATER	TRUCK	PIPE	TOTAL
1	GRAINS	(1965-1974)					
		DIEWERT PRED	5.3	7.0	8.1	.0	.1
		LOGISTIC PRED	3.4	4.9	4.4	.0	.1
3	IRON ORE	(1965-1974)					
		DIEWERT PRED	1.6	2.3	.0	.0	.2
		LOGISTIC PRED	1.5	2.1	.0	.0	.2
4	COPPER ORE	(1965-1974)					
		DIEWERT PRED	4.1	.0	16.5	.0	.0
		LOGISTIC PRED	1.7	.0	6.1	.0	.0
5	COAL	(1965-1974)					
		DIEWERT PRED	.7	1.9	.0	.0	.9
		LOGISTIC PRED	1.0	1.3	.0	.0	.9
6	CRUD PETRO+NA	(1965-1974)					
		DIEWERT PRED	.0	7.2	.0	.9	.6
		LOGISTIC PRED	.0	7.0	.0	.8	.6
7	STONE+CLAY MI	(1965-1974)					
		DIEWERT PRED	7.8	2.6	13.2	.0	.3
		LOGISTIC PRED	1.0	1.3	1.1	.0	.3
8	CHEM+FERT MIN	(1965-1974)					
		DIEWERT PRED	2.7	8.1	20.7	.0	.0
		LOGISTIC PRED	3.6	4.2	9.1	.0	.0
9	LOGS	(1965-1974)					
		DIEWERT PRED	2.6	9.9	3.0	.0	.2
		LOGISTIC PRED	1.4	4.8	.8	.0	.2
10	LUMBER	(1965-1974)					
		DIEWERT PRED	2.8	.0	2.3	.0	.8
		LOGISTIC PRED	3.1	.0	3.5	.0	.8
11	PULP,PAPER,PP	(1965-1974)					
		DIEWERT PRED	1.0	.0	2.3	.0	.3
		LOGISTIC PRED	.9	.0	2.4	.0	.3
12	INDUST CHEMIC	(1965-1974)					
		DIEWERT PRED	3.8	9.8	3.3	.0	.0
		LOGISTIC PRED	1.9	3.0	2.1	.0	.0
13	MISC PETRO PR	(1965-1974)					
		DIEWERT PRED	.0	2.7	2.9	1.4	.8
		LOGISTIC PRED	.0	1.8	1.6	1.6	.8
14	FUEL OIL	(1965-1974)					
		DIEWERT PRED	.0	3.1	3.1	2.9	.3
		LOGISTIC PRED	.0	2.4	2.9	2.5	.3
15	CEMENT	(1965-1974)					
		DIEWERT PRED	6.7	.0	3.3	.0	1.0
		LOGISTIC PRED	4.7	.0	4.5	.0	1.0
16	STEEL	(1965-1974)					
		DIEWERT PRED	7.7	.0	8.9	.0	.4
		LOGISTIC PRED	3.4	.0	3.9	.0	.4
17	MOTOR VEHICL	(1965-1974)					
		DIEWERT PRED	2.4	.0	1.9	.0	.2
		LOGISTIC PRED	2.5	.0	1.9	.0	.2

Table 5.3 (Cont'd)

SUMMARY TABLE
AVERAGE ABSOLUTE PERCENTAGE ERROR

FITS OF PRICE PREDICTED AND LOGISTIC PREDICTED POINTS AROUND ACTUAL

		RAIL	WATER	TRUCK	PIPE	TOTAL
20	OTH AGRIC PR (1965-1974)					
	DIEWERT PRED	12.6	.0	4.9	.0	.2
	LOGISTIC PRED	2.1	.0	.7	.0	.2
21	OTH NON-FERR (1965-1974)					
	DIEWERT PRED	6.5	32.5	16.4	.0	.1
	LOGISTIC PRED	3.7	23.6	11.8	.0	.1
22	FOOD,TOBAC P (1965-1974)					
	DIEWERT PRED	2.7	.0	2.3	.0	.1
	LOGISTIC PRED	1.1	.0	.9	.0	.1
23	TEXT+LEATH PR (1965-1974)					
	DIEWERT PRED	4.4	.0	1.3	.0	1.4
	LOGISTIC PRED	3.1	.0	1.4	.0	1.4
25	PAP PROD(-)CO (1965-1974)					
	DIEWERT PRED	1.5	.0	4.0	.0	1.7
	LOGISTIC PRED	4.4	.0	5.6	.0	1.7
26	PRINT MATT+PP (1965-1974)					
	DIEWERT PRED	14.0	.0	2.3	.0	.3
	LOGISTIC PRED	4.5	.0	.8	.0	.3
27	OTH CHEMICAL (1965-1974)					
	DIEWERT PRED	2.1	.0	2.8	.0	1.7
	LOGISTIC PRED	4.5	.0	2.6	.0	1.7
28	PLASTICS (1965-1974)					
	DIEWERT PRED	2.1	.0	2.0	.0	.9
	LOGISTIC PRED	3.4	.0	2.1	.0	.9
29	DRUGS+PAINTS (1965-1974)					
	DIEWERT PRED	3.4	.0	.8	.0	.2
	LOGISTIC PRED	8.1	.0	1.9	.0	.2
31	RUBBER PROD (1965-1974)					
	DIEWERT PRED	5.1	.0	1.8	.0	.1
	LOGISTIC PRED	6.1	.0	2.1	.0	.1
32	OTH WOOD PROD (1965-1974)					
	DIEWERT PRED	2.0	.0	6.1	.0	1.7
	LOGISTIC PRED	2.0	.0	2.3	.0	1.7
33	FURNIT+MISC M (1965-1974)					
	DIEWERT PRED	9.5	14.1	3.4	.0	.1
	LOGISTIC PRED	5.1	12.8	1.9	.0	.1
34	GLASS PROD (1965-1974)					
	DIEWERT PRED	11.6	.0	2.6	.0	.4
	LOGISTIC PRED	2.7	.0	1.0	.0	.4
35	STONE+CLAY PR (1965-1974)					
	DIEWERT PRED	4.0	.0	6.3	.0	.5
	LOGISTIC PRED	2.9	.0	4.1	.0	.5
36	PRIM NON-FERR (1965-1974)					
	DIEWERT PRED	2.9	.0	2.6	.0	.6
	LOGISTIC PRED	1.9	.0	1.5	.0	.8

Table 5.3 (Cont'd)

SUMMARY TABLE
AVERAGE ABSOLUTE PERCENTAGE ERROR

FITS OF PRICE PREDICTED AND LOGISTIC PREDICTED POINTS AROUND ACTUAL

			RAIL	WATER	TRUCK	PIPE	TOTAL
37	FAB STRU MET	(1965-1974)					
		DIEWERT PRED	5.5	.0	3.9	.0	.0
		LOGISTIC PRED	5.5	.0	3.9	.0	.0
38	ORD+MISC FAB	(1965-1974)					
		DIEWERT PRED	5.7	.0	1.4	.0	.6
		LOGISTIC PRED	10.4	.0	3.2	.0	.6
40	OTH MACH EXC	(1965-1974)					
		DIEWERT PRED	4.7	.0	1.9	.0	.4
		LOGISTIC PRED	3.5	.0	1.5	.0	.4
41	COMMUNICATION	(1965-1974)					
		DIEWERT PRED	7.2	.0	2.0	.0	.2
		LOGISTIC PRED	6.7	.0	1.7	.0	.2
42	ELEC MACH+EQP	(1965-1974)					
		DIEWERT PRED	3.2	.0	1.3	.0	.1
		LOGISTIC PRED	3.2	.0	1.3	.0	.1
43	OTH TRANSP EQ	(1965-1974)					
		DIEWERT PRED	13.4	.0	17.4	.0	1.6
		LOGISTIC PRED	4.3	.0	2.8	.0	1.6
45	OTH SCRAP	(1965-1974)					
		DIEWERT PRED	10.9	7.0	.0	.0	.9
		LOGISTIC PRED	2.0	1.5	.0	.0	.9
ALL FITS-FAUCETT TONS		(1965-1974)					
		DIEWERT PRED	5.3	8.3	5.2	1.7	.2
		LOGISTIC PRED	3.5	5.4	2.9	1.6	.2

regression fits where the sum of squared errors are minimized for each mode. The result is that the Diewert equation will always do better in estimating total tons while the logistic curve has an edge in individual modal estimation. To compensate for these biases the modal predictions of the logistic technique were adjusted so as to reduce the total error of the estimate across all modes for each industry to the level of the Diewert predictions. This was done by adjusting, by the same amount, the logistic prediction for each mode so that the sum of these modal predictions equaled the sum of Diewert estimated modal predictions for each period.

The results of this adjusted comparison are, for the 85 non-zero fit comparisons, 20 AAPE fits were better for the Diewert equation and 60 were better for the logistic; five were the same. Breaking this down by mode, 29 percent of the rail fits were better using Diewert and 66 percent were better using the logistic trends; for water, logistic: 100 percent; for truck, Diewert: 26 percent, logistic: 65 percent; and for pipe, Diewert: 33 percent, logistic: 66 percent. Looking at the summary AAPE'S in the last row of the table we see that the error of prediction of the Diewert equations across all sectors was on average higher for all modes relative to the logistic predictions.

Why didn't more of the Diewert equations do better? To a certain extent the deck was stacked in favor of the logistic curve fits because these preditions come from ordinary least squares regressions where the sum of the squared errors are minimized for each mode with no imposed constraints. However, since economic theory dictates that the cross-price effects between modes are equal ($b_{ij} = b_{ji}$), imposing this condition on the estimating equation, as the Diewert technique does, produces a fit which is nearly always worse than a minimum least squares fit for each mode.

A closer look at some of the superior logistic predicted fits can also shed some light on why the logistic trend technique so often out performed Diewert. Looking at AAPE's for truck, 15 sectors show logistic fits to be significantly better. (These are sectors where the Diewert AAPE is more than 50 percent greater than the logistic.) Of these, eight show more than 50 percent of the truck shares to be hauled by private truck. The worst Diewert fits are for "Other Transportation Equipment," and "Stone and Clay Mining" with AAPE's of 17.4 percent, and 13.2 percent respectively. For the first, the private truck share is 70 percent. The high AAPE's for the sectors with high private truck shares probably reflect interpolated points since the only readily available data for this mode comes from the Census of Transportation, which is published approximately every five years. Consequently, tons shipped by truck, made up mostly of interpolated private truck data, will not be as responsive to price changes from the Diewert equations as it will be to trend equations such as the logistic curve since the data itself is created using a trend between known points. Trend analysis will always outperform other equations explaining these points. The second sector with a particularly large AAPE, "Stone and Clay Mining" has only 12 percent of the truck tonnage hauled privately. However, the data shows almost perfect linearity in the trends for both the private and commercial trucking which leads one to suspect the commercial truck numbers for this sector are also interpolated points.

The existence of possible errors in the data base, such as interpolated numbers, points up the strengths of the Diewert equation. Given inexact data with possible errors in measurement, this technique balances the raw precision of regression analysis with economic theory by putting constraints, derived from theory, on the estimated parameters, in order to correct for imperfect data. By inforcing the property of symmetry on the price coefficients the number of observations for estimating each price coefficient is doubled. Consequently, price effects are estimated where data that is inconsistent across modes is discounted. However, applying this constraint naturally lowers the simulation fit for particular modes since less weight is given to some data. Here we see, then, that while not all Diewert equation fits are the best possible, the results make economic sense.

Comparing Forecasts

How do the Diewert and logistic curve forecasts compare? Graph 5.1 presents predictions for two selected sectors. These graphs show plotted points for the Faucett actual data (*), the Diewert predicted data (+), and the logistic curve predicted data (0). Included for each sector are forecasts for each mode and all modes combined. Also included is a 1985 point prediction made by Jack Faucett Associates using the same data set as in this study. The "F" on each plot and the value in the first column for 1985 show the Faucett prediction in

Graph 5.1

Comparison of Predictions

```
COMPARISON : ALTERNATIVE FORECASTS          FAUCETT FORECAST(F)     ACTUAL(*)   DIEWERT BASE RUN(+)   LOGISTIC SKIRT RUN(O)
```

```
 6      CRUD PETRO+NA  SHIPPED BY  WATER     (1000 TONS)
   ACTUAL    DIEWERT PRED    LOGIST PRED
   92046.         91427.         98582.    1965
   92508.         97459.         99324.    1966
  102511.        100030.         98589.    1967
  106468.        103248.        100378.    1968
  109403.        106245.        100438.    1969
  116540.        105585.        100012.    1970
  114112.        100507.         96866.    1971
  103673.        100117.         97546.    1972
   90724.         98301.         98674.    1973
   83486.         94621.         97691.    1974

       0.        102765.         95672.    1975
       0.        113410.        100290.    1976
       0.        116687.         98435.    1977
       0.        121455.         98908.    1978
       0.        124858.         98567.    1979
       0.        128102.         98197.    1980
       0.        130298.         97414.    1981
       0.        131926.         96358.    1982
       0.        133662.         95371.    1983
       0.        135192.         94428.    1984
  200911.        136698.         93441.    1985
       0.        138683.         92888.    1986
       0.        140431.         92248.    1987
       0.        142133.         91635.    1988
       0.        143796.         91045.    1989
       0.        145428.         90480.    1990
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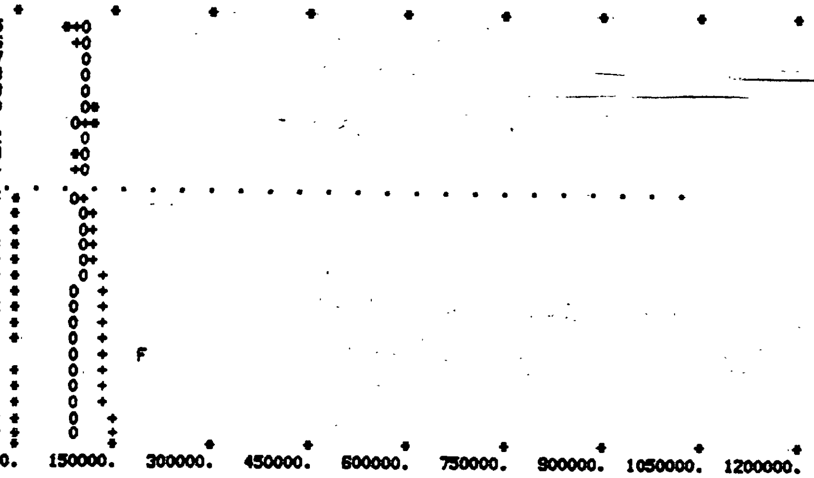
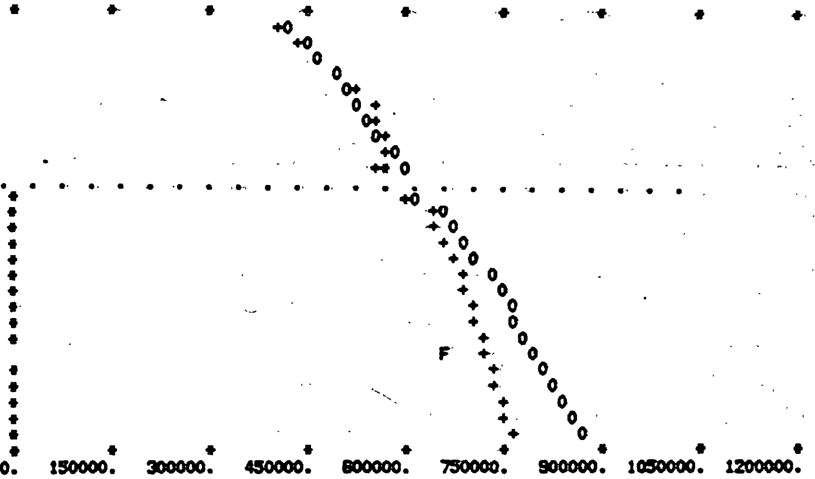


```
 6      CRUD PETRO+NA  SHIPPED BY   PIPE     (1000 TONS)
   ACTUAL    DIEWERT PRED    LOGIST PRED
  401041.        399673.        418515.    1965
  433898.        434882.        442638.    1966
  465123.        469589.        464790.    1967
  495296.        497906.        489643.    1968
  528431.        528989.        511149.    1969
  555216.        561474.        530130.    1970
  548228.        556247.        533974.    1971
  566957.        566284.        558406.    1972
  575847.        565392.        585821.    1973
  585762.        554708.        600760.    1974

       0.        585915.        608723.    1975
       0.        638528.        659488.    1976
       0.        640487.        668311.    1977
       0.        658388.        682679.    1978
       0.        671031.        711399.    1979
       0.        683255.        729779.    1980
       0.        692646.        744883.    1981
       0.        699737.        757526.    1982
       0.        706767.        770304.    1983
       0.        713819.        783045.    1984
  660881.        719995.        795035.    1985
       0.        728203.        810413.    1986
       0.        737437.        824797.    1987
       0.        745579.        839175.    1988
       0.        753614.        853539.    1989
       0.        761560.        867909.    1990
```



```
 6      CRUD PETRO+NA  SHIPPED BY   ALL MODES     (1000 TONS)
   ACTUAL    DIEWERT PRED    LOGIST PRED
  502933.        510946.        536923.    1965
  545454.        551378.        561019.    1966
  586045.        588030.        582790.    1967
  619787.        619177.        608044.    1968
  655453.        652853.        629206.    1969
  689982.        684265.        647368.    1970
  678784.        673198.        647284.    1971
  687005.        682776.        672327.    1972
  682996.        680118.        700920.    1973
  665411.        665483.        714614.    1974

       0.        714447.        720162.    1975
       0.        768430.        776270.    1976
       0.        773353.        782925.    1977
       0.        798114.        807858.    1978
       0.        812138.        826215.    1979
       0.        827588.        844217.    1980
       0.        839124.        858477.    1981
       0.        847748.        869969.    1982
       0.        856441.        881687.    1983
       0.        864967.        893429.    1984
  877703.        872593.        904376.    1985
       0.        883811.        918225.    1986
       0.        893807.        932984.    1987
       0.        903675.        946773.    1988
       0.        913404.        960578.    1989
       0.        923020.        974421.    1990
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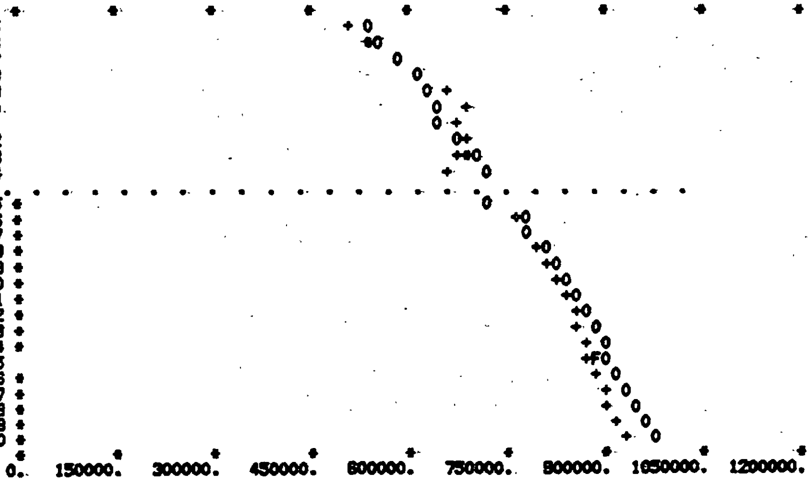
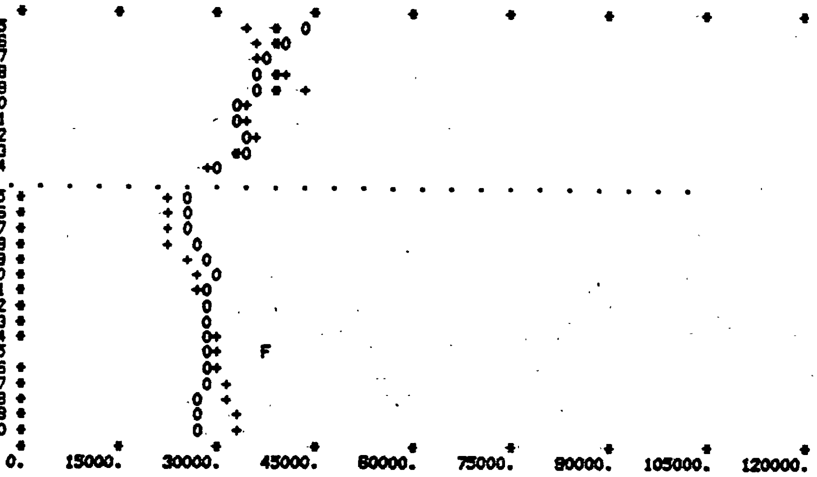


Graph 5.1 (Cont'd)

COMPARISON : ALTERNATIVE FORECASTS FAUCETT FORECAST(F) ACTUAL(*) DIEWERT BASE RUN(+) LOGISTIC SKIRT RUN(O)

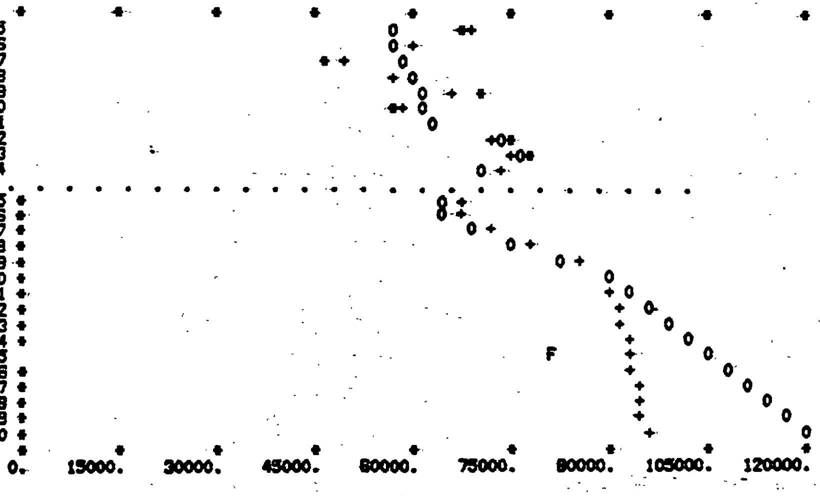
15 CEMENT SHIPPED BY RAIL (1000 TONS)

ACTUAL	DIEWERT PRED	LOGIST PRED	
39898.	35180.	43768.	1965
38414.	35353.	40619.	1966
37899.	35312.	38220.	1967
39450.	40996.	36643.	1968
38458.	43372.	35328.	1969
34026.	35041.	32976.	1970
33166.	35073.	32335.	1971
34748.	36741.	35092.	1972
33511.	35146.	34852.	1973
29787.	28966.	30654.	1974
0.	23136.	26170.	1975
0.	22414.	25408.	1976
0.	21827.	25402.	1977
0.	22798.	26698.	1978
0.	24773.	28263.	1979
0.	26602.	29329.	1980
0.	27266.	29078.	1981
0.	27880.	28888.	1982
0.	28613.	28705.	1983
0.	29516.	28521.	1984
38946.	30228.	28365.	1985
0.	30723.	28052.	1986
0.	31235.	27795.	1987
0.	31757.	27582.	1988
0.	32280.	27400.	1989
0.	32806.	27248.	1990



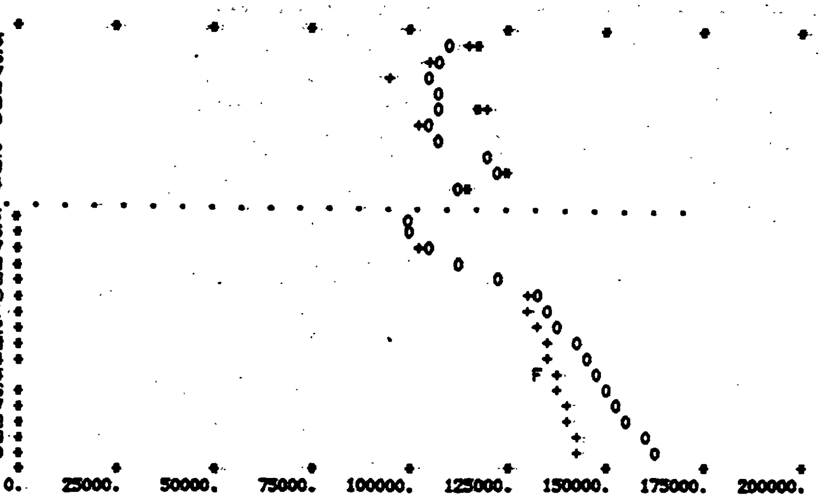
15 CEMENT SHIPPED BY TRUCK (1000 TONS)

ACTUAL	DIEWERT PRED	LOGIST PRED	
67017.	69319.	56690.	1965
56551.	59720.	57070.	1966
46762.	49831.	57934.	1967
58982.	56930.	59644.	1968
70058.	65294.	61498.	1969
57653.	58175.	61171.	1970
63587.	62691.	63713.	1971
74477.	72253.	73237.	1972
78394.	75136.	76841.	1973
73088.	73735.	71234.	1974
0.	67331.	63962.	1975
0.	68163.	65185.	1976
0.	71586.	68288.	1977
0.	78191.	75083.	1978
0.	84752.	83023.	1979
0.	89601.	89861.	1980
0.	90390.	92801.	1981
0.	91400.	95916.	1982
0.	92181.	99040.	1983
0.	92637.	102143.	1984
81697.	93386.	105334.	1985
0.	93580.	107807.	1986
0.	93920.	110651.	1987
0.	94366.	113532.	1988
0.	94885.	116520.	1989
0.	95468.	118607.	1990



15 CEMENT SHIPPED BY ALL MODES (1000 TONS)

ACTUAL	DIEWERT PRED	LOGIST PRED	
116586.	114350.	110329.	1965
105774.	104882.	107498.	1966
94490.	94972.	105983.	1967
106419.	107913.	106274.	1968
118681.	118830.	108890.	1969
101656.	103193.	104124.	1970
107009.	108020.	106304.	1971
120861.	120629.	119864.	1972
123852.	122329.	123740.	1973
113807.	113723.	112910.	1974
0.	100234.	99899.	1975
0.	100401.	100417.	1976
0.	103570.	103847.	1977
0.	112011.	112803.	1978
0.	121555.	123316.	1979
0.	129056.	132043.	1980
0.	130759.	134882.	1981
0.	132649.	138173.	1982
0.	134423.	141374.	1983
0.	136031.	144542.	1984
132776.	137747.	147832.	1985
0.	138601.	150257.	1986
0.	139635.	152926.	1987
0.	140798.	155789.	1988
0.	142044.	158799.	1989
0.	143364.	161945.	1990



thousands of tons shipped. For the Diewert predictions, the indexed transport price series developed for the estimation procedure was used out to 1976. The remainder of the forecasted period was calculated using transport prices generated by a standard run of the INFORUM price model.

The set of plots for 6: Crude Petroleum and Natural Gas show substitution toward more water transportation and less pipeline use than would be expected from pure trend extrapolations such as the logistic curve estimates. Water transport turns up rather than continuing to decline and pipeline slows its increase slightly due to changes in the relative prices for these modes. Both Faucett 1985 predictions agree with this scenario. For tons shipped by all modes it can be seen that the summation of the individual logistic curve extrapolations forecast higher tons shipped than does the Diewert equation. Since the summation of the Diewert predictions must equal, on average, the total tons logistic curve we see here that the summation of the individual mode logistic curves can miss a total-tons trend. The Diewert equations, of course, are bound by this constraint. The Faucett prediction is in close agreement with the Diewert value for total tons shipped in 1985.

The next set of plots --tonnage forecasts for 15: Cement -- show substitution first away from, and then, slowly, toward rail services. By 1984, rail services are above trend while truck services start to fall below trend in 1980 as the result of relatively higher truck rates than in earlier years. Again, the Faucett predictions agree, and here again, the summed logistic curve estimates over predict the trend for total tons by all modes. We see that while the logistic curve often produces the best fit, the logistic extrapolations produce results which are inconsistant since they are not constrained.

Ex-Post Forecasting

To test the forecasting ability of the Diewert technique versus the logistic technique, a period outside the estimation period is picked for simulation. Though data on tons shipped by mode exists only for the period 1965 to 1974, total tons shipped by each mode is available through 1978 from trade associations, the Interstate Commerce Commission, and other sources. This data is gathered and published by the Transportation Association of America (TAA)[22]. By summing across commodities for each mode, Diewert and logistic curve forecasted tons can be aggregated and compared to actual totals.

The plots in Graph 5.2 show the results of this exercise. Plotted are the TAA actual tonnage data (*), the Diewert estimated tonnage (+), and the logitic curve data (0) for the 1965 to 1978 period. The TAA data has been indexed to equal the JFA data in 1972. The plots presented are for tons shipped by rail, water, truck, pipeline, and all tons shipped by all modes. AAPE values have been calculated for both types of estimates around the TAA actuals for the period 1975 to 1978. These values appear at the top of each graph.

Graph 5.2

Total Tons Predictions

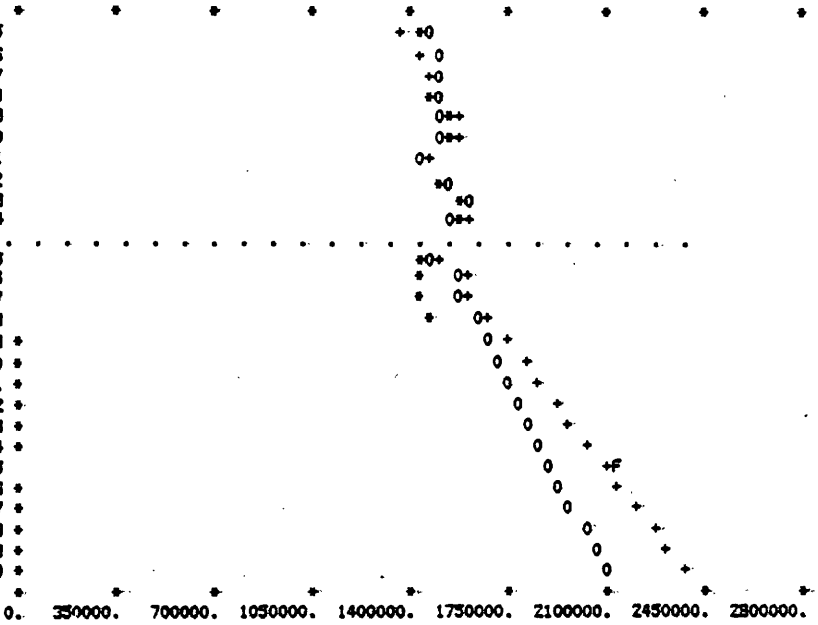
SUMMARY OF MODAL SHIPMENTS BY ALL INDUSTRIES

COMPARISON : ALTERNATIVE FORECASTS   FAUCETT FORECAST(F)   ACTUAL(*)   DIEWERT BASE RUN(+)   LOGISTIC SKIRT RUN(0)

TOTAL TONS SHIPPED BY   RAIL

FIT DIEWERT PRED 1975 - 1978 AAPE= 11.0
FIT LOGISTIC PRED 1975 - 1978 AAPE= 8.5

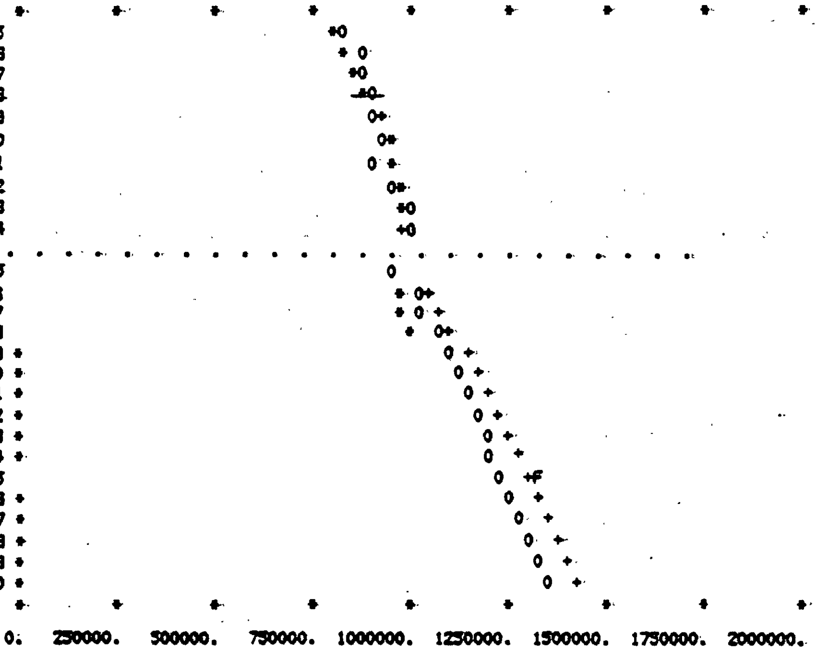
ACTUAL	DIEWERT PRED	LOGIST PRED	
1451398.	1354478.	1475168.	1965
1514204.	1452345.	1509580.	1966
1470044.	1465259.	1488519.	1967
1486727.	1517075.	1501548.	1968
1528924.	1560930.	1516565.	1969
1542663.	1559380.	1509127.	1970
1444529.	1487193.	1450094.	1971
1502428.	1555406.	1542555.	1972
1585842.	1621834.	1594277.	1973
1588786.	1608875.	1553046.	1974
1443548.	1506337.	1477323.	1975
1449436.	1603507.	1569916.	1976
1435697.	1625669.	1588948.	1977
1453381.	1684943.	1638785.	1978
0.	1743479.	1682595.	1979
0.	1804080.	1723602.	1980
0.	1856307.	1755754.	1981
0.	1912165.	1791836.	1982
0.	1970378.	1828775.	1983
0.	2031069.	1865930.	1984
2135801.	2090148.	1903008.	1985
0.	2147240.	1938669.	1986
0.	2205359.	1975380.	1987
0.	2264482.	2013052.	1988
0.	2324431.	2051448.	1989
0.	2385508.	2090822.	1990



TOTAL TONS SHIPPED BY   WATER

FIT DIEWERT PRED 1975 - 1978 AAPE= 6.8
FIT LOGISTIC PRED 1975 - 1978 AAPE= 4.8

ACTUAL	DIEWERT PRED	LOGIST PRED	
795172.	821742.	830484.	1965
834802.	878225.	863871.	1966
841174.	877803.	865101.	1967
~~870746.~~	~~899801.~~	~~889515.~~	~~1968~~
918836.	825282.	904636.	1969
948606.	935262.	929452.	1970
945225.	902324.	908525.	1971
980274.	948799.	960258.	1972
982465.	988594.	1008814.	1973
974798.	968440.	992122.	1974
947416.	948737.	954104.	1975
976888.	1038977.	1023980.	1976
970416.	1065052.	1036376.	1977
1002180.	1110315.	1070351.	1978
0.	1148455.	1100106.	1979
0.	1184120.	1128130.	1980
0.	1208484.	1148954.	1981
0.	1233398.	1169873.	1982
0.	1258119.	1191115.	1983
0.	1282225.	1212042.	1984
1320093.	1305289.	1232282.	1985
0.	1331048.	1254730.	1986
0.	1356781.	1277125.	1987
0.	1382887.	1298806.	1988
0.	1409339.	1322704.	1989
0.	1436220.	1345923.	1990



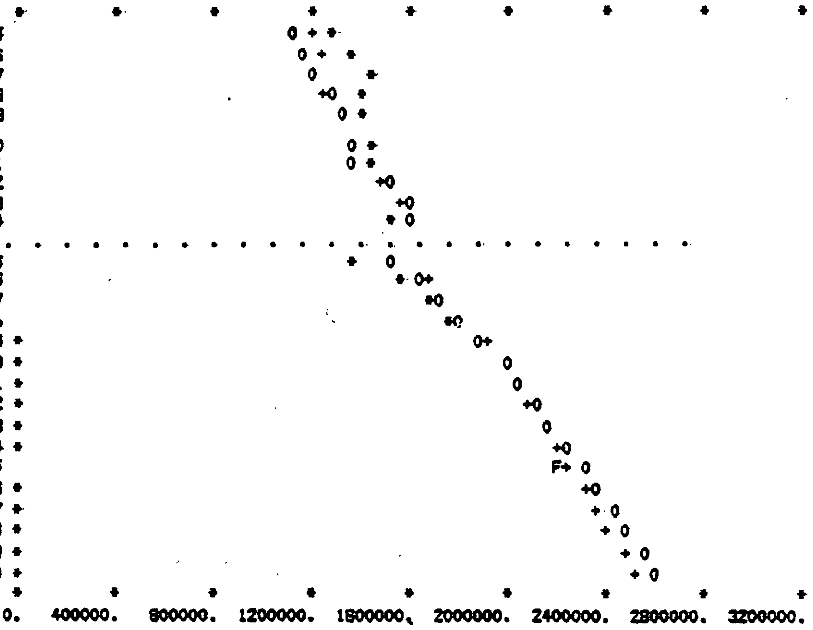
Graph 5.2 (Cont'd)

COMPARISON : ALTERNATIVE FORECASTS FAUCETT FORECAST(F) ACTUAL(*) DIEWERT BASE RUN(+) LOGISTIC SKIRT RUN(0)

TOTAL TONS SHIPPED BY TRUCK

FIT DIEWERT PRED 1975 - 1978 AAPE= 6.2
FIT LOGISTIC PRED 1975 - 1978 AAPE= 5.3

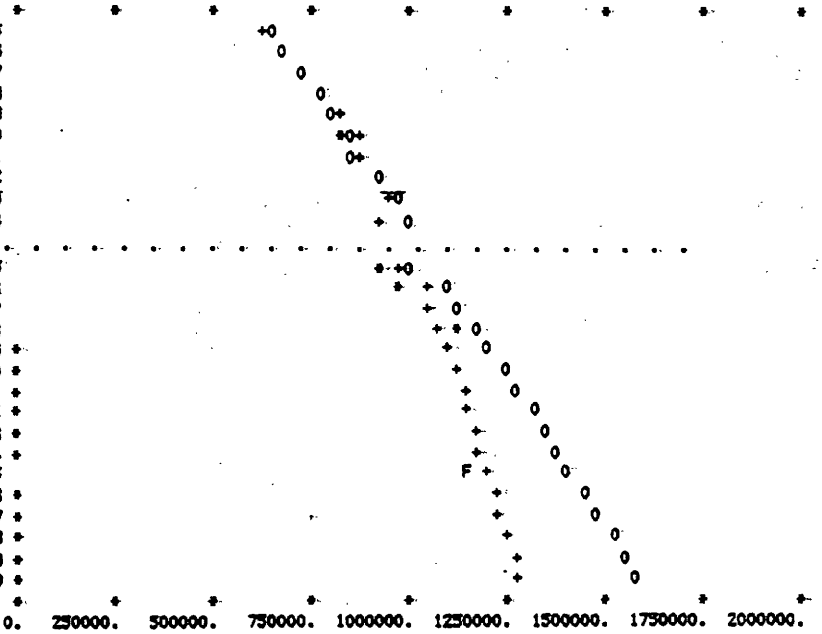
ACTUAL	DIEWERT PRED	LOGIST PRED	
1284482.	1202947.	1126103.	1965
1363105.	1225036.	1173935.	1966
1444162.	1181393.	1211181.	1967
1417549.	1251344.	1280537.	1968
1383891.	1325131.	1333403.	1969
1430855.	1347034.	1358134.	1970
1457468.	1367354.	1377005.	1971
1513826.	1488127.	1519877.	1972
1587404.	1577085.	1601256.	1973
1530284.	1580083.	1592505.	1974
1363105.	1522156.	1507951.	1975
1545136.	1662747.	1652315.	1976
1677419.	1727092.	1709943.	1977
1769000.	1819607.	1804434.	1976
0.	1903537.	1896038.	1979
0.	1982247.	1986230.	1980
0.	2034401.	2048518.	1981
0.	2089547.	2111327.	1982
0.	2144221.	2175384.	1983
0.	2195337.	2239226.	1984
2184010.	2250058.	2302788.	1985
0.	2302870.	2363514.	1986
0.	2356018.	2425131.	1987
0.	2410379.	2487728.	1988
0.	2465419.	2550942.	1989
0.	2521459.	2615101.	1990



TOTAL TONS SHIPPED BY PIPE

FIT DIEWERT PRED 1975 - 1978 AAPE= 3.8
FIT LOGISTIC PRED 1975 - 1978 AAPE= 7.8

ACTUAL	DIEWERT PRED	LOGIST PRED	
820283.	814188.	839870.	1965
684568.	868940.	879047.	1966
716257.	728105.	718205.	1967
765836.	772923.	766480.	1968
801701.	822843.	806840.	1969
833347.	877504.	844843.	1970
851280.	883992.	860697.	1971
924066	929957	914803.	1972
~~982041.~~	~~955218.~~	~~985071.~~	~~1973~~
933560.	932087.	992085.	1974
927231.	973215.	1002973.	1975
985248.	1044819.	1096915.	1976
1060144.	1048723.	1123227.	1977
1112888.	1078667.	1170183.	1978
0.	1088594.	1208764.	1979
0.	1120671.	1248966.	1980
0.	1138955.	1285330.	1981
0.	1153201.	1316476.	1982
0.	1167805.	1348383.	1983
0.	1183005.	1379921.	1984
1142734.	1196005.	1410103.	1985
0.	1214748.	1446392.	1986
0.	1232191.	1480855.	1987
0.	1248714.	1515254.	1988
0.	1267245.	1548546.	1989
0.	1284800.	1583765.	1990



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COMPARISON : ALTERNATIVE FORECASTS          FAUCETT FORECAST(F)     ACTUAL(*)   DIEWERT BASE RUN(+)   LOGISTIC SKIRT RUN(O)
 TOTAL TONS SHIPPED BY ALL MODES

                                            **FIT**  DIEWERT PRED  1975 - 1978   AAPE=   6.6
                                            **FIT** LOGISTIC PRED  1975 - 1978   AAPE=   6.5
    ACTUAL    DIEWERT PRED   LOGIST PRED
   4151316.        3993355.       4071623.   1965
   4378479.        4222546.       4226233.   1966
   4471636.        4252560.       4282986.   1967
   4540857.        4441143.       4433080.   1968
   4633454.        4633966.       4561444.   1969
   4756471.        4719180.       4639676.   1970
   4698502.        4640863.       4596321.   1971
   4920594.        4922289.       4937293.   1972
   5117751.        5142729.       5169418.   1973
   5027407.        5088495.       5129738.   1974.
   4683299.        4950445.       4942351.   1975
   4956808.        5351150.       5343126.   1976
   5143677.        5466536.       5458495.   1977
   5337429.        5691732.       5683733.   1978
         0.        5895065.       5888601.   1979
         0.        6091118.       6087928.   1980
         0.        6239147.       6238556.   1981
         0.        6388311.       6389512.   1982
         0.        6540523.       6543637.   1983
         0.        6691636.       6697119.   1984
   6782638.        6841498.       6842161.   1985
         0.        6995706.       7003305.   1986
         0.        7150329.       7158491.   1987
         0.        7307462.       7315840.   1988
         0.        7466434.       7474640.   1989
         0.        7627987.       7635611.   1990
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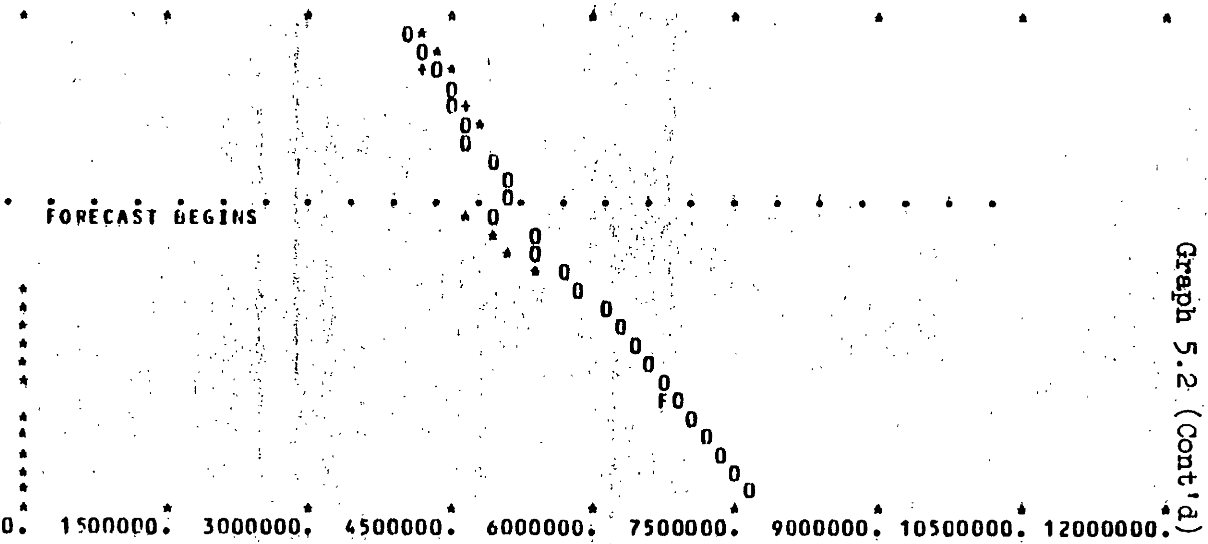

Graph 5.2 (Cont'd)

The results show that the AAPE's are higher, implying worse fits, for the Diewert equations than for the logistic equations for rail, water, and truck. The Diewert fit is only slightly worse for total tons shipped by all modes and the Diewert fit is better for pipelines.

While it appears that the logistic curves come out the winner, a look at the actual points for 1975 through 1978 shows that both logistic and Diewert predictions are close and both significantly over-estimate total tons shipped by rail, water, and truck for the 1975 to 1978 period. This point is best seen in the last plot. Here, total tons shipped by all modes show that tons dropped significantly during the recession of 1974 and never fully recovered. The logistic and Diewert predictions for total tons, which are essentially the same, are tied to the output of the economy which recovers after 1974. The TAA data surprisingly never does. It appears from this data that tons shipped per dollar of output drops off after 1974 and never fully recovers. It is interesting to note that the Faucett predictions agree with the Diewert and logistic expectations of a snap back after 1974.

It appears then, that the poor AAPE fits show less that the Diewert technique is a poorer predicter than the logistic method than that both techniques missed the unexplained drop off in transport demand after the 1974 recession -- a drop off which is unfortunately outside the range of the data on commodity shipments used for estimation.

Price Sensitivity Test

How sensitive are the industry modal split decisions to a change in transport prices? This section analyzes this question by applying the Diewert price sensitive equations to alternative transport price scenarios. A comparison is made of forecasted modal demands for tons shipped under differing price scenarios. Yearly forecasts to 1990 were made of tons shipped by each mode for each industry. The procedure for forecasting tons shipped was carried out using the following equation for each industry,

$$T_i = S_i \cdot \frac{T}{Q} \cdot Q$$

Tons of an industry's output ,T_i, shipped by mode i are forecasted by multiplying projected industry output ,Q, times the trended total tons marked quotient ,T/Q, and this is multiplied by the forecasted modal share ,S_i. The industry outputs are forecasted from 1976 to 1990 for 200 sectors of the U.S. economy using the INFORUM forecasting model and these numbers are aggregated up to the Faucett commodity level. The total tons market quotients are extrapolations of the quotient trends estimated in Step One using the logistic curve technique. Modal shares are forecasted by adding forecasted transport prices to the estimated Diewert price equations shown in Appendix D.

Price Scenarios

Two transport price forecasts were generated. The first was produced from a standard or "base" run of the INFORUM price model. This model forecasts prices for the 200 INFORUM sectors using a cost-pass-through technique where output prices change as the result of the changing costs of inputs into their production.[23]

An alternative price run was made where it was assumed that truck productivity would remain at its 1976 level rather than continue the upward trend evidenced in the base run. The flat productivity assumption, when added to the INFORUM model, generated new forecasted labor requirements to meet expected transport service demands. Adding these labor requirements to the price submodel caused significant unit labor cost increases leading to higher truck transport prices. The following table shows the two sets of forecasted truck transport prices.

Truck Service Price Forecasts (Indexed to 1976)

	1976	1980	1985
Base run price	1.00	1.30	1.68
Constant truck productivity price	1.00	1.35	1.80

Alternative Scenario Ton Forecasts

Feeding the two price forecasts into the Diewert price equations and adding the resulting modal share predictons to equation (5.5) above produced two forecasts of tons shipped. These results are listed in

Table 5.4 for the 38 industries for which Diewert price sensitive equations have been estimated. The first two groups of numbers show the change in tons shipped using the baseline price forecast, "BASE," and the alternative constant truck productivity price forecast, "ALT." The numbers show the predicted 1980 and 1985 tons shipped by each mode divided by the 1976 value. The last two columns show the percent difference between the baseline and alternative ratios for both years. The last set of numbers at the bottom of the table are calculated from a summation of modal shipments over all industries. A look at these last numbers summarizes the impact of higher truck transport prices. By 1985, tons shipped by truck have decreased 4.9 percent relative to BASE while rail, pipe, and water tons have increased by 2.8 percent, 1.2 percent, and 1.5 percent respectively due to an approximately seven percent increase in the prices for truck services. The complete effect of an increase in the price of truck services would also have to include a decrease in the demand for shipping services in general, as production of the rest of the economy adjusted to lowered truck productivity. To model this it would have been necessary to feed the higher price scenarios back into the INFORUM model in order to see the change in total transport services demanded by each of the 200 sectors as their production levels changed. This was not carried out, however, since it would have obscured the substitution between modes coming strictly from the Diewert price sensitive equations. By holding total tons shipped constant, Table 5.4 explicitly shows the price sensitivity of the Diewert price equations because only the pure substitution effect between modes, as the result of changing modal prices, is allowed to occur.

Table 5.4

TRANSPORTATION PRICE SENSITIVITY TEST

COMPARISON : ALTERNATIVE DIEWERT FORECASTS (TONS DIVIDED BY 1976 TONS)

		BASE		ALT		PCT DIFF	
		1980	1985	1980	1985	1980	1985
1	GRAINS						
	RAIL	1.15	1.40	1.15	1.40	.0	.0
	WATER	1.16	1.38	1.18	1.44	1.7	4.9
	TRUCK	1.15	1.41	1.14	1.38	-.7	-2.1
	PIPE	.00	.00	.00	.00	.0	.0
3	IRON ORE						
	RAIL	1.27	1.41	1.27	1.41	.0	.0
	WATER	1.30	1.46	1.30	1.46	.0	.0
	TRUCK	.00	.00	.00	.00	.0	.0
	PIPE	.00	.00	.00	.00	.0	.0
4	COPPER ORE						
	RAIL	1.18	1.17	1.18	1.17	.0	.0
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.18	1.17	1.18	1.17	.0	.0
	PIPE	.00	.00	.00	.00	.0	.0
5	COAL						
	RAIL	.93	1.07	.93	1.07	-.1	.0
	WATER	.96	1.05	.97	1.05	.2	-.0
	TRUCK	.00	.00	.00	.00	.0	.0
	PIPE	.00	.00	.00	.00	.0	.0
6	CRUD PETRO+NA						
	RAIL	.00	.00	.00	.00	.0	.0
	WATER	1.13	1.21	1.14	1.20	.5	-.2
	TRUCK	.00	.00	.00	.00	.0	.0
	PIPE	1.07	1.13	1.07	1.13	-.1	.0
7	STONE+CLAY MI						
	RAIL	1.18	1.38	1.20	1.49	2.2	7.3
	WATER	1.23	1.38	1.25	1.46	1.8	5.2
	TRUCK	1.28	1.47	1.23	1.27	-4.3	-13.2
	PIPE	.00	.00	.00	.00	.0	.0
8	CHEM+FERT MIN						
	RAIL	1.32	1.53	1.32	1.53	.0	.0
	WATER	1.32	1.53	1.32	1.53	.0	.0
	TRUCK	1.32	1.53	1.32	1.53	.0	.0
	PIPE	.00	.00	.00	.00	.0	.0
9	LOGS						
	RAIL	1.19	1.40	1.20	1.44	.7	2.5
	WATER	1.26	1.23	1.37	1.60	9.3	30.7
	TRUCK	1.20	1.42	1.18	1.34	-1.8	-5.1
	PIPE	.00	.00	.00	.00	.0	.0
10	LUMBER						
	RAIL	1.09	1.13	1.10	1.20	1.7	5.7
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.13	1.13	1.11	1.07	-1.9	-5.9
	PIPE	.00	.00	.00	.00	.0	.0

Table 5.4 (Cont'd)

TRANSPORTATION PRICE SENSITIVITY TEST

COMPARISON : ALTERNATIVE DIEWERT FORECASTS (TONS DIVIDED BY 1976 TONS)

			BASE		ALT		PCT DIFF	
			1980	1985	1980	1985	1880	1985
11	PULP,PAPER,PP							
		RAIL	1.21	1.42	1.21	1.42	.0	.0
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.21	1.42	1.21	1.42	.0	.0
		PIPE	.00	.00	.00	.00	.0	.0
12	INDUST CHEMIC							
		RAIL	1.20	1.35	1.20	1.35	.0	.1
		WATER	1.20	1.35	1.20	1.35	.0	.0
		TRUCK	1.20	1.35	1.20	1.35	-.0	-.1
		PIPE	.00	.00	.00	.00	.0	.0
13	MISC PETRO PR							
		RAIL	.00	.00	.00	.00	.0	.0
		WATER	1.20	1.38	1.20	1.38	.5	-.1
		TRUCK	1.20	1.42	1.19	1.35	-1.0	-4.6
		PIPE	1.09	1.20	1.09	1.25	.6	3.9
14	FUEL OIL							
		RAIL	.00	.00	.00	.00	.0	.0
		WATER	1.06	1.12	1.06	1.12	.0	.0
		TRUCK	1.07	1.14	1.07	1.13	-.3	-1.5
		PIPE	1.05	1.10	1.05	1.11	.2	.9
15	CEMENT							
		RAIL	1.19	1.35	1.26	1.60	5.9	18.9
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.31	1.37	1.28	1.27	-2.3	-7.4
		PIPE	.00	.00	.00	.00	.0	.0
16	STEEL							
		RAIL	1.14	1.26	1.18	1.41	3.5	11.7
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.18	1.22	1.15	1.11	-2.9	-9.5
		PIPE	.00	.00	.00	.00	.0	.0
17	MOTOR VEHICL							
		RAIL	1.24	1.37	1.25	1.38	.4	1.4
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.25	1.36	1.24	1.35	-.4	-1.2
		PIPE	.00	.00	.00	.00	.0	.0
20	OTH AGRIC PR							
		RAIL	1.00	1.11	1.04	1.25	4.0	13.3
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.04	1.08	1.02	1.04	-1.2	-3.9
		PIPE	.00	.00	.00	.00	.0	.0

Tabld 5.4 (Cont'd)

TRANSPORTATION PRICE SENSITIVITY TEST

COMPARISON : ALTERNATIVE DIEWERT FORECASTS (TONS DIVIDED BY 1976 TONS)

		BASE		ALT		PCT DIFF	
		1980	1985	1980	1985	1980	1985
21	OTH NON-FERR						
	RAIL	1.23	1.46	1.22	1.46	-.2	.0
	WATER	1.45	1.33	1.47	1.33	1.0	-.0
	TRUCK	1.26	1.44	1.26	1.44	.0	.0
	PIPE	.00	.00	.00	.00	.0	.0
22	FOOD,TOBAC P						
	RAIL	1.13	1.32	1.15	1.39	1.6	5.2
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.15	1.30	1.14	1.25	-1.3	-4.0
	PIPE	.00	.00	.00	.00	.0	.0
23	TEXT+LEATH PR						
	RAIL	1.23	1.35	1.23	1.35	.0	.0
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.23	1.35	1.23	1.35	.0	.0
	PIPE	.00	.00	.00	.00	.0	.0
25	PAP PROD(-)CO						
	RAIL	1.18	1.40	1.21	1.51	2.5	8.2
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.19	1.34	1.16	1.23	-2.6	-8.5
	PIPE	.00	.00	.00	.00	.0	.0
26	PRINT MATT+PP						
	RAIL	1.21	1.56	1.31	1.99	8.8	27.4
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.23	1.44	1.22	1.39	-.9	-2.9
	PIPE	.00	.00	.00	.00	.0	.0
27	OTH CHEMICAL						
	RAIL	1.08	1.14	1.08	1.16	.5	1.7
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	.88	.95	.96	.91	-1.3	-4.5
	PIPE	.00	.00	.00	.00	.0	.0
28	PLASTICS						
	RAIL	1.47	1.89	1.48	1.96	1.0	3.3
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.45	1.92	1.43	1.76	-1.0	-3.1
	PIPE	.00	.00	.00	.00	.0	.0
29	DRUGS+PAINTS						
	RAIL	1.11	1.28	1.17	1.52	6.0	19.2
	WATER	.00	.00	.00	.00	.0	.0
	TRUCK	1.14	1.23	1.13	1.18	-1.1	-3.4
	PIPE	.00	.00	.00	.00	.0	.0

Table 5.4 (Cont'd)

TRANSPORTATION PRICE SENSITIVITY TEST

COMPARISON : ALTERNATIVE DIEWERT FORECASTS (TONS DIVIDED BY 1876 TONS)

			BASE		ALT		PCT DIFF	
			1980	1985	1980	1885	1880	1985
31	RUBBER PROD							
		RAIL	1.28	1.52	1.31	1.63	2.3	7.7
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.32	1.50	1.31	1.47	-.8	-2.4
		PIPE	.00	.00	.00	.00	.0	.0
32	OTH WOOD PROD							
		RAIL	1.38	1.70	1.40	1.83	2.1	7.1
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.44	1.70	1.41	1.57	-2.3	-7.4
		PIPE	.00	.00	.00	.00	.0	.0
33	FURNIT+MISC M							
		RAIL	1.20	1.28	1.20	1.30	.6	1.9
		WATER	1.21	1.25	1.24	1.33	2.3	6.6
		TRUCK	1.20	1.28	1.20	1.26	-.4	-1.2
		PIPE	.00	.00	.00	.00	.0	.0
34	GLASS PROD							
		RAIL	1.21	1.63	1.31	2.02	8.1	23.8
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.18	1.32	1.16	1.25	-1.7	-5.4
		PIPE	.00	.00	.00	.00	.0	.0
35	STONE+CLAY PR	RAIL	1.23	1.43	1.24	1.47	.8	2.6
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.22	1.33	1.20	1.27	-1.4	-4.5
		PIPE	.00	.00	.00	.00	.0	.0
36	PRIM NON-FERR							
		RAIL	1.33	1.61	1.34	1.67	1.2	3.9
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.34	1.59	1.33	1.54	-.9	-3.0
		PIPE	.00	.00	.00	.00	.0	.0
37	FAB STRU MET							
		RAIL	1.21	1.28	1.21	1.30	.5	1.7
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.21	1.27	1.21	1.26	-.4	-1.3
		PIPE	.00	.00	.00	.00	.0	.0
38	ORD+MISC FAB							
		RAIL	1.10	1.34	1.18	1.67	7.9	24.9
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.19	1.31	1.17	1.24	-1.7	-5.6
		PIPE	.00	.00	.00	.00	.0	.0
40	OTH MACH EXC							
		RAIL	1.04	1.08	1.06	1.14	1.8	6.2
		WATER	.00	.00	.00	.00	.0	.0
		TRUCK	1.08	1.07	1.05	1.05	-.7	-2.1
		PIPE	.00	.00	.00	.00	.0	.0

Table 5.4 (Cont'd)

TRANSPORTATION PRICE SENSITIVITY TEST

COMPARISON : ALTERNATIVE DIEWERT FORECASTS (TONS DIVIDED BY 1976 TONS)

SUMMARY OF MODAL SHIPMENTS BY ALL INDUSTRIES

	BASE		ALT		PCT DIFF	
	1980	1985	1980	1985	1980	1985
TOTAL TONS SHIPPED BY						
RAIL	1.12	1.29	1.12	1.32	.8	2.8
WATER	1.13	1.25	1.14	1.27	.7	1.5
TRUCK	1.19	1.35	1.18	1.28	-1.5	-4.9
PIPE	1.07	1.14	1.07	1.16	.1	1.2

Step Three: Consideration of Distance Hauled

Tons shipped by mode per dollar of output can be calculated by multiplying the total-tons market quotients times modal shares estimated in steps one and two above respectively. However, in order to calculate and forecast an I/O coefficient of transport services demanded per unit of output, consideration must be taken of the changing distance of hauls for each mode since this will also effect the measure of shipping services provided. The only data that identifies the distance of haul by mode and commodity is found in the Census of Transportation.[24] Using this data for 1972, the most recent year of the census available when this work was done, and assuming the total shipment distance by all modes for each commodity remains constant over time, an adjustment can be made to the distance of haul by mode shipped as the result of modal substitution. The 1972 data shows the average length of haul by mode and commodity shipped and reflects the fact that different modes specialize in different lengths of haul. To the extent that one mode captures the freight hauls of another mode, the gaining mode's average freight hauls should increase or decrease depending on whether the captured hauls are coming from a mode which averages longer or shorter hauls. Using a technique developed by Jack Faucett Associates (JFA), each mode's average distance of haul is adjusted to reflect the gain or loss of its longer or shorter hauls as is modal share changes depending on the average length of haul of the substitute modes.[25]

Application to the A Matrix

Looking at equation (5.1) we can see that including the average distance of haul for each mode, M_i, in the equation produces a measure of transport services demanded per dollar of output for rail, water, pipeline, and truck. These transportation I/O coefficients were calculated for the 38 sectors where the Diewert equations were used. For consistency, the transport I/O coefficients for the remaining sectors (which represented less than ten percent of the total tonnage shipments) were calculated using the logistic curve estimations calculated and presented in step two above.

While there exists matching INFORUM A matrix transportation rows for rail, water, and pipelines so that the changes in these transport I/O coefficients can be added directly to INFORUM, the A matrix handles truck inputs differently, breaking truck shipments into commercial and private. Commercial truck has is own row while private truck demand is represented by purchases of the components of private truck services which are inputs into each industry. The major intermediate component inputs representing private truck are INFORUM sectors: 67: Miscellaneous Chemical Products, 76: Petroleum Refining, 77: Fuel Oil, 80: Tires and Inner Tubes, 145: Motor Vehicles, 183: Insurance and, 190: Auto Repair.

For trucking services then, the calculated trucking service I/O coefficients were divided into private and commercial using modal share splits estimated with logistic curves above in Step two, for the two modal categories. The commercial truck row was adjusted by the change in the commercial truck portion of the truck I/O coefficient calculations derived by equation (5.3). For private truck, first a weight had to be calculated which determined the portion of the component input that directly went for the purchase of private truck services rather than some other use such as private car or vehicular machinery services. The component inputs were then moved by the change in the private truck I/O coefficient calculated from equation (5.3) multiplied by the calculated private truck weights. A detailed description of this procedure is presented in Appendix E.

CHAPTER VI

Summing Up

Forecasting the economy using I/O techniques requires accurate predictions of the matrix of I/O coefficients. This dissertation has attempted to improve estimates of these predictions. Previous to this work I/O matrices were projected using various forms of extrapolating techniques such as logistic curve fitting. These techniques were employed to pick up, in total, the trend movements of the determinants of coefficient change such as technological change, product mix and changing input prices. Little attention was paid to applying economic theory because of a lack of comprehensive data through time which would have allowed an investigation of the relevant economic relationships. As well, comprehensive projections of industry variables such as industry prices, essential to the forecasting of coefficient change, were unavailable. The object of this dissertation has been to take advantage of new techniques, new data on industry prices, and new data on I/O coefficients in particular sectors, to determine the effects of input price change on portions of the I/O matrix. Specifically, the areas that were modeled were the energy sectors; oil, coal, natural gas, electricity, and the transportation sectors; rail, water, truck, and pipeline.

Approach

The Diewert function was used to estimate price effects on I/O coefficients because it incorporates the theories of production functions and the cost minimizing nature of the firm to relate substitutable I/O coefficients in one functional relationship. The requirement of symmetry between price effects on alternative inputs reduced the number of parameters to be estimated, often important when working with a limited number of observations. Also, unlike other production function specifications such as the CES or the translog, the dependent variable of the Diewert function is the I/O coefficient itself, the variable to be modeled.

In previous studies, intermediate inputs were aggregated in order to reduce the number of substitutes to a manageable level for estimation, but this aggregation created problems of separating the effects of product mix from other effects. In this study, the assumption of separability was applied to appropriate groups of inputs so that a manageable number of variables would be included in the Diewert function and still allow for a moderately high level of disaggregation of industry data. In this way, coefficient change due to changes in product mix was minimized. In the case of energy use, it was assumed that fuels used for heat and power substituted with capital and labor but these decisions were separate from the demands for intermediate inputs used in production. For transportation, since all tons of output produced must eventually be shipped, it was assumed that the total demand for transportation services is a constant function of industry output, and decisions about the optimal mode for shipping this tonnage are separate from decisions about the mix of other intermediate inputs used in production. Consequently, only alternative modal inputs need be considered in the transportation cost minimizing decision.

Methodology

The Diewert function was applied to the two groups of I/O coefficients--energy and transportation. Each group presented a different challenge because of the type of data available; consequently, two different approaches had to be taken.

Energy

In the case of energy use by manufacturing for heat and power, extensive cross-section data for states was available. This data set had a number of advantages for estimating price effects. First, a relatively large number of observations were available for estimation. Second, holding time constant effectively removed technological change as an explanation for variation in the data, leaving only the effects of prices and product mix. The use of a two-digit level of disaggregation reduced product mix influences.

Also, some problems with the data were encountered such as small or misleading data points. In states with small observations, i.e. few industries of one type, some fuel use was unreported due to non-disclosure laws. Also, total state natural gas use made up mostly of intra-state natural gas may present a distorted picture of price effects. This is because, in these states, uncontrolled natural gas prices on the intra-state gas would not reflect the same transport and other cost differentials considered by inter-state users who face controlled prices. To handle these problems, observations not reported due to disclosure laws were dropped; where zero use was reported the observation was used. Two states were dropped from the analysis because of their large natural gas production and intra-state use.

The Diewert function was set up to include the relative prices of coal, oil, natural gas, and electricity as well as labor and capital. Five inputs were estimated simultaneously in order to take advangage of the property of symmetry of coefficients. The sixth input, capital, was lett out as a dependent variable because we had no data on it; its price was assumed to be constant across states. The Diewert coefficients estimated from the cross-section data represented adjustments to price differentials across states and therefore indicated only long-run responses to energy price changes. The next step was to estimate short run, yearly responses to price changes. To do this, first, a series was compiled of actual data on fuel use by industry for eight points in time spanning twenty-three years. For the same period, long run or "desired" energy inputs were calculated using the estimated cross-section Diewert equations. Then, an adjustment variable was estimated to determine the yearly adjustment in actual use to the desired level. This was done across fuels for each industry. In order to reconcile the cross-section long run adjustment with actual movements, two time trends had to be added to the equation to account for coefficient change due to, first, energy conservation, and then pollution control.

Transportation

The study of modal substitution for freight transportation posed different problems. No data on modal demands by industry that is consistent across modes is available. However, a yearly time-series was compiled by Jack Faucett Associates on tons shipped by commodity and mode for the 1965 to 1974 period. Close attention was given to this data for consistency across modes. This consistency would allow accurate measurement of modal substitution.

To take advantage of this data, the following methodology was devised. First, it was assumed that the transport input coefficients of an industry could be broken into three factors. The first factor was the demand for total tons of product shipments per unit of product output. This demand was assumed to be unrelated to the cost of transportation. The second factor was the share of total tons shipped by each mode, assumed to be a function of relative modal prices. The third factor was a measure of the length of haul by each mode. This was needed to take into account the distance aspect of the transport input. The multiplication of these three factors produced a measure of modal transport inputs demanded by industry and was used to add price sensitive transport I/O coefficients to the INFORUM A matrix.

The estimation of the first factor, a total tons to output ratio for each industry, was done by using logistic curves to project trends into the future. Here the denominator, industry output, was augmented with imports in order to be consistent with the industry shipments data. The second factor, modal shares, was estimated using the Diewert equation. Tonnage shares shipped by rail, water, truck, and pipeline were estimated simultaneously for each industry using as the independent variables, relative modal prices. While the Faucett data provided tonnage information for both commercial an private trucking, no price existed for the latter. Consequently, it was assumed that the two prices moved coincidentally and the tonnage data was combined to form a single trucking category.

Input prices proved to be a more difficult problem for this study since transport prices can differ not only by mode but also by commodity shipped. In particular, it is possible that a drop in an aggregate modal price may simply be the result of increased transportation of a commodity with a lower transport price. Unfortunately, no consistent set of time-series data exists for modal transport prices differentiated by commodity shipped. Consequently, a technique was developed to weight total modal prices by the changing importance of industry shipments in total revenues collected by each mode. In this way any change in an aggregate modal price due to the changing importance of a particular commodity shipped would be taken out of the price series. Also, transport rate data which does exist for rail only, was incorporated to adjust the total rail rate depending on the commodity group being shipped.

An investigation was made of other factors unrelated to price that might affect modal shares but this study turned up few operational measures. Two that were added to the Diewert equation were measures of commodity weight and commodity value. Each improved the estimation of a few sectors but on the whole they added little to the study.

The third factor to be considered in the transport service equation, distance traveled, was calculated by taking advantage of 1972 data on average distance of hauls by mode and commodity. Assuming a constant total distance of haul for each commodity, the average distance of haul by each mode was adjusted up or down depending on whether its modal share was gaining or losing hauls to modes with longer or shorter hauls on average.

Combining the three factors of the transport service equation produced price sensitive I/O coefficients for the rail, water, and pipeline rows of the INFORUM A matrix. Because the truck row of the matrix represents only commercial truck while private truck enters through its composite pieces, commercial truck and private truck shares of the total Diewert truck estimate were split using the logistic curve technique. The commercial price entered as coefficients in the truck row and private truck demands entered through changes in coefficients for such items as tires, fuel, and automotive parts, etc.

Results

The results showed that the application of the Diewert function to energy consumption by two-digit industries produced on the whole, satisfactory results for the estimation of long run price effects. Estimates were constrained to rule out small or misleading data points that would produce coefficients that violated economic assumptions. Here, all inputs were assumed to be substitutes except for the relationship between capital and electricity which was allowed to be complementary.

In total, the estimations produced the aggregate own long-run elasticities shown in column one of Table 6.1.

Table 6.1

Energy Price Elasticities (All Manufacturing Sectors)

	This Study	Halverson
Oil	-3.0	-2.8
Coal	-.9	-1.5
Natural Gas	-1.3	-1.5
Electricity	-1.1	-.9

These estimates are similar to ones made by Halverson[1]. His approach differs in that total cross-section data for the same industries was used for the earlier period, 1971; the translog function was applied; and no allowance was made in his estimates for substitution with capital and labor. The total elasticities presented in the second column above were generated by Halverson by combining his estimates with capital, labor and energy substitution elasticities for total manufacturing produced by Berndt and Wood[2].

To observe the short run price sensitivity of the Diewert equation with the estimated lag adjustments, the time-series equations were added to the INFORUM model and a full model simulation was carried out. In this simulation, domestic crude oil prices were deregulated and made to rise to the foreign price by 1985. In the baseline scenario, crude oil prices rose at the rate of the wholesale price index. The higher price scenario generated approximately a six percent increase in fuel oil prices and approximately a one percent increase in coal and electricity prices above the baseline scenario by 1985. The natural gas price was made to follow the crude oil price increase. The results of this exercise on energy use for manufacturing by 1985 were to lower national demand for oil by approximately .2 percent, natural gas by .07 percent, and coal demand by .05 percent relative to the baseline scenario. Here, the increased demand for fossil fuels to meet increased electricity requirements was taken into account.

When applied to the transportation sectors, the Diewert equation produced mixed results. Many of the Diewert estimates behaved as expected but others performed quite poorly, indicating heterogeneity in modal demand depending on the product being shipped. Of the original forty-five sectors, seven had only one major mode of transportation and, therefore, were inappropriate for the estimation of substitution effects. Of the remainder, twenty-nine sectors produced coefficients with either the correct signs or signs that were wrong but statistically insignificant. Each of the remaining nine sectors contained at least one coefficient with a statistically significant wrong sign. Of these, three produced coefficients, all with the wrong sign, and t statistics in the significant range. The three were Copper Ore, Chemicals and Fertilizer Mining, and Other Scrap. Here apparently other factors not included in the equation were creating shifts in modal shares and were colinear with price changes. Because this data set was a time-series, other factors associated with the evolution of transport services could not be separated out of the data. Attempts to include other variables for these effects were successful in a few cases but produced no improvement for the above three sectors.

To evaluate the accuracy of the Diewert transportation predictions, the average absolute percentage error (AAPE) of the predictions around the actual tonnage data was calculated for each mode and commodity. These were compared to AAPE's calculated from logistic curve estimates on the same data. In general the Diewert equations performed worse than the logistic curve estimates. Upon reflection, this is not a surprising result since the application of the Diewert equation is an attempt to impose theoretical constraints on the raw data. Theory indicates a linkage of coefficient change between alternative inputs resulting from relative price changes between those inputs. This linkage is embodied in the symmetry of coefficients in the Diewert function and implicitly imposed in the simultaneous estimating procedure used here for alternative inputs. On the other hand, the fitting of logistic curves to a time-series of individual input to output ratios using unconstrained ordinary least squares procedures will generally produce a good fit if coefficient change approximates a trend. As a consequence of this technique, however, the summation across modes of the logistically estimated coefficients is not constrained to follow a consistent pattern of total transportation demand as is the case with the Diewert estimates. Here we see that while the logistic curve produces the best fit on the raw data the summation of the results does not make very good sense. Another explanation for the success of the logistic curve could be due to the inaccuracy of the portions of the data that had to be estimated by Jack Faucett Associates to maintain consistency and completeness. Inadvertent trends may have been introduced into the data in this way. The "softness" in general of data on tons shipped by mode is exemplified by the estimates of the Transportation Association of America on total tons shipped. This data was plotted in Graph 5.2 of Chapter 5. Here, it can be seen that, after 1974, the summation of the data showed a significant decrease in total tons shipped of all commodities by all modes per constant dollar of total national output and imports. While it is conceivable that there were large changes in product weight, such a large shift seems questionable. In this study, the imposition of the Diewert functional relationship, while not necessarily producing the best fit, has forced the data to conform to relationships derived from economic theory and basic logic. This I beleive would produce a theoretically more sound basis for forecasting.

To look at the price sensistivity of modal demands for transportation a simulation was done using the estimated Diewert equations. Here, starting in 1977, the price for trucking services was increased to be approximately 7 percent greater than the baseline case by 1985. The other modal prices were kept the same as in the baseline. The result of this was to decrease tons shipped by truck to 4.9 percent below the baseline case by 1985. Tons shipped by rail increased by 2.8 percent, water by 1.5 percent, and pipeline by 1.2 percent. These results show only changes that would result from the substitution of modes and does not include any decrease in total transportation that might occur from reduced industry output coming from the higher truck price. These effects would most likely be quite small.

Conclusions

The estimation of price effects on I/O coefficients has always been a difficult task because of significant data problems. However, the use of the Diewert function for estimation has reduced some of the difficulties and made the task a feasable one on a limited basis.

The data limitations generally are the availability of a detailed I/O matrix only every four or five years. Consequently, not enough data has been available on a large scale to comprehensively analyse the effects of price changes on coefficients. Other detailed data can be found, however, on a limited basis for particular rows of the matrix. Where this data covers rows of close substitutes the Diewert function can be applied to estimate price sensitivity. The Diewert function has the advantage, over other previously used methods, of being derived from standard economic theory on the cost minimizing behavior of the firm. The symmetry of coefficients implicit in this function, ties together movements of alternative inputs and reduces the number of coefficients necessary for estimation. While the estimated fits to the data may not be the best possible, given the paucity of data this approach for estimating price sensitivity is the most sound because it balances econometric techniques with prior knowledge derived from economic theory.

The long-run price elasticities for the areas of energy and transportation demand appear to be fairly large as has been demonstrated by this and other studies. Consequently, it is desirable and, indeed, necessary to replace the implicit assumption of price insensitivity in I/O matrices with the Diewert estimated price sensitive coefficients. The Diewert function has proven to be a valuable tool to further that end, and I am sure it will be useful in the future for estimating the price sensitivity of other rows of coefficients.

This dissertation has demonstrated the feasibility of estimating the price sensitivity of rows of coefficients in an input-output matrix in order to project this matrix more accurately into the future in a world of rapidly changing prices. With the help of the Diewert cost function, industry data, and industry price forecasts, such modeling is now possible.

Appendix A

DEFINITIONS FOR THE 200 SECTORS IN THE INFORUM MODEL

THE 90-ORDER AGGREGATE SECTOR NUMBER, FOR INVESTMENT AND EMPLOYMENT, FOLLOWS THE SECTOR TITLE. THE 4-DIGIT SIC CODES ARE THOSE USED FOR THE 1967 CENSUS OF MANUFACTURES. A CODE ENDING WITH A '0' DESIGNATES AN ENTIRE 3-DIGIT GROUP; A CODE ENDING WITH '00' DESIGNATES AN ENTIRE 2-DIGIT GROUP. A MINUS SIGN INDICATES THAT THIS SIC IS EXCLUDED FROM THE SECTOR.

	SECTOR TITLES	90-ORDER	STANDARD INDUSTRIAL CLASSIFICATION				
1	DAIRY FARM PRODUCTS	(1)	132				
2	POULTRY AND EGGS	(1)	133				
3	MEAT ANIMALS, OTH LIVESTK	(1)	135	136	139	193	
4	COTTON	(1)	112				
5	GRAINS	(1)	113				
6	TOBACCO	(1)	114				
7	FRUIT,VEGETABLES,OTH CROPS	(1)	119	120	192		
8	FORESTRY & FISHERY PRODUCTS	(1)	740 910	810	820	840	860
9	EMPTY						
10	AGR,FORESTRY+FISH SERVICES	(1)	710	720	730	850	980
11	IRON ORES	(2)	1010	1060			
12	COPPER ORE	(2)	1020				
13	OTHER NON-FERROUS ORES	(2)	1030	1050	1090		
14	COAL MINING	(2)	1110	1210			
15	CRUDE PETROLEUM, NAT. GAS	(3)	1310	1320			
16	EMPTY						
17	STONE AND CLAY MINING	(2)	1410	1420	1440	1450	1490
18	CHEMICAL FERTILIZER MINING	(2)	1470				
19	NEW CONSTRUCTION	(4)	1600				
20	MAINTENANCE CONSTRUCTION	(0)	1500				
21	COMPLETE GUIDED MISSILES	(5)	1925				
22	AMMUNITION	(5)	1929	1960			
23	OTHER ORDNANCE	(5)	1910	1930	1940	1950	1990
24	MEAT PRODUCTS	(6)	2010				
25	DAIRY PRODUCTS	(7)	2020				
26	CANNED AND FROZEN FOODS	(8)	2030				
27	GRAIN MILL PRODUCTS	(9)	2040				
28	BAKERY PRODUCTS	(10)	2050				
29	SUGAR	(11)	2060				
30	CONFECTIONERY PRODUCTS	(12)	2070				
31	ALCOHOLIC BEVERAGES	(13)	2082	2083	2084	2085	
32	SOFT DRINKS AND FLAVORINGS	(13)	2086	2087			
33	FATS AND OILS	(14)	2091	2092	2093	2094	2096
34	MISC FOOD PRODUCTS	(14)	2095	2097	2098	2099	
35	TOBACCO PRODUCTS	(15)	2110	2120	2130	2140	

36	BROAD AND NARROW FABRICS	(16)	2210	2220	2230	2240	2261
			2262				
37	YARN, THREAD, FINISHING	(16)	2269	2280			
38	FLOOR COVERINGS	(17)	2270				
39	MISC TEXTILES	(18)	2290				
40	KNITTING	(19)	2250				
41	APPAREL	(20)	2310	2320	2330	2340	2350
			2380	3992	2360	2370	
42	HOUSEHOLD TEXTILES	(21)	2390				
43	LOGGING CAMPS	(22)	2410				
44	SAW AND PLANING MILLS	(22)	2420				
45	VENEER AND PLYWOOD	(23)	2432				
46	MILLWORK AND WOOD PRODUCTS	(23)	2431	2433	2490		
47	WOODEN CONTAINERS	(24)	2440				
48	HOUSEHOLD FURNITURE	(25)	2510				
49	OTHER FURNITURE	(25)	2520	2530	2540	2590	
50	PULP MILLS	(27)	2610				
51	PAPER AND PAPERBOARD MILLS	(27)	2620	2630			
52	PAPER PRODUCTS, NEC	(27)	2641	2642	2643	2645	2646
			2649	2647			
53	WALL & BUILDING PAPER	(27)	2644	2660			
54	PAPERBOARD CONTAINERS	(28)	2650				
55	NEWSPAPERS	(29)	2710				
56	PERIODICALS	(30)	2720				
57	BOOKS	(30)	2730				
58	BUSINESS FORMS, BLANK BOOKS	(30)	2760	2782			
59	COMMERCIAL PRINTING	(30)	2751	2752			
60	OTHER PRINTING, PUBLISHING	(30)	2740	2753	2770	2789	2790
61	EMPTY						
62	EMPTY						
63	EMPTY						
64	INDUSTRIAL CHEMICALS	(31)	2810				
65	FERTILIZERS	(32)	2871	2872			
66	PESTICIDES + AGRIC. CHEM.	(32)	2879				
67	MISC CHEMICAL PRODUCTS	(33)	2860	2890			
68	PLASTIC MAT'LS. + RESINS	(34)	2821				
69	SYNTHETIC RUBBER	(34)	2822				
70	CELLULOSIC FIBERS	(34)	2823				
71	NON-CELLULOSIC FIBERS	(34)	2824				
72	DRUGS	(35)	2830				
73	CLEANING + TOILET PROD.	(36)	2840				
74	PAINTS	(37)	2850				
75	EMPTY						
76	PETROLEUM REFINING	(38)	2911	2990			
77	FUEL OIL [1]	(38)	2911				
78	PAVING AND ASPHALT	(38)	2950				
79	EMPTY						
80	TIRES AND INNER TUBES	(39)	3010				
81	RUBBER PRODUCTS	(40)	3020	3030	3060		
82	MISC PLASTIC PRODUCTS	(41)	3070				
83	LEATHER + IND LTHR PROD	(42)	3110	3120			
84	FOOTWEAR (EXC. RUBBER)	(43)	3130	3140			
85	OTHER LEATHER PRODUCTS	(43)	3150	3160	3170	3190	

86	GLASS	(44)	3210	3220	3230		
87	STRUCTURAL CLAY PRODUCTS	(45)	3250				
88	POTTERY	(45)	3260				
89	CEMENT, CONCRETE, GYPSUM	(45)	3240	3270			
90	OTHER STONE + CLAY PROD.	(45)	3280	3290			
91	STEEL	(46)	3310	3320	3391	3399	
92	COPPER	(47)	3331	3340	3351	3362	
93	LEAD	(47)	3332				
94	ZINC	(47)	3333				
95	ALUMINUM	(47)	3334	3352	3361		
96	OTH PRIM NON-FER METALS	(47)	3339				
97	OTH NON-FER ROLL + DRAW	(47)	3356				
98	NON-FERROUS WIRE DRAWING	(47)	3357				
99	NON-FER CASTING + FORGING	(47)	3369	3392			
100	METAL CANS	(48)	3410				
101	METAL BARRELS AND DRUMS	(48)	3491				
102	PLUMBING + HEATING EQUIP.	(49)	3430				
103	BOILER SHOPS	(50)	3443				
104	OTH STRUCTURAL METAL PRD.	(50)	3441	3442	3444	3446	3449
105	SCREW MACHINE PRODUCTS	(51)	3450				
106	METAL STAMPINGS	(51)	3460				
107	CUTLERY,HAND TOOLS,HARDWR	(52)	3420				
108	MISC FABRICATED WIRE PRODS.	(52)	3480				
109	PIPES,VALVES,FITTINGS	(52)	3494	3498			
110	OTH FABRICATED METAL PRD.	(52)	3470	3492	3493	3496	3497
			3499				
111	ENGINES AND TURBINES	(53)	3510				
112	FARM MACHINERY	(54)	3520				
113	CONSTR,MINE,OILFIELD MACH.	(55)	3531	3532	3533		
114	MATERIALS HANDLNG MACH.	(55)	3534	3535	3536	3537	
115	MACH.TOOLS,METAL CUTTING	(56)	3541				
116	MACH.TOOLS,METAL FORMING	(56)	3542				
117	OTHER METAL WORKING MACH.	(56)	3544	3545	3548		
118	SPECIAL INDUSTRIAL MACH.	(57)	3550				
119	PUMPS,COMPRESSORS,BLOWERS	(58)	3561	3564			
120	BALL & ROLLER BEARINGS	(58)	3562				
121	POWER TRANSMISSION EQUIP.	(58)	3566				
122	INDL FURNACES, INDL PATTERNS	(58)	3565	3567	3569		
123	COMPUTERS + RELATED MACH.	(60)	3573	3574			
124	OTHER OFFICE MACHNERY	(60))	3572	3576	3579		
125	SERVICE INDUSTRY MACHINERY	(61)	3580				
126	MACHINE SHOP PRODUCTS	(59)	3590				
127	EMPTY						
128	EMPTY						
129	ELECTRICAL MEASURING INSTRUME	(62)	3825				
130	TRANSFORMERS + SWITCHGEAR	(62)	3612	3613			
131	MOTORS AND GENERATORS	(63)	3621				
132	INDUSTRIAL CONTROLS	(63)	3622				
133	WELDING APP, GRAPHITE PROD	(63)	3623	3624	3629		
134	HOUSEHOLD APPLIANCES	(64)	3630				
135	ELEC LIGHTING + WIRING EQ.	(65)	3640				
136	RADIO AND TV RECEIVING	(66)	3651				
137	PHONOGRAPH RECORDS	(66)	3652				

138	COMMUNICATION EQUIPMENT	(67)	3660				
139	ELECTRONIC COMPONENTS	(68)	3670				
140	BATTERIES	(69)	3691	3692			
141	ENGINE ELECTRICAL EQUIP.	(69)	3694				
142	X-RAY, ELEC EQUIP,NEC	(69)	3693	3699			
143	EMPTY						
144	TRUCK, BUS, TRAILER BODIES	(70)	3713	3715			
145	MOTOR VEHICLES	(70)	3711	3714			
146	EMPTY						
147	AIRCRAFT	(71)	3721				
148	AIRCRAFT ENGINES	(71)	3724	3764			
149	AIRCRAFT EQUIPMENT, NEC	(71)	3728	3769			
150	SHIP AND BOAT BUILDING	(72)	3730				
151	RAILROAD EQUIPMENT	(73)	3740				
152	CYCLES, TRANS EQUIP NEC	(74)	3750	3799			
153	MOBILE HOMES & CAMPERS	(74)	2451	3792			
154	EMPTY						
155	EMPTY						
156	ENGR. + SCIENTIFIC INSTR.	(75)	3810				
157	MECH. MEASURING DEVICES	(76)	3820				
158	OPTICAL + OPHTHALMIC GOODS	(78)	3830	3850			
159	MEDICAL + SURGICAL INSTR.	(77)	3840				
160	PHOTOGRAPHIC EQUIPMENT	(78)	3860				
161	EMPTY						
162	WATCHES AND CLOCKS	(78)	3870				
163	JEWELRY AND SILVERWARE	(79)	3910	3961			
164	TOYS,SPORT,MUSICAL INSTR.	(79)	3930	3940			
165	OFFICE SUPPLIES	(79)	3950				
166	MISC MANUFACTURING, NEC	(79)	3962	3963	3964	3991	3993
			3995	3996	3999	3980	3994
167	RAILROADS	(80)	4000	4740			
168	BUSSES AND LOCAL TRANSIT	(82)	4100				
169	TRUCKING	(81)	4200	4730			
170	WATER TRANSPORTATION	(82)	4400				
171	AIRLINES	(83)	4500				
172	PIPELINES	(82)	4600				
173	FREIGHT FORWARDING	(82)	4700	-4740	-4730		
174	TELEPHONE AND TELEGRAPH	(85)	4800	-4830			
175	RADIO AND TV BROADCASTING	(85)	4830				
176	ELECTRIC UTILITIES	(87)	4910	4930			
177	EMPTY						
178	NATURAL GAS	(88)	4920	4930			
179	WATER AND SEWER SERVICES	(88)	4930	4940	4950	4960	4970
180	WHOLESALE TRADE	(84)	5000				
181	RETAIL TRADE	(84)	5200	5300	5400	5500	5600
			5700	5800			
			5960	7390			
182	BANKS,CREDIT AGEN.,BROKERS	(86)	6000	6100	6200	6700	
183	INSURANCE	(86)	6300				
184	OWNER-OCCUPIED DWELLINGS	(0)	6400				
185	REAL ESTATE	(86)	6500	6600	-6561		
186	HOTEL AND LODGING PLACES	(86)	7000				
187	PERSONAL + REPAIR SERVICES	(86)	7600	-7692	-7694	-7699	

188 BUSINESS SERVICES	(86)	7300	7692	8100	8900	-7310
		-7396	-8921			
189 ADVERTISING	(86)	7310				
190 AUTO REPAIR	(86)	7500				
191 MOVIES + AMUSEMENTS	(86)	7800	7900			
192 MEDICAL SERVICES	(86)	8010	8020	8030	8040	8060
		8090	0722	8070		
193 PRIVATE SCHOOLS + NPO	(86)	8200	8400	8600	8921	
194 POST OFFICE						
195 FED AND S&L GOV. ENTERPRISES						
196 NON-COMPETITIVE IMPORTS						
197 BUSINESS TRAVEL(DUMMY)						
198 OFFICE SUPPLIES(DUMMY)						
199 UNIMPORTANT IND.(DUMMY)						
200 COMPUTER RENTAL(DUMMY)						

SECTOR 76 SHOWS SHIPMENTS OF ALL PETROLEUM REFINING. HOWEVER ALL FUEL OIL IS SOLD TO SECTOR 77; THEREFORE, THE SALES TO OTHER SECTORS SHOW PURCHASES OF GASOLINE, AVIATION FUEL, AND PETROCHEMICAL FEEDSTOCKS. THE DISTRIBUTION OF SALES FOR SECTOR 77 SHOWS PURCHASES OF RESIDUAL AND DISTILLATE FUEL OIL, DIESEL FUEL, AND KEROSENE.

APPENDIX B

Diewert Data Matrix

$$\begin{array}{l|c|c|c|c|c|c|c}
 & S_i = & b_{11}\,\dfrac{p_j}{p_i}^{*} + & b_{12}\,\dfrac{p_j}{p_i}^{*} + & b_{13}\,\dfrac{p_j}{p_i}^{*} + & b_{22}\,\dfrac{p_j}{p_i}^{*} + & b_{23}\,\dfrac{p_j}{p_i}^{*} + & b_{33}\,\dfrac{p_j}{p_i}^{*} \\
\hline
 & \vdots & 1 & \vdots & \vdots & 0 & 0 & 0 \\
\text{10 obs.} & S_1 & \vdots & \dfrac{p_2}{p_1} & \dfrac{p_3}{p_1} & \vdots & \vdots & \vdots \\
 & \vdots & 1 & \vdots & \vdots & 0 & 0 & 0 \\
\hline
 & \vdots & 0 & \vdots & 0 & 1 & \vdots & 0 \\
\text{10 obs.} & S_2 & \vdots & \dfrac{p_1}{p_2} & \vdots & \vdots & \dfrac{p_3}{p_2} & \vdots \\
 & \vdots & 0 & \vdots & 0 & 1 & \vdots & 0 \\
\hline
 & \vdots & 0 & 0 & \vdots & 0 & \vdots & 1 \\
\text{10 obs.} & S_3 & \vdots & \vdots & \dfrac{p_1}{p_3} & \vdots & \dfrac{p_2}{p_3} & \vdots \\
 & \vdots & 0 & 0 & \vdots & 0 & \vdots & 1 \\
\hline
\end{array}$$

* all price ratios are taken to the 1/2 power.

Appendix C

Energy

Diewert Estimations

20 FOOD PRODUCTS DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	95.5	-38.8	.0	1.6	.1	.0 !
3 OIL !	1.1	.0	-9.3	.0	6.1	4.6 !
4 COAL !	.0	1.6	.0	-1.1	.0	.0 !
5 N GAS !	.1	.1	6.1	.0	-3.7	.0 !
6 ELEC !	-3.6	.0	4.6	.0	.0	3.8 !

20 FOOD PRODUCTS PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	.8	-.8	.0	.0	.0	.0 !
3 OIL !	.2	.0	-2.4	.0	1.2	.9 !
4 COAL !	.0	1.3	.0	-1.3	.0	.0 !
5 N GAS !	.0	.0	1.1	.0	-1.1	.0 !
6 ELEC !	-.4	.0	.5	.0	.0	-.1 !

22 TEXTILE MILL PRODUCTS DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	291.7	-139.3	.1	.0	.0	11.3 !
3 OIL !	.0	.1	-12.0	.0	17.4	.0 !
4 COAL !	.0	.0	.0	.8	.0	.0 !
5 N GAS !	.0	.0	17.4	.0	-13.3	.0 !
6 ELEC !	100.9	11.3	.0	.0	.0	-112.2 !

22 TEXTILE MILL PRODUCTS PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	.9	-.9	.0	.0	.0	.0 !
3 OIL !	.0	.0	-1.5	.0	1.5	.0 !
4 COAL !	.0	.0	.0	.0	.0	.0 !
5 N GAS !	.0	.0	2.0	.0	-2.0	.0 !
6 ELEC !	3.5	.4	.0	.0	.0	-3.9 !

23 APPAREL,OTH TEXTILES DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	428.6	-202.6	.0	.0	.1	.0 !
3 OIL !	.0	.0	-.1	.0	.5	.0 !
4 COAL !	.0	.0	.0	.0	.0	.0 !
5 N GAS !	.0	.1	.5	.0	-.0	.0 !
6 ELEC !	.7	.0	.0	.0	.0	5.6 !

23 APPAREL,OTH TEXTILES PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	.8	-.8	.0	.0	.0	.0 !
3 OIL !	.0	.0	-.6	.0	.6	.0 !
4 COAL !	.0	.0	.0	.0	.0	.0 !
5 N GAS !	.0	.1	.4	.0	-.5	.0 !
6 ELEC !	.1	.0	.0	.0	.0	-.1 !

24 LUMBER AND WOOD PRODUCTS DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	318.3	-149.1	.0	.0	.0	.0 !
3 OIL !	19.6	.0	-20.4	.1	3.9	.0 !
4 COAL !	.0	.0	.1	-.0	.0	.0 !
5 N GAS !	11.2	.0	3.9	.0	-12.5	.0 !
6 ELEC !	59.7	.0	.0	.0	.0	-6.2 !

24 LUMBER AND WOOD PRODUCTS PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	.9	-.9	.0	.0	.0	.0 !
3 OIL !	2.0	.0	-2.4	.0	.4	.0 !
4 COAL !	.0	.0	.3	-.4	.1	.0 !
5 N GAS !	1.9	.0	.7	.0	-2.6	.0 !
6 ELEC !	2.5	.0	.0	.0	.0	-2.5 !

25 FURNITURE AND FIXTURES DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	419.1	-235.5	.0	.0	1.3	.0
3 OIL	.0	.0	-4.5	.0	3.3	2.6
4 COAL	.0	.0	.0	.1	.0	.0
5 N GAS	.0	1.3	3.3	.0	-3.1	.0
6 ELEC	2.9	.0	2.6	.0	.0	2.7

25 FURNITURE AND FIXTURES PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	1.1	-1.1	.0	.0	.0	.0
3 OIL	.0	.0	-2.4	.0	1.4	1.1
4 COAL	.0	.0	.1	-.1	.0	.0
5 N GAS	.0	.4	1.0	.0	-1.4	.0
6 ELEC	.2	.0	.2	.0	.0	-.4

26 PAPER, ALLIED PRODUCTS DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	143.2	-101.3	.0	.0	24.7	53.3
3 OIL	109.6	.0	-113.3	9.1	.0	12.2
4 COAL	.0	.0	9.1	-3.2	.0	.0
5 N GAS	.0	24.7	.0	.0	-18.1	.0
6 ELEC	-31.9	53.3	12.2	.0	.0	-17.7

26 PAPER, ALLIED PRODUCTS PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	.6	-.9	.0	.0	.1	.2
3 OIL	2.0	.0	-2.4	.2	.0	.2
4 COAL	.0	.0	.7	-.7	.0	.0
5 N GAS	.0	1.5	.0	.0	-1.5	.0
6 ELEC	-.9	1.5	.3	.0	.0	-.9

27 PRINTING AND PUBLISHING DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	366.8	-221.3	.0	37.3	.0	.0
3 OIL	.0	.0	-.7	.1	1.2	.0
4 COAL	.0	37.3	.1	-40.8	.0	.0
5 N GAS	.0	.0	1.2	.0	-.2	.0
6 ELEC	1.3	.0	.0	.0	.0	4.2

27 PRINTING AND PUBLISHING PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	1.0	-1.1	.0	.1	.0	.0
3 OIL	.0	.0	-.9	.1	.8	.0
4 COAL	.0	.0	.0	.0	.0	.0
5 N GAS	.0	.0	.6	.0	-.6	.0
6 ELEC	.1	.0	.0	.0	.0	-.1

28 CHEMICALS,ALLIED PROD DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	211.1	-199.7	8.6	8.3	41.3	2.2
3 OIL	74.6	8.8	-96.5	.2	4.5	19.1
4 COAL	.0	8.3	.2	-3.3	.0	.0
5 N GAS	.0	41.3	4.5	.0	-36.2	.0
6 ELEC	64.0	2.2	18.1	.0	.0	-67.4

28 CHEMICALS,ALLIED PROD PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR	1.5	-1.9	.1	.1	.3	.0
3 OIL	4.1	.5	-5.8	.0	.2	1.0
4 COAL	.0	.7	.0	-.7	.0	.0
5 N GAS	.0	1.8	.2	.0	-2.0	.0
6 ELEC	1.2	.0	.3	.0	.0	-1.5

```
30  RUBBER MISC PLASTIC PROD      DIEWERT COEFS(MULTIPLIED BY 1000)
                          1        2         3          4        5          6
                       CAPITAL   LABOR      OIL       COAL     N GAS      ELEC
                     ---------------------------------------------------------

       2  LABOR !     306.3   -167.9       3.4        1.1       4.5        .0 !
       3  OIL   !        .0      3.4     -11.7         .0       4.0       8.2 !
       4  COAL  !        .0      1.1        .0        -.7        .0        .0 !
       5  N GAS !        .0      4.5       4.0         .0      -6.0        .0 !
       6  ELEC  !       2.3       .0       8.2         .0        .0      14.7 !
                     ---------------------------------------------------------
30  RUBBER MISC PLASTIC PROD      PRICE ELASTICITIES
                          1        2         3          4        5          6
                       CAPITAL   LABOR      OIL       COAL     N GAS      ELEC
                     ---------------------------------------------------------

       2  LABOR !       1.0     -1.0        .0         .0        .0        .0 !
       3  OIL   !        .0       .4      -2.0         .0        .5       1.0 !
       4  COAL  !        .0      1.1        .0       -1.1        .0        .0 !
       5  N GAS !        .0       .8        .7         .0      -1.6        .0 !
       6  ELEC  !        .1       .0        .3         .0        .0       -.4 !
                     ---------------------------------------------------------
```

```
32  STONE,CLAY,GLASS PROD         DIEWERT COEFS(MULTIPLIED BY 1000)
                          1        2         3          4        5          6
                       CAPITAL   LABOR      OIL       COAL     N GAS      ELEC
                     ---------------------------------------------------------

       2  LABOR !     245.6   -168.4        .0       50.1      36.4        .0 !
       3  OIL   !      58.5       .0     -70.5        4.3       4.5      17.0 !
       4  COAL  !       1.1     50.1       4.3      -47.5       5.9        .0 !
       5  N GAS !      13.5     36.4       4.5        5.9     -36.4        .0 !
       6  ELEC  !       4.7       .0      17.0         .0        .0        .1 !
                     ---------------------------------------------------------
32  STONE,CLAY,GLASS PROD         PRICE ELASTICITIES
                          1        2         3          4        5          6
                       CAPITAL   LABOR      OIL       COAL     N GAS      ELEC
                     ---------------------------------------------------------

       2  LABOR !        .7     -1.0        .0         .2        .1        .0 !
       3  OIL   !       2.4       .0      -3.5         .2        .2        .7 !
       4  COAL  !        .0      1.5        .1       -1.9        .2        .0 !
       5  N GAS !        .3       .7        .1         .1      -1.2        .0 !
       6  ELEC  !        .1       .0        .3         .0        .0       -.4 !
                     ---------------------------------------------------------
```

33 PRIMARY METAL INDUSTRIES DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	126.0	-25.6	27.8	1.4	1.9	.0 !
3 OIL !	.0	27.8	-26.3	.0	4.5	.0 !
4 COAL !	.0	1.4	.0	.0	.0	.0 !
5 N GAS !	2.5	1.9	4.5	.0	.2	.0 !
6 ELEC !	105.6	.0	.0	.0	.0	-77.8 !

33 PRIMARY METAL INDUSTRIES PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	.5	-.6	.1	.0	.0	.0 !
3 OIL !	.0	2.7	-3.1	.0	.4	.0 !
4 COAL !	.0	.4	.0	-.4	.0	.0 !
5 N GAS !	.1	.1	.2	.0	-.4	.0 !
6 ELEC !	1.5	.0	.0	.0	.0	-1.5 !

34 FABRICATED METAL PRODS DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	260.3	-107.5	.0	.1	.5	.0 !
3 OIL !	.0	.0	-1.7	.0	3.0	.0 !
4 COAL !	.0	.1	.0	-.1	.0	.0 !
5 N GAS !	.0	.5	3.0	.0	-1.8	.7 !
6 ELEC !	-.7	.0	.0	.0	-.7	7.2 !

34 FABRICATED METAL PRODS PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	.8	-.8	.0	.0	.0	.0 !
3 OIL !	.0	.0	-1.2	.0	1.2	.0 !
4 COAL !	.0	.7	.0	-.7	.0	.0 !
5 N GAS !	.0	.1	.6	.0	-.8	.1 !
6 ELEC !	-.0	.0	.0	.0	.0	-.0 !

```
35  MACHINERY EXCEPT ELEC        DIEWERT COEFS(MULTIPLIED BY 1000)
                        1        2        3         4        5        6
                     CAPITAL   LABOR     OIL       COAL    N GAS     ELEC
                   ---------------------------------------------------------
     2  LABOR !     129.2     21.2       .0        .4      1.8       .0 !
     3  OIL   !        .0       .0     -2.0        .0      2.8       .7 !
     4  COAL  !        .0       .4       .0       -.3       .0       .0 !
     5  N GAS !        .0      1.8      2.8        .0     -3.9       .0 !
     6  ELEC  !      21.6       .0       .7        .0       .0      1.3 !
                   ---------------------------------------------------------
35  MACHINERY EXCEPT ELEC        PRICE ELASTICITIES
                        1        2        3         4        5        6
                     CAPITAL   LABOR     OIL       COAL    N GAS     ELEC
                   ---------------------------------------------------------
     2  LABOR !        .4      -.4       .0        .0       .0       .0 !
     3  OIL   !        .0       .0     -1.9        .0      1.6       .4 !
     4  COAL  !        .0      1.1       .0      -1.1       .0       .0 !
     5  N GAS !        .0       .6       .9        .0     -1.5       .0 !
     6  ELEC  !       1.7       .0       .1        .0       .0     -1.7 !
                   ---------------------------------------------------------


36  ELECTRIC,ELECTRONIC EQ       DIEWERT COEFS(MULTIPLIED BY 1000)
                        1        2        3         4        5        6
                     CAPITAL   LABOR     OIL       COAL    N GAS     ELEC
                   ---------------------------------------------------------
     2  LABOR !      75.1     74.9       .0        .2       .0       .0 !
     3  OIL   !        .0       .0     -3.7        .0      1.0      3.7 !
     4  COAL  !        .0       .2       .0       -.2       .0       .0 !
     5  N GAS !       1.2       .0      1.0        .0      -.5       .0 !
     6  ELEC  !       1.9       .0      3.7        .0       .0      2.8 !
                   ---------------------------------------------------------
36  ELECTRIC,ELECTRONIC EQ       PRICE ELASTICITIES
                        1        2        3         4        5        6
                     CAPITAL   LABOR     OIL       COAL    N GAS     ELEC
                   ---------------------------------------------------------
     2  LABOR !        .2      -.2       .0        .0       .0       .0 !
     3  OIL   !        .0       .0     -2.6        .0       .5      2.1 !
     4  COAL  !        .0      1.2       .0      -1.2       .0       .0 !
     5  N GAS !        .4       .0       .3        .0      -.6       .0 !
     6  ELEC  !        .1       .0       .2        .0       .0      -.3 !
                   ---------------------------------------------------------
```

37 TRANSPORTATION EQUIPMENT DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	403.1	-260.8	.0	.3	2.0	.0 !
3 OIL !	.0	.0	.3	.0	.5	.7 !
4 COAL !	.0	.3	.0	-.1	.0	.0 !
5 N GAS !	.0	2.0	.5	.0	-1.3	.0 !
6 ELEC !	-.7	.0	.7	.0	.0	6.0 !

37 TRANSPORTATION EQUIPMENT PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	1.3	-1.3	.0	.0	.0	.0 !
3 OIL !	.0	.0	-.4	.0	.2	.2 !
4 COAL !	.0	.7	.0	-.7	.0	.0 !
5 N GAS !	.0	.8	.2	.0	-1.0	.0 !
6 ELEC !	-.1	.0	.1	.0	.0	-.0 !

38 INSTRUMENTS,RELATED PROD DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	458.6	-310.4	.9	.0	.0	.0 !
3 OIL !	.0	.9	-4.5	.0	1.3	3.1 !
4 COAL !	.0	.0	.0	-.0	.0	.0 !
5 N GAS !	.0	.0	1.3	.0	-.5	.0 !
6 ELEC !	2.4	.0	3.1	.0	.0	1.3 !

38 INSTRUMENTS,RELATED PROD PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	1.5	-1.5	.0	.0	.0	.0 !
3 OIL !	.0	.5	-2.8	.0	.7	1.7 !
4 COAL !	.0	.0	.0	.0	.0	.0 !
5 N GAS !	.0	.0	.8	.0	-.8	.0 !
6 ELEC !	.2	.0	.2	.0	.0	-.4 !

39 TOYS,SPORTS,MISC MANUF DIEWERT COEFS(MULTIPLIED BY 1000)

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	196.5	-37.5	4.1	.0	1.2	.0 !
3 OIL !	.0	4.1	-11.6	.0	2.4	5.7 !
4 COAL !	.0	.0	.0	-.1	.1	.1 !
5 N GAS !	.0	1.2	2.4	.1	-2.2	.0 !
6 ELEC !	7.3	.0	5.7	.1	.0	-5.7 !

39 TOYS,SPORTS,MISC MANUF PRICE ELASTICITIES

	1 CAPITAL	2 LABOR	3 OIL	4 COAL	5 N GAS	6 ELEC
2 LABOR !	.6	-.6	.0	.0	.0	.0 !
3 OIL !	.0	1.5	-4.4	.0	.9	2.1 !
4 COAL !	.0	.0	.0	.0	.0	.0 !
5 N GAS !	.0	.4	.8	.0	-1.2	.0 !
6 ELEC !	.5	.0	.4	.0	.0	-.9 !

APPENDIX D

Transportation
Diewert Estimations

```
1      GRAINS               DIEWEPT COEFS (MULTIPLIED BY 1000)

                      1        2        3         4
                    RAIL     WATER    TRUCK      PIPE
                  ----------------------------------------
   1  RAIL   !   542.00     #.00      .00       .00  !
   2  WATER  !     #.00    42.50    95.60       .00  !
   3  TRUCK  !      .00    95.60   223.50       .00  !
   4  PIPE   !      .00      .00      .00       .00  !
                  ----------------------------------------
1      GRAINS                     PRICE ELASTICITIES

                      1        2        3         4
                    RAIL     WATER    TRUCK      PIPE
                  ----------------------------------------
   1  RAIL   !                .00      .00            !
   2  WATER  !      .00     -.29      .29            !
   3  TRUCK  !      .00      .14     -.14            !
   4  PIPE   !                                       !
                  ----------------------------------------


2      IRON ORE             DIEWERT COEFS (MULTIPLIED BY 1000)

                      1        2        3         4
                    RAIL     WATER    TRUCK      PIPE
                  ----------------------------------------
   1  RAIL   !   589.60     #.00      .00       .00  !
   2  WATER  !     #.00   381.40      .00       .00  !
   3  TRUCK  !      .00      .00      .00       .00  !
   4  PIPE   !      .00      .00      .00       .00  !
                  ----------------------------------------
2      IRON ORE                   PRICE ELASTICITIES

                      1        2        3         4
                    RAIL     WATER    TRUCK      PIPE
                  ----------------------------------------
   1  RAIL   !                .00                    !
   2  WATER  !      .00                              !
   3  TRUCK  !                                       !
   4  PIPE   !                                       !
                  ----------------------------------------
```

```
3        COPPER ORE          DIEWERT COEFS (MULTIPLIED BY 1000)

                          1        2         3         4
                        RAIL    WATER     TRUCK      PIPE
                   ---------------------------------------
          1  RAIL   !  790.80      .00      #.00       .00 !
          2  WATER  !     .00      .00       .00       .00 !
          3  TRUCK  !    #.00      .00    208.70       .00 !
          4  PIPE   !     .00      .00       .00       .00 !
                   ---------------------------------------

3        COPPER ORE                 PRICE ELASTICITIES

                          1        2         3         4
                        RAIL    WATER     TRUCK      PIPE
                   ---------------------------------------
          1  RAIL   !                        .00           !
          2  WATER  !                                      !
          3  TRUCK  !     .00                              !
          4  PIPE   !                                      !
                   ---------------------------------------


4       * COAL               DIEWERT COEFS (MULTIPLIED BY 1000)

                          1        2         3         4
                        RAIL    WATER     TRUCK      PIPE
                   ---------------------------------------
          1  RAIL   !  540.40   140.30       .00       .00 !
             T      !   10.11     2.56       .00       .00 !
          2  WATER  !  140.30   131.30       .00       .00 !
             T      !    2.56     2.31       .00       .00 !
          3  TRUCK  !     .00      .00       .00       .00 !
             T      !     .00      .00       .00       .00 !
          4  PIPE   !     .00      .00       .00       .00 !
             T      !     .00      .00       .00       .00 !
                   ---------------------------------------

4        COAL                       PRICE ELASTICITIES

                          1        2         3         4
                        RAIL    WATER     TRUCK      PIPE
                   ---------------------------------------
          1  RAIL   !    -.10      .10                     !
          2  WATER  !     .28     -.28                     !
          3  TRUCK  !                                      !
          4  PIPE   !                                      !
                   ---------------------------------------
```

```
5     * CRUD PETRO+NA       DIEWERT COEFS (MULTIPLIED BY 1000)

                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    -------------------------------------------

          1  RAIL  !      .00      .00      .00       .00 !
               T   !      .00      .00      .00       .00 !

          2  WATER !      .00    55.20      .00     90.60 !
               T   !      .00     2.48      .00      4.77 !

          3  TRUCK !      .00      .00      .00       .00 !
               T   !      .00      .00      .00       .00 !

          4  PIPE  !      .00    90.60      .00    733.80 !
               T   !      .00     4.77      .00     42.68 !
                    -------------------------------------------

5       CRUD PETRO+NA              PRICE ELASTICITIES

                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    -------------------------------------------

          1  RAIL  !                                          !

          2  WATER !              -.30                  .30 !

          3  TRUCK !                                          !

          4  PIPE  !               .05                 -.05 !
                    -------------------------------------------


6       STONE+CLAY MI       DIEWERT COEFS (MULTIPLIED BY 1000)

                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    -------------------------------------------
          1  RAIL  !    -6.80     #.00   394.60       .00 !
          2  WATER !     #.00    84.50   239.10       .00 !
          3  TRUCK !   394.60   239.10  -348.60       .00 !
          4  PIPE  !      .00      .00      .00       .00 !
                    -------------------------------------------

6       STONE+CLAY MI              PRICE ELASTICITIES

                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    -------------------------------------------

          1  RAIL  !     -.55      .00      .55               !
          2  WATER !      .00     -.36      .36               !
          3  TRUCK !      .64      .38    -1.02               !
          4  PIPE  !                                          !
                    -------------------------------------------
```

```
7      CHEM+FERT MIN       DIEWERT COEFS (MULTIPLIED BY 1000)

                          1        2        3        4
                        RAIL     WATER    TRUCK     PIPE
                     ----------------------------------
      1  RAIL   !   589.40      #.00     #.00      .00 !
      2  WATER  !     #.00    270.40     #.00      .00 !
      3  TRUCK  !     #.00      #.00   140.20      .00 !
      4  PIPE   !      .00       .00      .00      .00 !
                     ----------------------------------

7      CHEM+FERT MIN             PRICE ELASTICITIES

                          1        2        3        4
                        RAIL     WATER    TRUCK     PIPE
                     ----------------------------------
      1  RAIL   !                  .00      .00          !
      2  WATER  !      .00                  .00          !
      3  TRUCK  !      .00         .00                   !
      4  PIPE   !                                        !
                     ----------------------------------


8      *LOGS               DIEWERT COEFS (MULTIPLIED BY 1000)

                          1        2        3        4
                        RAIL     WATER    TRUCK     PIPE
                     ----------------------------------
      1  RAIL   !   174.70     42.60   128.00      .00 !
         T      !      .90       .27     1.40      .00 !
      2  WATER  !    42.60   -271.20   307.70      .00 !
         T      !      .27      1.75     3.85      .00 !
      3  TRUCK  !   128.00    307.70   137.30      .00 !
         T      !     1.40      3.85     1.57      .00 !
      4  PIPE   !      .00       .00      .00      .00 !
         T      !      .00       .00      .00      .00 !
                     ----------------------------------

8      LOGS                      PRICE ELASTICITIES

                          1        2        3        4
                        RAIL     WATER    TRUCK     PIPE
                     ----------------------------------
      1  RAIL   !     -.25       .06      .19          !
      2  WATER  !      .27     -2.20     1.93          !
      3  TRUCK  !      .11       .26     -.37          !
      4  PIPE   !                                      !
                     ----------------------------------
```

```
 9      *LUMBER                DIEWERT COEFS (MULTIPLIED BY 1000)

                               1        2        3          4
                             RAIL    WATER    TRUCK       PIPE
                        ------------------------------------
          1  RAIL   !    88.90      .00   339.40       .00 !
             T      !     1.17      .00     5.26       .00 !

          2  WATER  !      .00      .00      .00       .00 !
             T      !      .00      .00      .00       .00 !

          3  TRUCK  !   389.40      .00    53.50       .00 !
             T      !     5.26      .00      .74       .00 !

          4  PIPE   !      .00      .00      .00       .00 !
             T      !      .00      .00      .00       .00 !
                        ------------------------------------
 9       LUMBER                        PRICE ELASTICITIES

                               1        2        3          4
                             RAIL    WATER    TRUCK       PIPE
                        ------------------------------------

          1  RAIL   !     -.41                .41            !

          2  WATER  !                                        !

          3  TRUCK  !      .44               -.44            !

          4  PIPE   !                                        !
                        ------------------------------------


10      PULP,PAPER,PP          DIEWERT COEFS (MULTIPLIED BY 1000)

                               1        2        3          4
                             RAIL    WATER    TRUCK       PIPE
                        ------------------------------------

          1  RAIL   !   692.40      .00      .00       .00 !

          2  WATER  !      .00      .00      .00       .00 !

          3  TRUCK  !      .00      .00   263.70       .00 !

          4  PIPE   !      .00      .00      .00       .00 !
                        ------------------------------------
10      PULP,PAPER,PP                  PRICE ELASTICITIES

                               1        2        3          4
                             RAIL    WATER    TRUCK       PIPE
                        ------------------------------------

          1  RAIL   !                         .00            !

          2  WATER  !                                        !

          3  TRUCK  !      .00                               !

          4  PIPE   !                                        !
                        ------------------------------------
```

```
11      INDUST CHEMIC      DIEWERT COEFS (MULTIPLIED BY 1000)
                                1        2        3          4
                              RAIL    WATER    TRUCK       PIPE
                        ------------------------------------------
            1  RAIL   !   472.80     #.00     4.10       .00 !
            2  WATER  !     #.00   270.90     #.00       .00 !
            3  TRUCK  !     4.10     #.00   248.10       .00 !
            4  PIPE   !      .00      .00      .00       .00 !
                        ------------------------------------------
11      INDUST CHEMIC             PRICE ELASTICITIES
                                1        2        3          4
                              RAIL    WATER    TRUCK       PIPE
                        ------------------------------------------
            1  RAIL   !     -.00      .00      .00           !
            2  WATER  !      .00               .00           !
            3  TRUCK  !      .01      .00     -.01           !
            4  PIPE   !                                      !
                        ------------------------------------------


12      MISC PETRO PR      DIEWERT COEFS (MULTIPLIED BY 1000)
                                1        2        3          4
                              RAIL    WATER    TRUCK       PIPE
                        ------------------------------------------
            1  RAIL   !      .00      .00      .00       .00 !
            2  WATER  !      .00    96.30     #.00    108.60 !
            3  TRUCK  !      .00     #.00   124.40    214.90 !
            4  PIPE   !      .00   108.60   214.90     75.60 !
                        ------------------------------------------
12      MISC PETRO PR             PRICE ELASTICITIES
                                1        2        3          4
                              RAIL    WATER    TRUCK       PIPE
                        ------------------------------------------
            1  RAIL   !                                      !
            2  WATER  !              -.26      .00       .26 !
            3  TRUCK  !               .00     -.32       .32 !
            4  PIPE   !               .14      .27      -.41 !
                        ------------------------------------------
```

```
13        FUEL OIL           DIEWERT COEFS (MULTIPLIED BY 1000)
                              1         2         3         4
                            RAIL     WATER     TRUCK      PIPE
                    ---------------------------------------------
          1  RAIL   !        .00       .00       .00       .00 !
          2  WATER  !        .00    483.90      #.00       .00 !
          3  TRUCK  !        .00      #.00    164.30     41.00 !
          4  PIPE   !        .00       .00     41.00    247.20 !
                    ---------------------------------------------
13        FUEL OIL                   PRICE ELASTICITIES
                              1         2         3         4
                            RAIL     WATER     TRUCK      PIPE
                    ---------------------------------------------
          1  RAIL   !                                          !
          2  WATER  !                            .00       .00 !
          3  TRUCK  !                  .00      -.10       .10 !
          4  PIPE   !                  .00       .07      -.07 !
                    ---------------------------------------------


14        CEMENT             DIEWERT COEFS (MULTIPLIED BY 1000)
                              1         2         3         4
                            RAIL     WATER     TRUCK      PIPE
                    ---------------------------------------------
          1  RAIL   !    -368.10       .00    672.10       .00 !
             T      !       3.36       .00      6.37       .00 !

          2  WATER  !        .00       .00       .00       .00 !
             T      !        .00       .00       .00       .00 !

          3  TRUCK  !     672.10       .00    -74.30       .00 !
             T      !       6.37       .00       .72       .00 !

          4  PIPE   !        .00       .00       .00       .00 !
             T      !        .00       .00       .00       .00 !
                    ---------------------------------------------
14        CEMENT                     PRICE ELASTICITIES
                              1         2         3         4
                            RAIL     WATER     TRUCK      PIPE
                    ---------------------------------------------
          1  RAIL   !      -1.17                1.17           !
          2  WATER  !                                          !
          3  TRUCK  !        .55                -.55           !
          4  PIPE   !                                          !
                    ---------------------------------------------
```

```
15      *STEEL                 DIEWERT COEFS (MULTIPLIED BY 1000)
                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                      -----------------------------------------

        1  RAIL   !  -248.30      .00   705.80       .00 !
           T      !     1.10      .00     3.24       .00 !

        2  WATER  !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !

        3  TRUCK  !   705.80      .00  -232.20       .00 !
           T      !     3.24      .00     1.10       .00 !

        4  PIPE   !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !
                      -----------------------------------------

15       STEEL                       PRICE ELASTICITIES
                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                      -----------------------------------------

        1  RAIL   !     -.88               .88               !

        2  WATER  !                                          !

        3  TRUCK  !      .68              -.68               !

        4  PIPE   !                                          !
                      -----------------------------------------


16      *MOTOR VEHICL          DIEWERT COEFS (MULTIPLIED BY 1000)
                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                      -----------------------------------------

        1  RAIL   !   334.80      .00    90.10       .00 !
           T      !     5.30      .00     1.48       .00 !

        2  WATER  !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !

        3  TRUCK  !    90.10      .00   473.90       .00 !
           T      !     1.48      .00     7.98       .00 !

        4  PIPE   !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !
                      -----------------------------------------

16       MOTOR VEHICL                PRICE ELASTICITIES
                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                      -----------------------------------------

        1  RAIL   !     -.11               .11               !

        2  WATER  !                                          !

        3  TRUCK  !      .08              -.08               !

        4  PIPE   !                                          !
                      -----------------------------------------
```

```
17       *OTH AGRIC PR       DIEWERT COEFS (MULTIPLIED BY 1000)

                          1        2        3         4
                        RAIL    WATER    TRUCK     PIPE
                   ------------------------------------
        1  RAIL   ! -174.80      .00   417.40      .00 !
           T      !     .77      .00     1.91      .00 !

        2  WATER  !     .00      .00      .00      .00 !
           T      !     .00      .00      .00      .00 !

        3  TRUCK  !  417.40      .00   327.10      .00 !
           T      !    1.91      .00     1.54      .00 !

        4  PIPE   !     .00      .00      .00      .00 !
           T      !     .00      .00      .00      .00 !
                   ------------------------------------
17        OTH AGRIC PR             PRICE ELASTICITIES

                          1        2        3         4
                        RAIL    WATER    TRUCK     PIPE
                   ------------------------------------

        1  RAIL   !    -.99               .99          !

        2  WATER  !                                    !

        3  TRUCK  !     .27              -.27          !

        4  PIPE   !                                    !
                   ------------------------------------
```

```
18        OTH NON-FERR        DIEWERT COEFS (MULTIPLIED BY 1000)

                          1        2        3         4
                        RAIL    WATER    TRUCK     PIPE
                   ------------------------------------
        1  RAIL   !  201.70   550.90     #.00      .00 !
        2  WATER  !  550.90  -464.90      .00      .00 !
        3  TRUCK  !    #.00      .00   160.50      .00 !
        4  PIPE   !     .00      .00      .00      .00 !
                   ------------------------------------
18        OTH NON-FERR             PRICE ELASTICITIES

                          1        2        3         4
                        RAIL    WATER    TRUCK     PIPE
                   ------------------------------------
        1  RAIL   !    -.34      .34      .00          !
        2  WATER  !    5.57    -5.57      .00          !
        3  TRUCK  !     .00      .00                   !
        4  PIPE   !                                    !
                   ------------------------------------
```

```
19     *FOOD,TOBAC P      DIEWERT COEFS (MULTIPLIED BY 1000)
                          1        2        3         4
                        RAIL    WATER    TRUCK      PIPE
                   ------------------------------------
          1  RAIL  !  103.30      .00   313.20      .00 !
             T     !    1.42      .00     4.46      .00 !

          2  WATER !     .00      .00      .00      .00 !
             T     !     .00      .00      .00      .00 !

          3  TRUCK !  313.20      .00   226.30      .00 !
             T     !    4.46      .00     3.31      .00 !

          4  PIPE  !     .00      .00      .00      .00 !
             T     !     .00      .00      .00      .00 !
                   ------------------------------------
19      FOOD,TOBAC P            PRICE ELASTICITIES
                          1        2        3         4
                        RAIL    WATER    TRUCK      PIPE
                   ------------------------------------

          1  RAIL  !    -.39               .39          !

          2  WATER !                                    !

          3  TRUCK !     .28              -.28          !

          4  PIPE  !                                    !
                   ------------------------------------


20     TEXT+LEATH PR      DIEWERT COEFS (MULTIPLIED BY 1000)
                          1        2        3         4
                        RAIL    WATER    TRUCK      PIPE
                   ------------------------------------
          1  RAIL  !  101.00      .00      .00      .00 !
          2  WATER !     .00      .00      .00      .00 !
          3  TRUCK !     .00      .00   893.50      .00 !
          4  PIPE  !     .00      .00      .00      .00 !
                   ------------------------------------
20     TEXT+LEATH PR            PRICE ELASTICITIES
                          1        2        3         4
                        RAIL    WATER    TRUCK      PIPE
                   ------------------------------------
          1  RAIL  !                       .00          !
          2  WATER !                                    !
          3  TRUCK !     .00                            !
          4  PIPE  !                                    !
                   ------------------------------------
```

```
21     *PAP PROD(-)CO        DIEWERT COEFS (MULTIPLIED BY 1000)

                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                     ----------------------------------------

         1  RAIL   !  -70.40      .00   583.10       .00  !
            T      !     .78      .00     6.66       .00  !

         2  WATER  !     .00      .00      .00       .00  !
            T      !     .00      .00      .00       .00  !

         3  TRUCK  !  583.10      .00  -132.10       .00  !
            T      !    6.66      .00     1.55       .00  !

         4  PIPE   !     .00      .00      .00       .00  !
            T      !     .00      .00      .00       .00  !
                     ----------------------------------------

21      PAP PROD(-)CO              PRICE ELASTICITIES

                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                     ----------------------------------------

         1  RAIL   !    -.59               .59            !

         2  WATER  !                                      !

         3  TRUCK  !     .66              -.66            !

         4  PIPE   !                                      !
                     ----------------------------------------


22     *PRINT MATT+PP        DIEWERT COEFS (MULTIPLIED BY 1000)

                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                     ----------------------------------------

         1  RAIL   ! -251.50      .00   365.50       .00  !
            T      !    1.93      .00     2.89       .00  !

         2  WATER  !     .00      .00      .00       .00  !
            T      !     .00      .00      .00       .00  !

         3  TRUCK  !  365.50      .00   502.60       .00  !
            T      !    2.89      .00     4.07       .00  !

         4  PIPE   !     .00      .00      .00       .00  !
            T      !     .00      .00      .00       .00  !
                     ----------------------------------------

22      PRINT MATT+PP              PRICE ELASTICITIES

                             1        2        3         4
                           RAIL    WATER    TRUCK      PIPE
                     ----------------------------------------

         1  RAIL   !   -1.84              1.84            !

         2  WATER  !                                      !

         3  TRUCK  !     .21              -.21            !

         4  PIPE   !                                      !
                     ----------------------------------------
```

```
23        OTH CHEMICAL        DIEWERT COEFS (MULTIPLIED BY 1000)

                              1        2        3         4
                            RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------
                                              #
          1  RAIL  !     248.30      .00   164.30       .00 !
             T     !       2.83      .00     2.04       .00 !

          2  WATER !        .00      .00      .00       .00 !
             T     !        .00      .00      .00       .00 !
                        #
          3  TRUCK !     164.30      .00   305.90       .00 !
             T     !       2.04      .00     4.11       .00 !

          4  PIPE  !        .00      .00      .00       .00 !
             T     !        .00      .00      .00       .00 !
                    ------------------------------------------

23        OTH CHEMICAL               PRICE ELASTICITIES

                              1        2        3         4
                            RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------

          1  RAIL  !       -.16               .16           !

          2  WATER !                                        !

          3  TRUCK !        .24              -.24           !

          4  PIPE  !                                        !
                    ------------------------------------------


24        PLASTICS            DIEWERT COEFS (MULTIPLIED BY 1000)

                              1        2        3         4
                            RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------

          1  RAIL  !     333.90      .00   221.50       .00 !
             T     !       5.45      .00     3.60       .00 !

          2  WATER !        .00      .00      .00       .00 !
             T     !        .00      .00      .00       .00 !

          3  TRUCK !     221.50      .00   189.00       .00 !
             T     !       3.60      .00     2.42       .00 !

          4  PIPE  !        .00      .00      .00       .00 !
             T     !        .00      .00      .00       .00 !
                    ------------------------------------------

24        PLASTICS                   PRICE ELASTICITIES

                              1        2        3         4
                            RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------

          1  RAIL  !       -.25               .25           !

          2  WATER !                                        !

          3  TRUCK !        .21              -.21           !

          4  PIPE  !                                        !
                    ------------------------------------------
```

```
25      * DRUGS+PAINTS        DIEWERT COEFS (MULTIPLIED BY 1000)
                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------
        1  RAIL   !  -225.20      .00   395.10       .00 !
           T      !     5.85      .00    10.61       .00 !

        2  WATER  !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !

        3  TRUCK  !   395.10      .00   419.90       .00 !
           T      !    10.61      .00    11.55       .00 !

        4  PIPE   !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !
                    ----------------------------------------
25        DRUGS+PAINTS              PRICE ELASTICITIES
                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------

        1  RAIL   !    -1.16              1.16             !

        2  WATER  !                                        !

        3  TRUCK  !      .24              -.24             !

        4  PIPE   !                                        !
                    ----------------------------------------


26      * RUBBER PROD         DIEWERT COEFS (MULTIPLIED BY 1000)
                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------
        1  RAIL   !   -16.90      .00   254.00       .00 !
           T      !      .24      .00     3.71       .00 !

        2  WATER  !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !

        3  TRUCK  !   254.00      .00   501.70       .00 !
           T      !     3.71      .00     7.54       .00 !

        4  PIPE   !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !
                    ----------------------------------------
26        RUBBER PROD               PRICE ELASTICITIES
                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------

        1  RAIL   !     -.52               .52             !

        2  WATER  !                                        !

        3  TRUCK  !      .17              -.17             !

        4  PIPE   !                                        !
                    ----------------------------------------
```

```
27   * OTH WOOD PROD      DIEWERT COEFS (MULTIPLIED BY 1000)

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------

       1  RAIL   !         .40      .00   512.80       .00 !
          T      !         .00      .00     4.09       .00 !

       2  WATER  !         .00      .00      .00       .00 !
          T      !         .00      .00      .00       .00 !

       3  TRUCK  !      512.80      .00   -58.30       .00 !
          T      !        4.09      .00      .48       .00 !

       4  PIPE   !         .00      .00      .00       .00 !
          T      !         .00      .00      .00       .00 !
                    ------------------------------------------

27     OTH WOOD PROD            PRICE ELASTICITIES

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------

       1  RAIL   !        -.52               .52           !

       2  WATER  !                                         !

       3  TRUCK  !         .53              -.53           !

       4  PIPE   !                                         !
                    ------------------------------------------


28     FURNIT+MISC M      DIEWERT COEFS (MULTIPLIED BY 1000)

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------

       1  RAIL   !      134.20      .00    54.00       .00 !

       2  WATER  !         .00     6.30    71.70       .00 !

       3  TRUCK  !       54.00    71.70   607.00       .00 !

       4  PIPE   !         .00      .00      .00       .00 !
                    ------------------------------------------

28     FURNIT+MISC M            PRICE ELASTICITIES

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ------------------------------------------

       1  RAIL   !        -.15               .15           !

       2  WATER  !                 -.44      .44           !

       3  TRUCK  !         .04      .05     -.08           !

       4  PIPE   !                                         !
                    ------------------------------------------
```

```
29      * GLASS PROD          DIEWERT COEFS (MULTIPLIED BY 1000)
                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                     ------------------------------------------
      1  RAIL   !        12.20      .00   596.80       .00 !
         T      !          .08      .00     4.52       .00 !
      2  WATER  !          .00      .00      .00       .00 !
         T      !          .00      .00      .00       .00 !
      3  TRUCK  !       596.80      .00  -216.60       .00 !
         T      !         4.52      .00     1.02       .00 !
      4  PIPE   !          .00      .00      .00       .00 !
         T      !          .00      .00      .00       .00 !
                     ------------------------------------------
29        GLASS PROD                PRICE ELASTICITIES
                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                     ------------------------------------------
      1  RAIL   !        -1.89              1.89             !
      2  WATER  !                                            !
      3  TRUCK  !          .36              -.36             !
      4  PIPE   !                                            !
                     ------------------------------------------


30      * STONE+CLAY PR       DIEWERT COEFS (MULTIPLIED BY 1000)
                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                     ------------------------------------------
      1  RAIL   !       744.50      .00   240.90       .00 !
         T      !         3.29      .00     1.77       .00 !
      2  WATER  !          .00      .00      .00       .00 !
         T      !          .00      .00      .00       .00 !
      3  TRUCK  !       240.90      .00  -242.30       .00 !
         T      !         1.77      .00      .82       .00 !
      4  PIPE   !          .00      .00      .00       .00 !
         T      !          .00      .00      .00       .00 !
                     ------------------------------------------
30        STONE+CLAY PR             PRICE ELASTICITIES
                           1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                     ------------------------------------------
      1  RAIL   !         -.21               .21             !
      2  WATER  !                                            !
      3  TRUCK  !          .29              -.29             !
      4  PIPE   !                                            !
                     ------------------------------------------
```

```
31     * PRIM NON-FERR      DIEWERT COEFS (MULTIPLIED BY 1000)
                                1        2        3        4
                              RAIL    WATER    TRUCK     PIPE
                         ----------------------------------------

           1  RAIL   !  174.30      .00   235.30      .00  !
              T      !    2.07      .00     2.90      .00  !

           2  WATER  !     .00      .00      .00      .00  !
              T      !     .00      .00      .00      .00  !

           3  TRUCK  !  235.30      .00   324.40      .00  !
              T      !    2.90      .00     4.12      .00  !

           4  PIPE   !     .00      .00      .00      .00  !
              T      !     .00      .00      .00      .00  !
                         ----------------------------------------

31       PRIM NON-FERR            PRICE ELASTICITIES
                                1        2        3        4
                              RAIL    WATER    TRUCK     PIPE
                         ----------------------------------------

           1  RAIL   !    -.29               .29              !

           2  WATER  !                                         !

           3  TRUCK  !     .21              -.21              !

           4  PIPE   !                                         !
                         ----------------------------------------


32     * FAB STRU MET       DIEWERT COEFS (MULTIPLIED BY 1000)
                                1        2        3        4
                              RAIL    WATER    TRUCK     PIPE
                         ----------------------------------------

           1  RAIL   !  292.60      .00    99.30      .00  !
              T      !    2.23      .00      .78      .00  !

           2  WATER  !     .00      .00      .00      .00  !
              T      !     .00      .00      .00      .00  !

           3  TRUCK  !   99.30      .00   462.60      .00  !
              T      !     .78      .00     3.77      .00  !

           4  PIPE   !     .00      .00      .00      .00  !
              T      !     .00      .00      .00      .00  !
                         ----------------------------------------

32       FAB STRU MET             PRICE ELASTICITIES
                                1        2        3        4
                              RAIL    WATER    TRUCK     PIPE
                         ----------------------------------------

           1  RAIL   !    -.14               .14              !

           2  WATER  !                                         !

           3  TRUCK  !     .08              -.08              !

           4  PIPE   !                                         !
                         ----------------------------------------
```

```
33    * ORD+MISC FAB        DIEWERT COEFS (MULTIPLIED BY 1000)

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------

        1  RAIL   !  -403.00      .00   628.80       .00 !
           T      !     5.69      .00     9.20       .00 !

        2  WATER  !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !

        3  TRUCK  !   628.80      .00   139.90       .00 !
           T      !     9.20      .00     2.10       .00 !

        4  PIPE   !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !
                    ----------------------------------------

33      ORD+MISC FAB               PRICE ELASTICITIES

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------

        1  RAIL   !    -1.38              1.38           !

        2  WATER  !                                      !

        3  TRUCK  !      .41              -.41           !

        4  PIPE   !                                      !
                    ----------------------------------------


34    * METWORK MACH+       DIEWERT COEFS (MULTIPLIED BY 1000)

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------

        1  RAIL   !   767.00      .00  2721.40       .00 !
           T      !     1.79      .00    10.42       .00 !

        2  WATER  !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !

        3  TRUCK  !  2721.40      .00-5225.30       .00 !
           T      !    10.42      .00     8.16       .00 !

        4  PIPE   !      .00      .00      .00       .00 !
           T      !      .00      .00      .00       .00 !
                    ----------------------------------------

34      METWORK MACH+              PRICE ELASTICITIES

                            1        2        3         4
                          RAIL    WATER    TRUCK      PIPE
                    ----------------------------------------

        1  RAIL   !   -20.16             20.16           !

        2  WATER  !                                      !

        3  TRUCK  !     1.49             -1.49           !

        4  PIPE   !                                      !
                    ----------------------------------------
```

```
35    * OTH MACH EXC       DIEWERT COEFS (MULTIPLIED BY 1000)
                               1        2         3         4
                             RAIL     WATER     TRUCK      PIPE
                      -----------------------------------------

             1  RAIL   !    29.10       .00    216.80       .00 !
                T      !      .37       .00      2.82       .00 !

             2  WATER  !      .00       .00       .00       .00 !
                T      !      .00       .00       .00       .00 !

             3  TRUCK  !   216.80       .00    506.00       .00 !
                T      !     2.82       .00      6.77       .00 !

             4  PIPE   !      .00       .00       .00       .00 !
                T      !      .00       .00       .00       .00 !
                      -----------------------------------------
35      OTH MACH EXC              PRICE ELASTICITIES
                               1        2         3         4
                             RAIL     WATER     TRUCK      PIPE
                      -----------------------------------------

             1  RAIL   !     -.47                 .47           !
             2  WATER  !                                        !
             3  TRUCK  !      .15                -.15           !
             4  PIPE   !                                        !
                      -----------------------------------------


36      COMMUNICATION      DIEWERT COEFS (MULTIPLIED BY 1000)
                               1        2         3         4
                             RAIL     WATER     TRUCK      PIPE
                      -----------------------------------------

             1  RAIL   !   201.40       .00       .00       .00 !
             2  WATER  !      .00       .00       .00       .00 !
             3  TRUCK  !      .00       .00    782.60       .00 !
             4  PIPE   !      .00       .00       .00       .00 !
                      -----------------------------------------
36      COMMUNICATION             PRICE ELASTICITIES
                               1        2         3         4
                             RAIL     WATER     TRUCK      PIPE
                      -----------------------------------------

             1  RAIL   !                          .00           !
             2  WATER  !                                        !
             3  TRUCK  !      .00                               !
             4  PIPE   !                                        !
                      -----------------------------------------
```

```
37      ELEC MACH+EQP       DIEWERT COEFS (MULTIPLIED BY 1000)

                              1         2         3          4
                             RAIL     WATER     TRUCK       PIPE
                         ------------------------------------------

          1   RAIL   !   242.40       .00     34.10        .00 !
          2   WATER  !      .00       .00       .00        .00 !
          3   TRUCK  !    34.10       .00    674.30        .00 !
          4   PIPE   !      .00       .00       .00        .00 !
                         ------------------------------------------

37      ELEC MACH+EQP              PRICE ELASTICITIES

                              1         2         3          4
                             RAIL     WATER     TRUCK       PIPE
                         ------------------------------------------

          1   RAIL   !     -.05                 .05            !
          2   WATER  !                                         !
          3   TRUCK  !      .03                -.03            !
          4   PIPE   !                                         !
                         ------------------------------------------


38    * OTH TRANSP EQ       DIEWERT COEFS (MULTIPLIED BY 1000)

                              1         2         3          4
                             RAIL     WATER     TRUCK       PIPE
                         ------------------------------------------

          1   RAIL   !  -320.80       .00    791.10        .00 !
              T      !      .85       .00      2.17        .00 !

          2   WATER  !      .00       .00       .00        .00 !
              T      !      .00       .00       .00        .00 !

          3   TRUCK  !   791.10       .00   -309.70        .00 !
              T      !     2.17       .00       .87        .00 !

          4   PIPE   !      .00       .00       .00        .00 !
              T      !      .00       .00       .00        .00 !
                         ------------------------------------------

38      OTH TRANSP EQ              PRICE ELASTICITIES

                              1         2         3          4
                             RAIL     WATER     TRUCK       PIPE
                         ------------------------------------------

          1   RAIL   !     -.92                 .92            !
          2   WATER  !                                         !
          3   TRUCK  !      .73                -.73            !
          4   PIPE   !                                         !
                         ------------------------------------------
```

```
39        OTH SCRAP          DIEWERT COEFS (MULTIPLIED BY 1000)
                              1        2         3         4
                            RAIL     WATER     TRUCK      PIPE
                      ----------------------------------------
          1  RAIL   !   360.00       .00       .00       .00 !
          2  WATER  !      .00    540.60       .00       .00 !
          3  TRUCK  !      .00       .00       .00       .00 !
          4  PIPE   !      .00       .00       .00       .00 !
                      ----------------------------------------
39        OTH SCRAP                PRICE ELASTICITIES
                              1        2         3         4
                            RAIL     WATER     TRUCK      PIPE
                      ----------------------------------------
          1  RAIL   !                .00                       !
          2  WATER  !      .00                                 !
          3  TRUCK  !                                          !
          4  PIPE   !                                          !
                      ----------------------------------------
```

Appendix E

Estimation of Private Truck Coefficient Changes

Private truck service demands for industries in the INFORUM A matrix of I/O coefficients are represented by the component inputs into the production of truck services. There are nine major inputs, seven of which are listed above in Step 3 of Chapter V. The seven are 67: Miscellaneous Chemical Products, 76: Petroleum Refining, 77: Fuel Oil, 80: Tires and Inner Tubes, 145: Motor Vehicles, 183: Insurance, and 190: Auto Repair. The remaining two are the retail and wholesale trade margins. Besides representing private truck services they also represent inputs used for other purposes such as maintaining a private car fleet or other machinery. In order to calculate how much of the input coefficient needs to be adjusted to represent a change in demand for private truck services, a weight was calculated which represents the private truck share of each input. Even though the retail and wholesale margins are the largest components of truck services these private truck service components will generally represent very small portions of the total retail and wholesale coefficients. Since the effect of changing private truck demands would have little impact on these coefficients, no adjustment for private truck services were made for these two. For the remaining seven inputs the following weight, w_i, was calculated:

$$w_i = \frac{c_i \cdot RPT}{\sum_j a_{ij} \cdot Q_j} \qquad i = 1, \ldots, 7 \text{ inputs}$$

where

c_i = amount spent on component input i per dollar of total private truck revenue in 1972. Data was taken from JFA calculations.

RPT = private truck revenue in 1972 collected for each of the 45 JFA commodity categories listed in Table 5.1.

a_{ij} = I/O coefficient for private truck component input i per dollar of output j in 1972, taken from the INFORUM 1972 A matrix.

Q_j = INFORUM output of industry j measured in 1972 dollars. In the equation outputs are summed over all industries making up each JFA commodity category.

Unfortunately, the combining of two separate data sources -- JFA and INFORUM -- led to both the calculation of weights greater than one in some cases and to no weights at all in others where JFA private truck input expenditures had no corresponding INFORUM input flows. Of the 315 possible weights (45 sectors times seven inputs) eight percent were of the former type and nine percent were of the latter type. In fact, in many cases the two sets of data seemed inconsistent. In order not to introduce more error into the private truck inputs in the INFORUM sectors, three paths were followed. First, all private truck shares that were less than 20 percent of total truck were grouped with commercial truck and the commercial truck row was moved as if it represented all truck services. Where private truck component weights were less than ten percent of the total input the weight was dropped and the coefficient was moved by the normal INFORUM "across-the-row-change" adjustment. The remaining larger weights were retained and used to weight the private truck I/O changes estimated above.

Notes

Chapter I

[1] Clopper Almon et al., *1985: Interindustry Forecasts of the American Economy*, (Boston: D.C. Heath, 1974), p. 148.

[2] A full discussion of the INFORUM model appears in Clopper Almon et al., *Interindustry Forecasts*. For an update of the price side of the model see Clopper Almon, David Belzer, and Peter Taylor, "Prices in Input-Output: The INFORUM Experience in Modeling the U.S. Deregulation of Domestic Oil," *Journal for Policy Modeling* 1 (September 1979): 399-412.

[3] Wassily Leontief, *Studies in the Structure of the American Economy* (Oxford: Oxford Press, 1963), p. 18.

[4] Osmo Forssell, "Explaining Changes in Input-Output Coefficients for Finland," *Input-Output Techniques*, ed. A.P. Carter and A. Brody (Amsterdam: North-Holland Publishing Co., 1972) p. 345.

[5] The inevitability of product aggregation in I/O has been noted as far back as 1952; L.R. Klein, "On the Interpretation of Professor Leontief's System", *The Review of Economic Studies* vol.20 (1952-1953): 131.

[6] David Belzer, "An Integration of Prices, Wages, and Income Flows in an Input-Output Model of the United States" (Ph.D. dissertation, University of Maryland, 1978).

[7] U.S., Department of Commerce, Bureau of Economic Analysis, *Input-Output Structure of the U.S. Economy*, 1962, 1967, and 1972.

[8] Row totals can be calculated from U.S., Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures: Value of Product Shipments*.

[9] A full discussion of this work and its results can be found in Clopper Almon et al., *Interindustry Forecasts*, pp. 161-5.

[10] W.E. Diewert, "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function," *Journal of Political Economy* 79 (May/June 1971): 481-507.

Chapter II

[1] Beatrice N. Vaccara, "Changes Over Time in Input-Output Coefficients for the United States," *Applications of Input-Output Analysis*, ed. A.P. Carter and A. Brody, 2 vols. (Amsterdam: North

Holland Publishing Co., 1970) 2: 238-60.

[2] Reiver Staglin and Hans Wessels, "Intertemporal Analysis of Structural Change in the German Economy," *Input-Output Techniques*, pp. 370-92.

[3] Per Sevaldson, "The Stability of Input-Output Coefficients," *Applications of Input-Output Analysis*, 2:207-37.

[4] E. Fontela, A. Duval, A. Gabus, M. Borlin, and C. Verlay, "Forecasting Technical Coefficients and Changes in Relative Prices," *Applications of Input-Output Analysis*, 2:331-48.

[5] For a discussion of RAS balancing see Michael Bacharach, "Estimating Non-negative Matrices from Marginal Data," *International Economic Review* 6 (September 1965): 294-309.

[6] William Peterson, "Factor Demand Equations and Input-Output Analysis," paper presented at the Sixth International Conference on Input-Output Techniques, Vienna, Austria, 22-26 April, 1974. (Mimeographed.)

[7] Kattamuri S. Sarma, "Comparative Performance of Input-Output Models with Alternative Production Functions" (Ph.D. dissertation, University of Pennsylvania, 1972), Abstract, p. 5.

[8] W. Halder Fisher and Cecil H. Chilton, "Developing ex ante Input-Output Flow and Capital Coefficients," *Input-Output Techniques* pp. 393-405.

[9] Henri Aujac, "New Approaches in French National Planning: Input-Output Tables and Technological Forecasting," *Input-Output Techniques* pp. 406-20.

[10] Forssell, "Explaining Changes in Coefficients," pp.343-69.

[11] W.E. Diewert, "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function," pp. 481-507.

[12] Richard W. Parks, "Price Responsiveness of Factor Utilization in Swedish Manufacturing, 1870-1950," *The Review of Economics and Statistics* 53 (May 1971): 129-39.

[13] Peterson, "Factor Demand Equations."

[14] David B. Humphrey, "Substitution in an Input-Output Table," Interindustry Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce (mimeographed, n.d.)

[15] Vaccara, "Changes Over Time in Input-Output Coefficients," p. 254.

[16] A discussion of the translog function can be found in Laurits R. Christensen, Dale W. Jorgenson, and Lawrence J. Lau, "Transcendental Logarithmic Production Frontiers," The Review of Economics and Statistics 55 (February 1973): 28-45.

[17] Wassily Leontief defines and discusses the implications of separability in terms of input-output coefficients in "Introduction to a Theory of the Internal Structure of Functional Relationships," Econometrica 15 (October 1947): 361-73.

[18] David B. Humphrey and J.R. Moroney," Substitution Among Capital, Labor, and Natural Resource Products in American Manufacturing," Journal of Political Economy 83 (February 1975): 57-82.

[19] R. Halvorsen, "Energy Substitution in U.S. Manufacturing," The Review of Economics and Statistics 59 (November 1977): 381-8.

Chapter III

[1] This proof was developed for deriving consumer demand equations in Clopper Almon Jr., Matrix Methods in Economics. (Reading, Massachusetts: Addison - Wesley Co.,1967) pp. 94-95.

[2] Paul A. Samuelson, Foundations of Economic Analysis (Cambridge: Harvard University Press, 1947; reprint ed., New York: Antheneum, 1972) : 61-65.

[3] Ibid., p. 69.

[4] R.W. Shephard, Cost and Production Functions (Princeton: Princeton University Press, 1953)

[5] Diewert, "Generalized Leontief Production Function," pp. 481-507.

[6] Halvorsen, "Energy Substitution," pp. 381-8.

[7] Christensen, "Transcendental Logarithmic Production Frontiers," pp. 28-45.

Chapter IV

[1] All designated sector names in this dissertation will begin with captial letters to distinguish them from generic groupings.

[2] U.S., Department of Commerce, Bureau of the Census, Annual Survey of Manufactures, 1975: Fuels and Electric Energy Consumed, pp. 1-11 ;1977 Census of Manufactures, Fuels and Electric Energy Consumed, MC77-SR-4(Part 3), p. 4.

[3] Halvorsen, "Energy Substitution," pp. 381-8.

[4] E.R. Berndt and D. Wood, "Engineering and Econometric Interpretations of Energy-Capital Complementarity," *The American Economic Review* 69 (June 1979): 342.

[5] Melvyn Fuss, "The Demand for Energy in Canadian Manufacturing," *Journal of Econometrics* 5 (January 1977): 109.

[6] Ibid.

[7] When fewer than three firms exist in a state, data is often withheld in order to avoid the disclosure of privileged firm information.

[8] U.S., Department of Commerce, Bureau of the Census, *Annual Survey of Manufacturers, 1975: Fuels and Electric Energy Consumed.*; *Annual Survey of Manufactures, 1975: Statistics for States, Standard Metropolitan Statistical Areas, Large Industrial Counties, and Selected Cities.*

[9] Jan Kmenta, *Elements of Econometrics* (New York: Macmillan Co., 1971) p. 257.

[10] U.S., Census, *Fuels and Electric Energy Consumed: 1975,* p. 11.

[11] The remaining price differential reflects transportation costs for foreign oil.

[12] U.S., Department of Commerce, Bureau of Census, *Annual Survey of Manufactures: Fuels and Electric Energy Consumed,* 1974, 1975, and 1976; U.S. Department of Commerce, Bureau of the Census, *1972 Census of Manufactures, Fuels and Electric Energy Consumed, Special Report Series* MC 72 (SR)-6.

[13] *Environmental Qualities, The First Annual Report of the Council of Environmental Quality* (U.S. Government Printing Office: August 1970) pp. 84-85.

[14] Interview with Mike Zemmer, American Gas Associates, Washington, D.C., 15 July, 1979.

Chapter V

[1] Unpublished data provided by Jack Faucett Associates, Inc., Chevy Chase, Maryland, 1977.

[2] The ratio of inputs to industry output is sometimes refered to as a "market quotient"; see Almon et al., *1985: Interindustry Forecasts*, p. 189.

[3] A majority of inter-modal shipping generally involves short distance shipping by all but the least expensive mode. This is because zero back hauling created by most inter-modal transfers prohibits all but the shortest trips by more expensive modes. These short distance hauls, according to Jack Faucett Associates, would not appear in their intercity shipments data, which is the source here, leaving each ton accounted for by only the primary mover.

A well known example of inter-modal transfers, piggyback trailers on flat cars, although a possible generater of doubly counted tons hauled is also discounted because it accounts for only two percent of rail freight tonnage as reported by the Task Force on Railroad Productivity in Improving Railroad Productivity: Final Report, Report to the National Commission on Productivity and the Council of Economic Advisers (Washington, D.C.: November, 1973) p. 143.

[4] For a derivation of the logistic curve technique, see Clopper Almon and Margaret Buckler, "Logistic Growth Curves for Coefficients," Research Memorandum No. 32, Maryland Interindustry Forecasting Project, 1971.

[5] The remaining six Faucett sectors have only one major mode of transport and, therefore, are not appropriate for the Diewert technique.

[6] Transportation Association of America, Transportation Facts and Trends (Washington, D.C.: July 1978) p. 9.

[7] U.S. Department of Commerce, Bureau of the Census, Census of Transportation: 1963, 1967, 1972, Vol. III, Part 1.

[8] U.S., Interstate Commerce Commission, Bureau of Economics, Transport Economics, Vol. III, No. 2, 1976; Vol. V, No. 1, 1978.

[9] Ibid.

[10] For a full discussion of the modal choice decision see Paul O. Roberts, Development of a Policy Sensitive Model for Forecasting Freight Demand, Phase 1 Report, U.S. Department of Transportation, Office of Transportation Systems Analysis and Information (Washington, D.C.: April 1977) p. 12-15.

[11] For modal split studies involving aggregate commodity shipments data see A.L. Morton, Competition in the Intercity Freight Market: A Waybill Study of the Motor Carrier Industry, U.S. Transportation Department, Office of the Secretary (February 1971). For modal split studies using cross-commodity data see Mark S. Jelavich, "A Study of the Determinants of Freight Modal Choice," Working Paper 159-2, Jack Faucett Associates, Inc., Chevy Chase, Maryland, (3 January 1977); or Ann Friedlander, Alternative Scenarios for Federal Transportation Policy, Second Year Report: Freight Policy Models, Center for Transportation Studies, M.I.T. (Cambridge, Massachusetts: 1 February 1978).

[12] Roberts, <u>Development of a Policy Sensitive Model</u>, "A Review of Available Data," Appendix B, p. B10.

[13] Friedlander, <u>Alternative Scenarios</u>, p. 144.

[14] John R. Meyer, et al., <u>The Economics of Competition in the Transportation Industries</u> (Cambridge: Harvard University Press, 1959) p. 194.

[15] For example see Jelavich, "Determinants of Freight Modal Choice," or Friedlander, <u>Alternative Scenarios</u>.

[16] Roberts, <u>Development of a Policy Sensitive Model</u>, p. 16.

[17] Ibid.

[18] Task Force on Railroad Productivity, <u>Improving Railroad Productivity</u>, pp. 32-3.

[19] Jan Kmenta, <u>Elements of Econometrics</u>, (New York: Macmillan Co., 1971) pp. 302-3.

[20] For a futher discussion of the skirt technique see Almon, et al., <u>1985: Interindustry Forecasts</u>, pp. 188-97.

[21] The seven remaining Faucett sectors have only one major mode of transport and, therefore, are not appropriate for the Diewert technique. To the six previously mentioned has been added Metal Working Machinery which ships predominately by truck even though a Diewert equation was estimated for it above.

[22] Transportation Association of America, <u>Facts and Trends</u>, 1979, p. 10.

[23] For a detailed discussion of the INFORUM wage-price model see David Belzer, "An Integration of Prices, Wages, and Income Flows in an Input-Output Model of the U.S." (Ph.D. dissertation, University of Maryland, 1978).

[24] U.S., Bureau of Census, <u>Census of Transportation: 1972</u>, Vol. III, Part 1.

[25] For a description of the distance of haul adjustment technique see Jack Faucett, "The Department of Transportation Long Range Forecast Model, Final Report", Jack Faucett Associates, Chevy Chase, Maryland, (March 1978).

Chapter VI

[1] Halverson, "Energy Substitution," p. 387.

[2] E.R. Berndt and D. Wood, "Technology, Prices and the Derived Demand for Energy," The Review of Economics and Statistics 57 (August 1975): 259-68.

Selected Bibliography

Almon, Clopper, Jr. *Matrix Methods in Economics.* Reading, Massachusetts: Addison-Wesley Publishing Company, Inc. 1967.

________, et al., *1985: Interindustry Forecasts of the American Economy,* Boston: D.C. Heath, 1974.

________, and Buckler, Margaret. "Logistic Growth Curves for Coefficients." Research Memorandum No. 32. Maryland Interindustry Forecasting Project, 1971.

________; Belzer, David; and Taylor, Peter. "Prices in Input-Output: The INFORUM Experience in Modeling the U.S. Deregulation of Domestic Oil." *Journal for Policy Modeling* 1 (September 1979).

Aujac, Henri. "New Approachs in French National Planning: Input-Output Tables and Technological Forecasting." In *Input-Output Techniques*. Edited by A.P. Carter and A. Brody. Amsterdam: North Holland Publishing Co., 1972.

Bacharach, Michael. "Estimating Non-negative Matrices from Marginal Data." *International Economic Review* 6 (September 1965).

Belzer, David. "An Integration of Prices, Wages, and Income Flows in an Input-Output Model of the United States." Ph.D. dissertation, University of Maryland, 1978.

Berndt, E.R. and Wood, D. "Engineering and Econometric Interpretation of Energy-Capital Complementarity." *The American Economic Review* 69 (June 1979).

________. "Technology, Prices and the Derived Demand for Energy." *The Review of Economics and Statistics* 57 (August 1975).

Christensen, Laurits R.; Jorgenson, Dale W.; and Lau, Lawrence J. "Transcendental Logarithmic Production Frontiers." *The Review of Economics and Statistics* 55 (February 1973).

Diewert, W.E. "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function." *Journal of Political Economy* 79 (May/June 1971).

Environmental Qualities: The First Annual Report of the Council of Environmental Quality. Washington, D.C.: Government Printing Office, August 1970.

Faucett, Jack. "The Department of Transportation Long Range Forecast Model, Final Report." Jack Faucett Associates. Chevy Chase, Maryland, March 1978.

Fisher, Halder and Chilton, Cecil H. "Developing ex ante Input-Output Flow and Capital Coefficients." *Input-Output Techniques*. Edited by A.P. Carter and A. Brody. Amsterdam: North Holland Publishing Co., 1972.

Fontela, A. Duval et al. "Forecasting Technical Coefficients and Changes in Relative Prices." *Applications of Input-Output Analysis*. Edited by A.P. Carter and A. Brody. 2 Vols. Amsterdam: North Holland Publishing Co., 1970.

Forssell, Osmo. "Explaining Changes in Input-Output Coefficients for Finland." *Input-Output Techniques.* Edited by A.P. Carter and A. Brody. Amsterdam: North Holland Publishing Co., 1972.

Friedlander, Ann. *Alternative Scenarios for Federal Transportation Policy. Second Year Report: Freight Policy Models.* Center for Transportation Studies. M.I.T. Cambridge, Massachusetts, 1978.

Fuss, Melvyn. "The Demand for Energy in Canadian Manufacturing." *Journal of Econometrics* 5 (January 1977).

Halvorsen, R. "Energy Substitution in U.S. Manufacturing." *The Review of Economics and Statistics* 59 (November 1977).

Humphrey, David B. "Substitution in an Input-Output Table." Interindustry Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce (mimeographed, n.d.).

________ and Moroney, J.R. "Substitution Among Capital, Labor, and Natural Resource Products in American Manufacturing." Journal of Political Economy 83 (February 1975).

Jelavich, Mark S. "A Study of the Determinants of Freight Modal Choice." Working paper 159-2. Jack Faucett Associates, Inc. Chevy Chase, Maryland, 3 January 1971.

Klein, L.R. "On the Interpretation of Professor Leontief's System." *The Review of Economic Studies* 20 (1952-1953).

Kmenta, Jan. *Elements of Econometrics*. New York: Macmillan Co., 1971.

Leontief, Wassily. "Introduction to a Theory of the Internal Structure of Functional Relationships." *Econometrica* 15 (October 1947).

________. *Studies in the Structure of the American Economy*. Oxford Press, 1963.

Meyer, John R. et al. The Economics of Competition in the Transportation Industries. Cambridge: Harvard University Press, 1959.

Morton, A.L. Competition in the Intercity Freight Market: A Waybill Study of the Motor Carrier Industry. U.S. Transportation Department, Office of the Secretary, February 1971.

National Commission on Productivity and Council of Economic Advisors. Improving Railroad Productivity: Final Report. Washington, D.C.: Government Printing Office, November, 1973.

Parks, Richard W. "Price Responsiveness of Factor Utilization in Swedish Manufacturing, 1870-1950." The Review of Economics and Statistics 53 (May 1971).

Peterson, William. "Factor Demand Equations and Input-Output Analysis." Paper presented at the Sixth International Conference on Input-Output Techniques. Vienna, Austria: 22-26 April, 1974. (Mimeographed.)

Roberts, Paul D. Development of a Policy Sensitive Model for Forecasting Freight Demand. Phase 1 Report. U.S. Department of Transportation. Office of Transportation Systems Analysis and Information. Washington, D.C.: April 1977.

Samuelson, Paul A. Foundations of Economic Analysis Cambridge: Harvard University Press, 1947. Reprint edition. New York: Antheneum, 1972.

Sarma, Kattamuri S. "Comparative Performance of Input-Output Models with Alternative Production Funtions." Ph.D. dissertation, University of Pennsylvania, 1972.

Sevaldson, Per. "The Stability of Input-Output Coefficients." Applications of Input-Output Analysis. Edited by A.P. Carter and A. Brody. 2 Vols. Amsterdam: North Holland Publishing Co., 1970.

Shephard, W. Cost and Production Functions. Princeton: Princeton University Press, 1953.

Staglin, Reiver and Wessels, Hans. "Intertemporal Analysis of Structural Change in the German Economy." Input-Output Techniques. Edited by A.P. Carter and A. Brody. Amsterdam: North Holland Publishing Co., 1972.

Transportation Association of America. "Transportation Facts and Trends." Washington, D.C., July 1978.

U.S. Department of Commerce. Bureau of Economic Analysis. Input-Output Structure of the U.S. Economy. 1962, 1967, 1972.

_______. Bureau of the Census. Annual Survey of Manufacturers. 1974 (1975, 1976): Fuels & Electric Energy Consumed.

________. *Annual Survey of Manufactures: Value of Product Shipments.*

________. *Annual Survey of Manufactures, 1975: Statistics for States, Standard Metropolitan Statistical Areas, Large Industrieal Counties and Selected Cities.*

________. *1972 Census of Manufacturers, Fuels and Electric Energy Consumed*. Special Report Series MC 72 (SR)-6; *1977 Census of Manufacturers, Fuels and Electric Energy Consumed*. MC 77 (SR)-4.

________. *Census of Transportation: 1963 (1967, 1972).* Vol. III, Part 1.

U.S. Interstate Commerce Commission. Bureau of Economics. *Transport Economics*. Vol. III, No.2, 1976

Vol. V, No. 1, 1978.

Vaccara, Beatrice N. "Changes Over Time in Input-Output Coefficients for the United States." *Applications of Input-Output Analysis.* Edited by A.P. Carter and A. Brody. 2 Vols. Amsterdam: North Holland Publishing Co., 1970.

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