8-1979

An economic model of Tennessee's lumber and wood products industry

Robert C. Abt

To the Graduate Council:

I am submitting herewith a thesis written by Robert C. Abt entitled "An economic model of Tennessee's lumber and wood products industry." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

David M. Ostermeier, Major Professor

We have read this thesis and recommend its acceptance:

G. R. Wells, David A. Hake

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Robert C. Abt entitled "An Econometric Model of Tennessee's Lumber and Wood Products Industry." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

David M. Ostermeier
David M. Ostermeier, Major Professor

We have read this thesis
and recommend its acceptance:

D. R. Wells

David A. Haken

Accepted for the Council:

L. E. von Roth
Vice Chancellor
Graduate Studies and Research

AN ECONOMETRIC MODEL OF TENNESSEE'S LUMBER AND WOOD PRODUCTS INDUSTRY

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Robert C. Abt

August 1979

ACKNOWLEDGEMENTS

The author is deeply indebted to those persons who have made this study possible.

Special appreciation is due to Dr. David M. Ostermeier for his valuable suggestions, continued confidence, and special friendship during the author's graduate program. His positive influence on this and all subsequent work by the author is gratefully acknowledged.

Recognition and appreciation is extended to Dr. G. R. Wells for his valuable assistance during several crucial phases of the study as a member of the author's graduate committee. The author is also indebted to Dr. David A. Hake for his contributions and generous assistance as a committee member.

The author is appreciative to Dr. Thomas H. Klindt and Dr. John C. Meadows for their assistance in the initial phase of the study, and to Patricia Price for her help in accumulating and refining the data.

Appreciation is also expressed to Sheila Ray, for her editorial and typing assistance, as well as to Lavonda Phelps and Lou Powers for their assistance in typing the original draft.

The author is especially indebted to his wife, Dona, whose continuous encouragement and support provided the inspiration and motivation necessary to accomplish the study.

The facilities for the study were provided by the Department of Forestry, Wildlife, and Fisheries and the Center for Business and Economic Research at The University of Tennessee, Knoxville.

ABSTRACT

The purpose of this study was to provide a better understanding of the contribution of the Tennessee lumber and wood products industry to the state economy. The approach taken was to develop equations that quantified historical relationships relevant to the lumber and wood products industry. This methodology provided a separate sector, consistent with the state econometric model for the lumber and wood products industry.

The Tennessee Econometric Model (TEM II) provided the basic framework within which the lumber and wood products equations were formulated. The framework for the manufacturing sector equations in TEM II consists of separate equations for forecasting output, employment, and wages. This basic structure was used in formulating the Tennessee lumber and wood products equations.

The constraints associated with working within the TEM II framework were considered significant in this study. In order to better identify structural relationships in the industry, an alternative set of output equations was developed for structural/simulation analysis. These equations were formulated using a different set of statistical and economic criteria than the forecasting equations.

The equations resulting from the study provide valuable information about the performance of the lumber and wood products industry in the state economy. The forecasting equations, in their current form,

provide forecasts for the industry in terms of output, employment, and wages for the 1979-1986 time period.

The final form of the simulation equation provides a statistically valid method of impact analysis. Specifically, the impact of changes in the furniture and housing markets on the state lumber industry can be tentatively identified.

Though the equations may not be incorporated into the state econometric model in their current form, the research accomplished in their formulation is valuable as a basis for further study of the industry. Additional research is needed to determine if the hardwood industry can be analyzed adequately as a separate sector of the state econometric model and/or by developing a more detailed satellite model.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

Determining the "importance"[1] of the forest products industries has been one of the focal points of forest economic analysis. The use of descriptive statistics on a county, state, regional, or national level has been widespread in order to provide a quantitative estimate of the relative position of wood-based industries in the economy.

The need for this type of information is not limited to forest industry. The rising importance of regional and/or industry economic analysis over the last 20 years has been due, in large part, to the need for more detailed information regarding all sectors of the economy. Broad aggregate national economic indicators (Gross National Product and Housing Starts, for example) provide only limited information for both public and private policy decisions.

Generally available detailed statistics are usually two to three years out of date by the time they are accumulated and published. Though these figures are useful, their utility is limited to providing a historical perspective. Even current statistics would be of limited value,

---

[1]"Importance" is often derived by interpreting the available descriptive statistics. In this study, the importance of the Tennessee lumber industry is derived by analyzing the dynamic properties of its output, employment, and wages.

since they would reveal only static relationships. Sound decision-making requires not only an understanding of the current economic environment, but a view of the future.

Since a view of the future is implicit in the decision-making function, the decision-maker (consciously or unconsciously) interprets the available information as to its probable meaning for the future. Economic modeling supplements the judgemental outlook of the individual decision-maker with a more objective forecast based on quantitative historical relationships.

The need for information on future expectations, coupled with the need for current disaggregated data, provides the impetus for regional econometric forecasting. In Tennessee, this effort has taken the form of a state model that is driven by forecasts from a national econometric model. The current version of the Tennessee Econometric Model (TEM II) disaggregates the state economy into components. Specifically, the manufacturing sector is broken down into 13 sectors. Forecasts and simulations are possible in terms of output, employment, and wages for each of these sectors. The wealth of information the model provides has proven valuable in terms of research applications, policy formulation, and business decision-making.

TEM II is maintained by the Center for Business and Economic Research at The University of Tennessee, Knoxville. The model is constantly being updated, and forecasts are made to reflect the most recent developments in the national and state economic environment. Currently, two of the three wood-based industry sectors are disaggregated in the model, these being furniture and fixtures (Standard Industrial Code (SIC) 25), and paper and allied products (SIC 26). In order to better understand the current and future roles of the forest products industries in the Tennessee economy, lumber and wood products (SIC 24) should be developed as a separate sector, in contrast to its current designation as part of the "Other Durables" sector.

This thesis reflects a first effort toward developing a lumber and wood products sector in the state econometric model. Benefits of developing such a sector of the state model are numerous. Among them are: (1) forecasting within the context of the state economy provides a better understanding of the dynamic role of the industry in the past as well as the future, (2) a sector structurally consistent with the state model would facilitate meaningful interpretation of an aggregate primary wood-using sector (SIC 24, 25, 26), (3) TEM II is maintained by an in-place support structure, with developed channels of information dissemination. Further, the development of this sector model will provide the opportunity to assess the data limitations and possible structure of a more detailed model of the industry.

I. OBJECTIVES

The general objective of this study was to assess the current and future economic contribution of the lumber and wood products industry in Tennessee. This dynamic estimate of the industry's economic role should be easily updated to take advantage of the most recent data available.

Specifically, the objectives were as follows:

(1) Develop equations that relate the performance of the state lumber and wood products industry (in terms of output, employment, and wages) to national and/or state variables for which forecasts are readily available.

(2) Develop equations that are consistent in definition and structure to the sectoral equations of the Tennessee Econometric Model.

(3) Identify, through the use of the equations, the key variables (of those studied) affecting lumber and wood products output.

(4) Forecast (both short-term, 1979-1981, and long-term, 1982-1986) the probable performance of the Tennessee lumber and wood products industry, given the forecast of the key variables mentioned above.

II. THE LUMBER AND WOOD PRODUCTS INDUSTRY IN TENNESSEE

Product Mix and Structure

One characteristic of the lumber industry[2] is that its structure and product mix in any particular geographic area is largely determined

---

[2]Throughout this paper, the term "lumber industry" refers to the Lumber and Wood Products industry, Standard Industrial Code (SIC) 24, as defined in the SIC Manual (52, p. 90).

by the constraints of the resource base. Over 80 percent of the sawtimber and growing stock volume in Tennessee is hardwood. In 1970, over 87 percent of the roundwood output was hardwoods, with southern pine accounting for most of the remaining softwood output (48). Though 1970 figures indicate that Tennessee was a net importer of sawlogs, the total amount of imports amounted to less than 10 percent of total sawlog production (29). Given these figures, it follows that the performance of the state lumber industry is largely determined by the markets available for hardwood lumber. This is almost the reciprocal of the situation found on the national level, where the softwood markets (particularly housing) dominate the industry. The significance of these differences to this study will be discussed later.

Figure 1 illustrates the 1972 breakdown of Tennessee's total value added in lumber by SIC 24 sub-industries.[3] Sawmills and planning mills (SIC 242) accounted for nearly half of the total value added in 1972. Hardwood dimension and flooring is a subcategory of SIC 242 and, as such, accounted for nearly 20 percent of the total lumber value added. Another 20 percent was accounted for by the millwork and veneer category (SIC 243). It can be assumed that hardwood roundwood is the primary input in all of the categories mentioned.

---

[3]The precise definition of value added by manufacture is as follows: The measure of manufacturing activity derived "by subtracting the cost of materials, supplies, containers, fuel, purchased electricity and contract work from the value of shipments for products manufactured plus receipts for services rendered. The result of this calculation is then adjusted by the addition of value added by merchandising operations ... plus the net change in finished goods and work-in-progress inventories between the beginning and end of the year." (45, 1976, p. B2) Note - value added is not equivalent to total production but, in this context, is a net concept approximating contribution to gross state product.

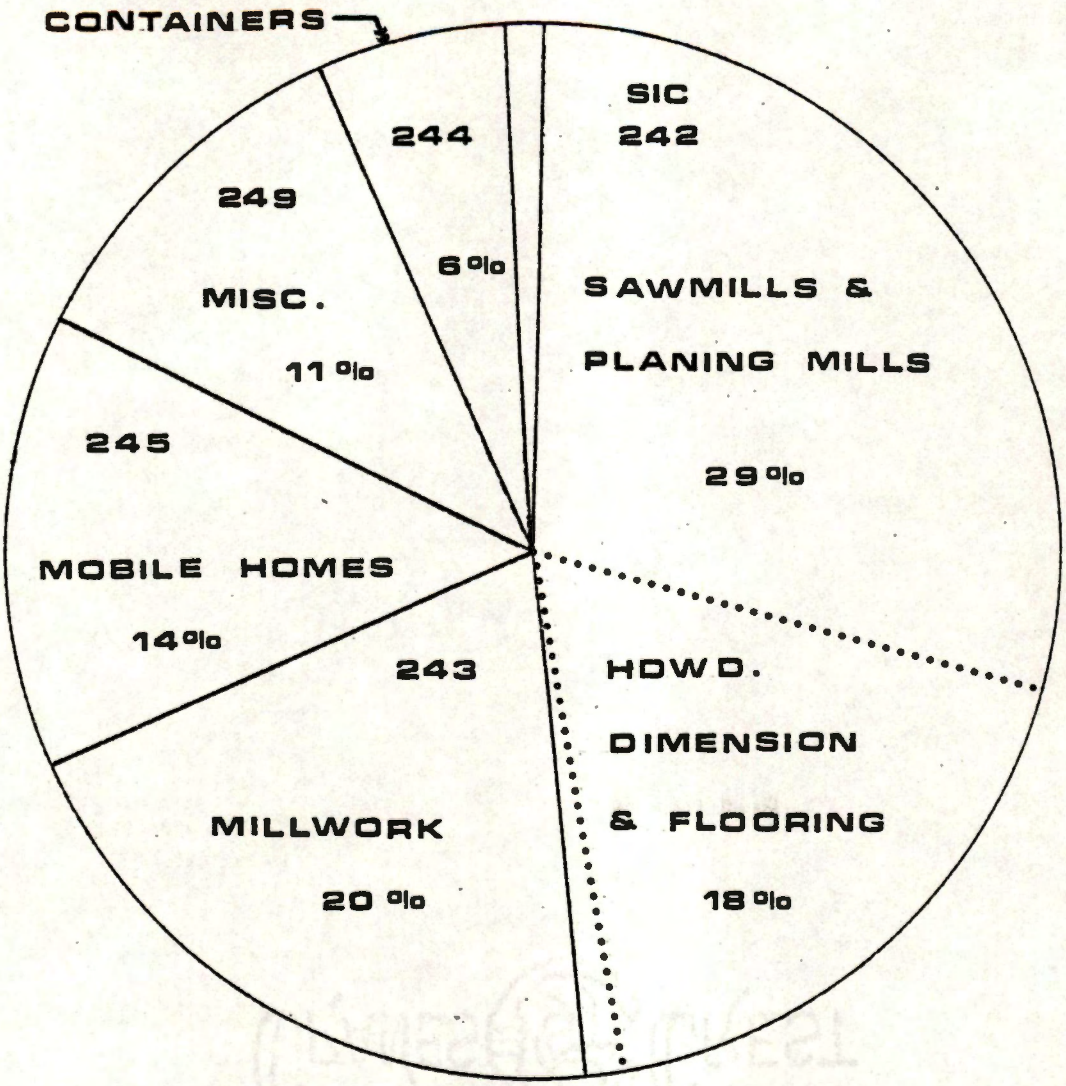

Figure 1. Industry Share of Tennessee SIC 24 Value-Added in 1972.

Source: (47)

In 1972, the definition of SIC 24 (specifically SIC 245) was expanded to include the production of mobile homes (52). This change elevated the importance of this subcategory to about 14 percent of the state's SIC 24 output. The changing importance of the products included in SIC 24 is shown in Figure 2. The sudden increase in importance of the wood buildings and mobile homes category (SIC 245) is one of the more pronounced changes. Though sawmills and planing mills continue to dominate output, as measured by value added, the difference in importance between the mill work and sawmill categories has steadily declined since 1963, giving a better balance to the product mix. Though the product mix will continue to change, the direction and magnitude of the change will be determined largely by the hardwood markets.

Historically, the Tennessee lumber industry has been labor intensive and, as such, consisted of many small mills (with minimal capital investments) that would tend to gear up or go out of business as business cycles (demand) dictated. There have been, however, significant changes in the last 30 years. Since the end of World War II, the number of active sawmills has decreased from 2800 to a figure of 546 in 1970. During the 1960's, this change in structure was accelerated. Though production dropped, the small, intermittent producers were being replaced by larger, more efficient sawmills, to the point that the number of large sawmills more than doubled between 1960 and 1970 (3). This substitution of capital for labor probably accounted for an increase in productivity in the industry.

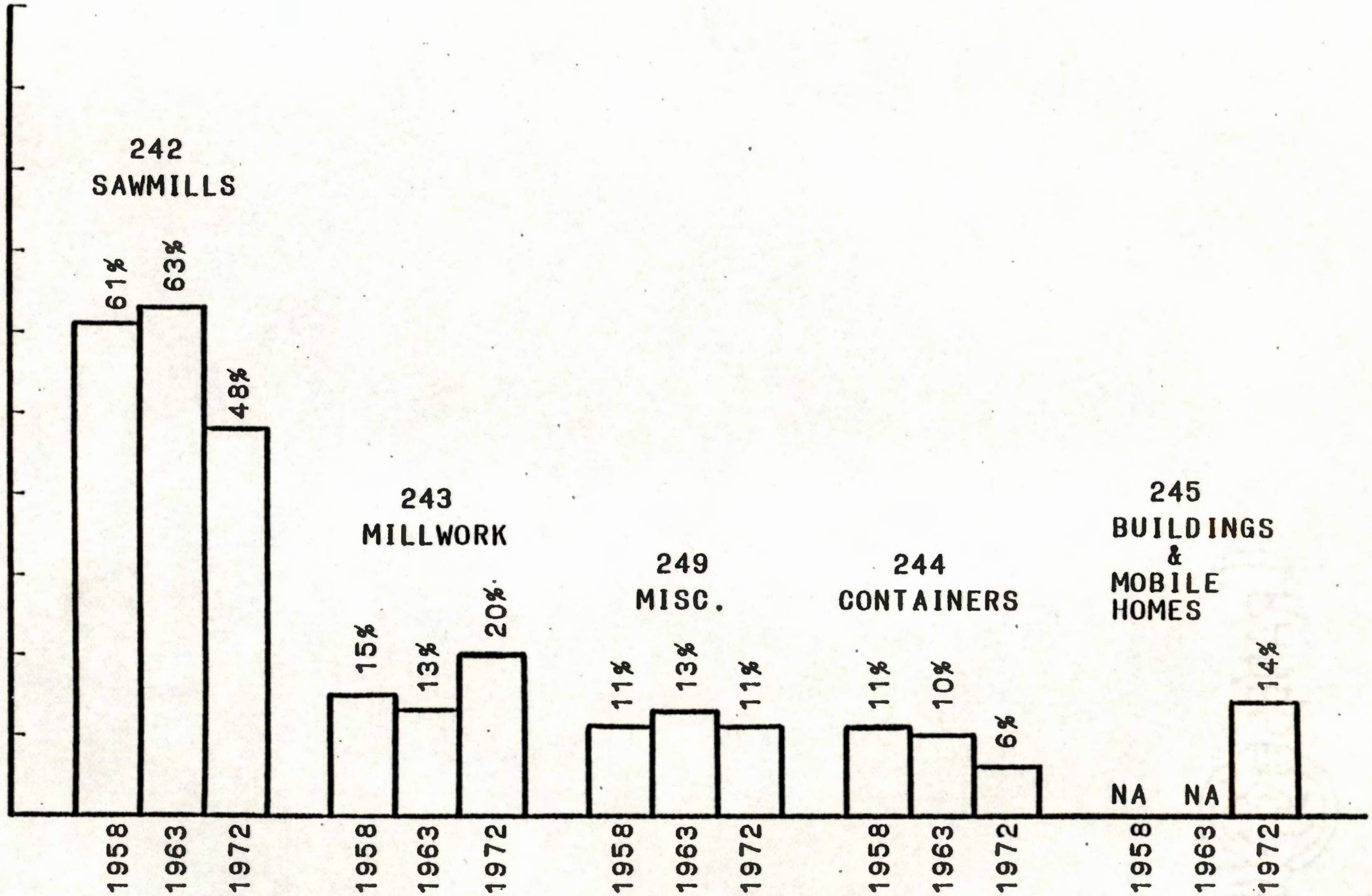

Figure 2, Industry Percentage of Tennessee SIC 24 Value-Added 1958-1972.

Source: (46, 47)

The Lumber Industry in the State's Economy

Output. In order to gain a perspective of the lumber industry's role in the Tennessee economy, it is important to have a valid measure of comparison. Value added by manufacture is recognized generally as "the best value measure available for comparing the relative economic importance among industries and geographic areas" (45, 1976, p. B2). It is used as a proxy of output throughout this paper. The relative importance of the major manufacturing industries in Tennessee is shown in Figure 3. Manufacturing, as a whole, comprised about 35 percent of the state's estimated total production in 1976, making it by far the most important sector of the economy in terms of percentage share of estimated Gross State Product (GSP). The lumber industry was a relatively small part of the total manufacturing effort. It should be noted, however, that if the state's primary wood-using industries (lumber and wood products, furniture and fixtures, and paper and allied products) are grouped together they would rank behind only the chemical and food industries in importance to Tennessee's manufacturing economy.

Employment. As mentioned earlier, the state lumber industry is relatively labor intensive and consists of many small firms. Though there has been a pronounced trend toward larger mills, 1977 data published by the Tennessee Department of Economic and Community Development show that of the total 564 SIC 24 operations, 231 are sawmills and planing mills which average only 7 workers per location (7).[4]

---

[4]The employment figures of the Tennessee Department of Economic and Community Development are gathered by their own survey and are not directly comparable to the Bureau of Labor Statistics figures used in the industry analysis in Chapter III.

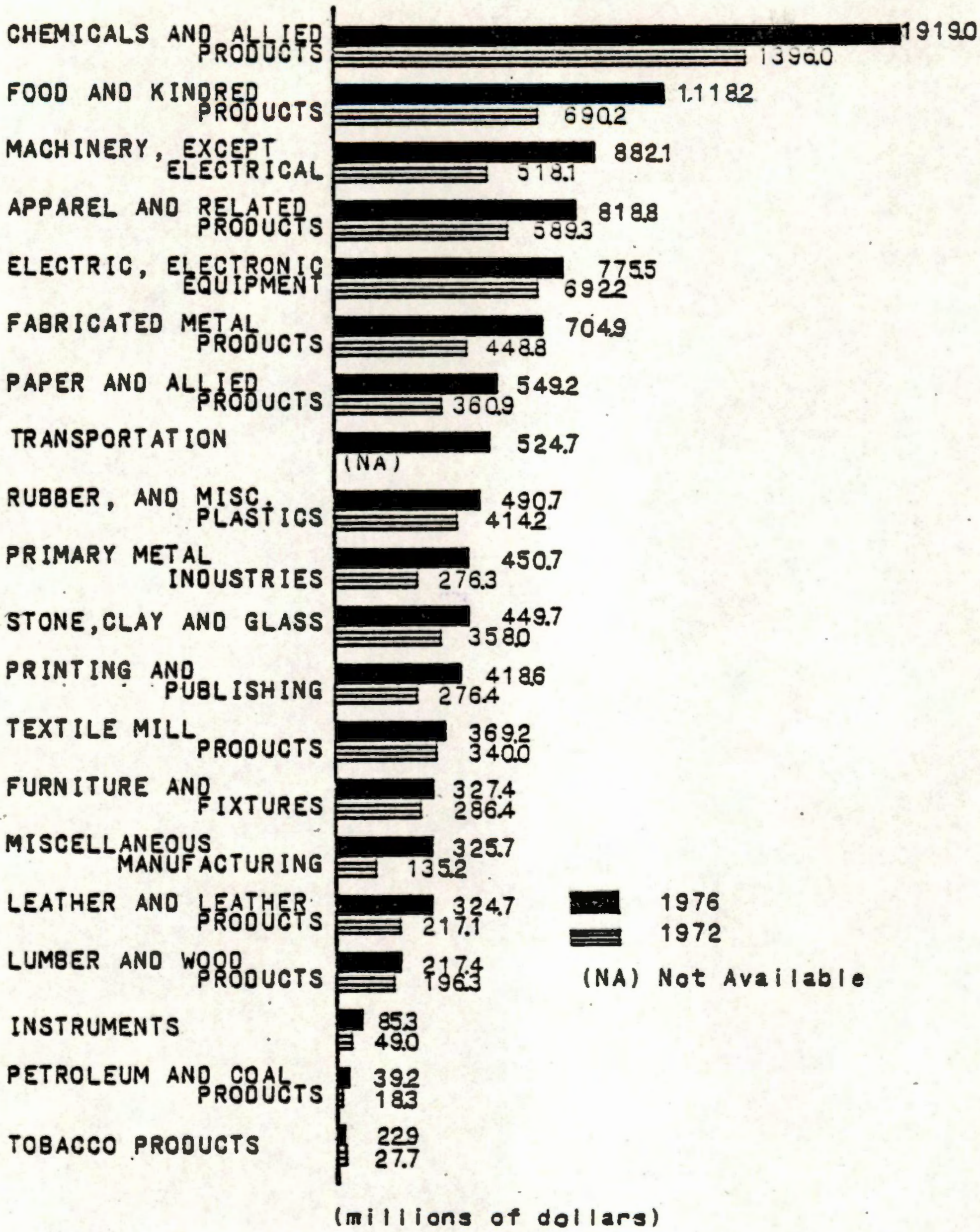

Figure 3. Tennessee Value-Added by Industry Group.

Source: (45, 47)

The relative labor intensity of the lumber industry is verified by noting that in 1976 the lumber industry accounted for 2 percent of the state's manufacturing production but employed 3.7 percent of its manufacturing workers. Figure 4 shows the breakdown of manufacturing employment in Tennessee. The uniform distribution of SIC 24 employment in the state is illustrated in Figure 5.

Wages. The Tennessee lumber sector historically has been a low wage scale industry. The trends in the annual average wage and salary of the state lumber industry are shown in Figure 6. Both nominal and constant dollar figures are plotted. The 1976 figure of 7,098 dollars (in current dollars) is lowest of the manufacturing sectors reported by the Center for Business and Economic Research, though not substantially different from the 7,768 dollar figure reported for the furniture industry. The growth in real wages averaged 1.9 percent annually for the 1958-1977 period. This compares with a 2.2 percent annual increase in the real hourly wage for the United States lumber industry and a 2.1 percent annual increase in the real weekly wage for all U. S. industries. The wage and salary figures for the 1968 through 1976 time period indicate that nominal wages in Tennessee lumber and wood products grew by an annual rate of 6.7 percent. This figure compares with a 6.9 percent increase for all wages and salaries in the state, and a 7.1 percent increase for the Tennessee manufacturing sector as a whole.

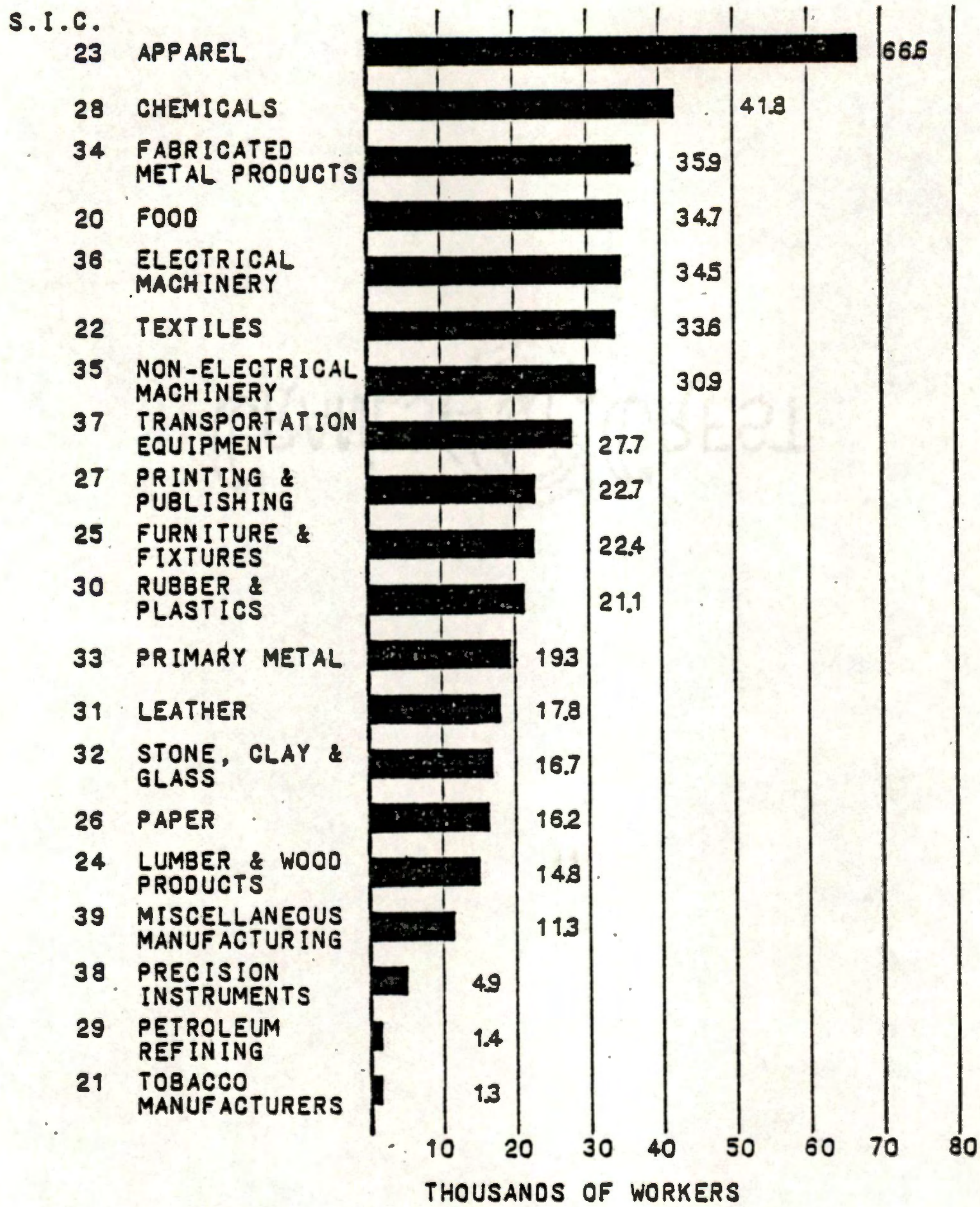

Figure 4. Tennessee Employment by Industry Group.

Source: (40)

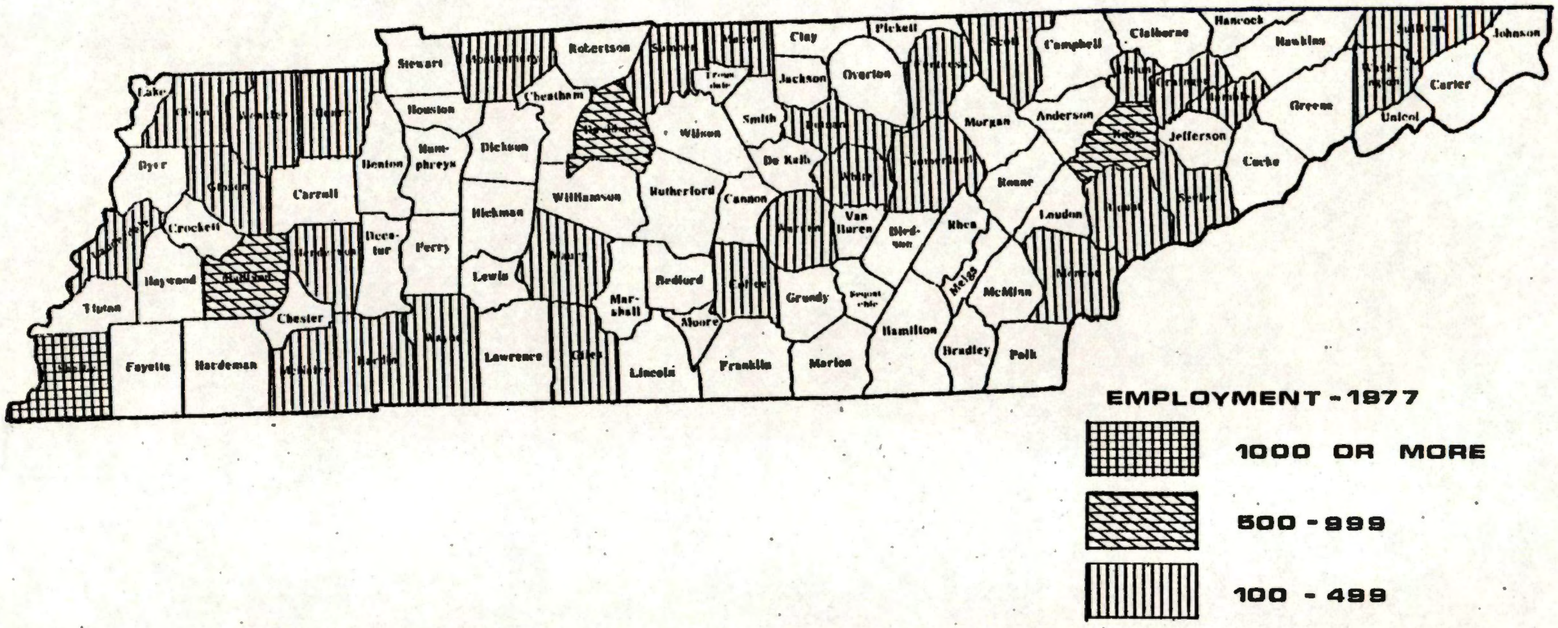

Figure 5. Distribution of Tennessee SIC 24 Employment.

Source: (40)

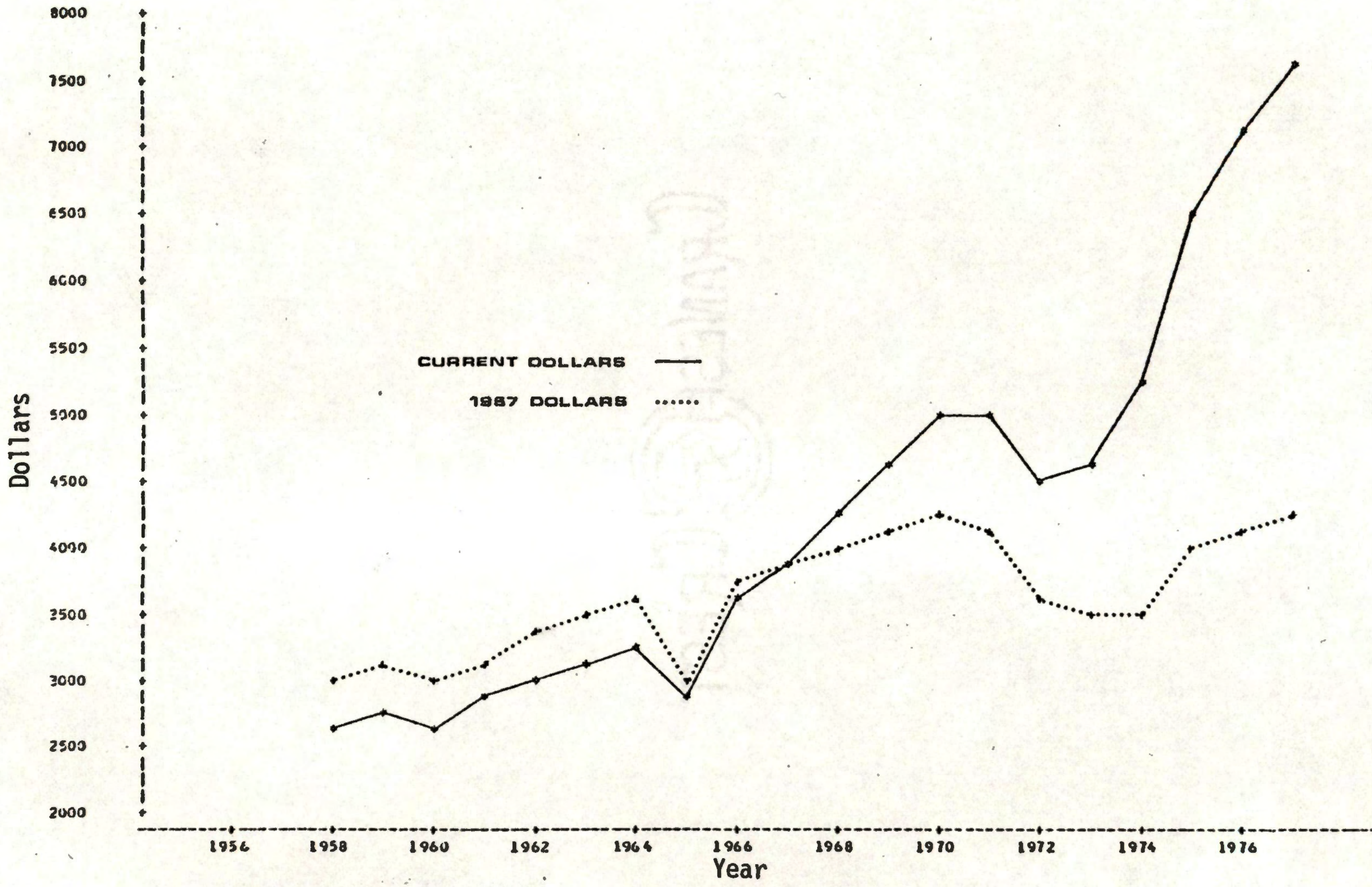

Figure 6. Tennessee SIC 24 Average Wage and Salary.

Source: (BLS, CBER)

CHAPTER II

LINEAR ECONOMIC MODELING

Chapter II provides a brief overview of several techniques of regional and/or industrial modeling. The purpose is neither to cite all pertinent literature nor to undertake an exhaustive critique of the techniques described; it is, 1) to provide an understanding of the relative strengths and/or weaknesses of the methods, 2) to illustrate examples of past applications relevant to forestry, and 3) to show how these methods relate to the development of the current "state of the art" econometric models. A more detailed review of the two specific models important to the development of the Tennessee lumber industry model is provided.

I. ALTERNATIVE APPROACHES TO ECONOMIC MODELING

Small-Scale Models

Economic-base studies. As its name implies, economic-base studies attempt to explain regional growth in terms of the economic base of a community. The premise is that the base of community growth are those goods and services serving markets outside the defined community. The remaining goods and services are considered "adaptive" or non-basic. Implicit in this premise is the assumption that exports are the prime mover of the local market. That is, if "exporting" industries increase employment, those serving the local market will do likewise to meet the increased demand for services.

The first step in an economic base study is to define the community boundaries. Once this is accomplished the "local" economy must be divided into two segments, 1) firms and individuals serving markets outside the community, and 2) those serving markets within the community (42). For an individual industry, employment (or output) may be placed into either category or divided between the two in accordance with the markets served. A detailed description of methods used in allocating the industries into these categories is given in Tiebout (1962).

After the industries have been categorized, the base multiplier is defined as the ratio of total goods and services to "basic" goods and services. This ratio is assumed to remain relatively constant over time. Therefore, by making projections of the growth or decline of the basic industries, one can "forecast" the associated impact on the non-basic industries and the economy as a whole.

Detailed economic base studies usually disaggregate the economy into more than the two categories above. The divisions are usually based either on sectors (according to markets served) or industries. In the industry studies an overall multiplier is derived by "tracing out" direct and indirect interactions in the economy.

Examples of applications to the forest product industry include a regional application by Maki, et al. for the Douglas-Fir Region in 1968 (25). Applications in forestry at the state level have been conducted in Idaho (39) and Montana (18), and at the local (or subregional) level in Tennessee (5).

Shift-share analysis. A somewhat more sophisticated technique of analyzing regional growth is shift-share analysis. The type of analysis addresses regional growth by decomposing it into its component parts. The components of regional growth identified are: (1) the national growth effect, (2) the industrial mix effect, and (3) the competitive effect. The original formulation has been refined and expanded by Esteban-Marquillas (10) to include an "allocation effect." Essentially, shift-share analysis considers national growth the norm to which the contribution and/or difficulties of specific regional factors are added or subtracted. The industry mix effect reflects the positive or negative aspects of specialization, while the competitive effect measures the contribution to growth due to the dynamics of a sector in a region compared to its growth at the national level. In the expanded version, the allocation effect measures the degree to which output or earnings are distributed among the growth industries. A more detailed explanation and an application to the Tennessee economy can be found in Kort (23). Appendix I contains an application to the Tennessee lumber industry.

The techniques of regional analysis discussed above provide valuable information from readily available data. The assumptions implicit in their application, however, limit the validity of the results. The basic limiting assumption of the economic base studies are the assumed stability of the base multiplier and the assumption that regional growth is totally dependent upon the exporting industries. The rising importance of the service industries would affect, in particular, the base multiplier. Shift-share analysis likewise depends upon assumed stability in its analysis. The average growth rate for any particular interval being analyzed undoubtedly masks many trends in the regional growth pattern within that time period. It is because of these and other weaknesses that more sophisticated techniques have been sought.

Large-Scale Models

Input-output analysis. The advent of high speed computers has facilitated the application on a large scale of many complicated and extensive regional analyses. These types of studies could only be theorized until such time as the mammoth computational load could be dealt with.

This is particularly true of input-output (or interindustry) analysis. Though first proposed in its current form by Leontif in 1941,[1] its application to regional or state studies did not follow until the late 1950's (53). Input-output analysis concentrates on the relationship between industries or sectors in the model. If one were interested in how an increase in output (or employment) in sector X affected the output (or employment) in sector Y, input-output analysis would provide the detailed information necessary.

---

[1]Leontif is generally credited with applying modern mathematic techniques to the work of Leon Walrus.

The application of input-output (I-O) analysis requires that the economy to be studied be broken down into sectors. The definition and/or detail of the sector is influenced by the preference of the researcher within the constraints of data available, regional economy characteristics, and the assumption that each sector produces a homogeneous type of product not produced in any other sector. The more sectors included, of course, the more insight provided into the economy. The use of computers has greatly facilitated the disaggregation of economies into meaningful components.

Basically, I-O studies consist of the derivation of multipliers by applying matrix algebra to a flow table. There are essentially two types of input-output models. In the "closed" model it is assumed that all sectors which make purchases provide inputs. In an "open" model it is assumed that one or more sectors (usually the final demand sectors) are exogenous.

The I-O flow table is a matrix of the intersectoral flow in the economy. The pertinent data may be gathered either by determining the sales of the intermediate sectors in the economy to all sectors (intermediate and final demand) or by a survey of all sectors to determine purchases from the intermediate sectors. Naturally, the accuracy of the data used in the flow table determines the validity of all subsequent information derived from I-O analysis.

The regional modeler basically has two choices in applying I-O analysis. He/she can conduct a primary survey of the defined sectors to construct the flow table, or one could depend upon using "adjusted" national coefficients in the regional model. There are problems with either possibility. The primary survey would obviously be expensive and time consuming, while the application of national coefficients to regional analysis has been found inadequate.[2] These considerations, along with the assumptions of stability in the technical coefficients (required to solve the system of equations), tend to limit its application particularly to regional and/or forecasting applications. The two most extensive applications to the Tennessee economy as a whole were a study by Lee, et al. in 1967 (24) and a study by Wilson emphasizing agriculture in 1968 (53).

There are several studies that have applied input-output to the forest products industry. These include models of the industry on a state and regional level. Generally, when input-output is applied to state industry analysis, the model aggregates the non-forest industries into large categories. The lumber industry, however, is broken down into its component parts. This type of structure allows for a concentrated look at the transactions in the sector and the impact of forest products on the state economy. A recent application of this approach is the study by Terfehr and Porterfield in Mississippi (41). This study adjusted the pertinent national coefficients through the use of a survey.

---

[2]See for example Czamanski and Malizia (1969), Miernyk (1969), Schaffer and Chic (1969).

A similar study for the Georgia Research Council in 1972 involved condensing and adjusting a large statewide I-O model into a model emphasizing forest products industries (9). A regional application of input-output was completed in 1969 by Kaiser. His study depended upon unpublished regional data from the 1963 Census of Manufactures to develop a model of the southern forest economy (20).

Econometric models. The most recently developed method of regional analysis is the econometric model. Econometrics can be described as a blend of economic theory and statistics such that statistical and mathematical techniques are used to describe, analyze, and/or test economic theory. The econometric model, therefore, is defined as an equation or system of equations, statistically validated, that attempt to represent the operations of the economy.

Econometric models represent combining, into one structure, four primary methods of forecasting that were prominent after World War II. These were: 1) the informal GNP models which consisted of piecemeal projections of the major components of final demand, 2) the leading indicator approach emphasizing systematic leads and lags among time series data, 3) monetarist forecasting that evaluated the critical importance of the money supply, and 4) extrapolative forecasting that projects a time series entirely from its own history (8).

Econometrics allows the researcher to develop a model that emphasizes the components important to the expected end-use of the model There are three main uses of econometric models: 1) forecasting, 2) structural analysis, and 3) policy simulation. Econometric models have proven their performance capabilities in each of these applications. As a result, virtually every major business currently subscribes to one of the three major models (11, 8).

The first econometric model was developed by Jan Tinbergen in 1939, in an attempt to test business cycle theories. This first attempt was followed by the Klein Interwar model in 1950 from which most of today's major econometric models evolved. Figure 7 indicates the influence of Klein's work and subsequent formulations.

The major differences in these models are in the purposes for which they were formulated and/or the focus of their analysis. For instance, the model developed by the Bureau of Economic Analysis is similar to the original Wharton model, but the emphasis is on the government sector rather than the private sector (17). The model developed by the Federal Reserve Bank of St. Louis differs from most others in its use of monetary aggregates and its dependence upon the monetarist viewpoint to explain employment, prices, and interest rates.

After the establishment of the large national models, the application of econometrics to regional and/or industrial models was simplified. The need for more detailed information than the macro-variables provided stimulated the emergence of satellite models that disaggregated these gross indicators into meaningful industrial and/or regional statistics (22). Lawrence Klein was one of the first proponents of this approach, and much of the work in the field either stems directly from his work or depends upon one of the large models he influenced.

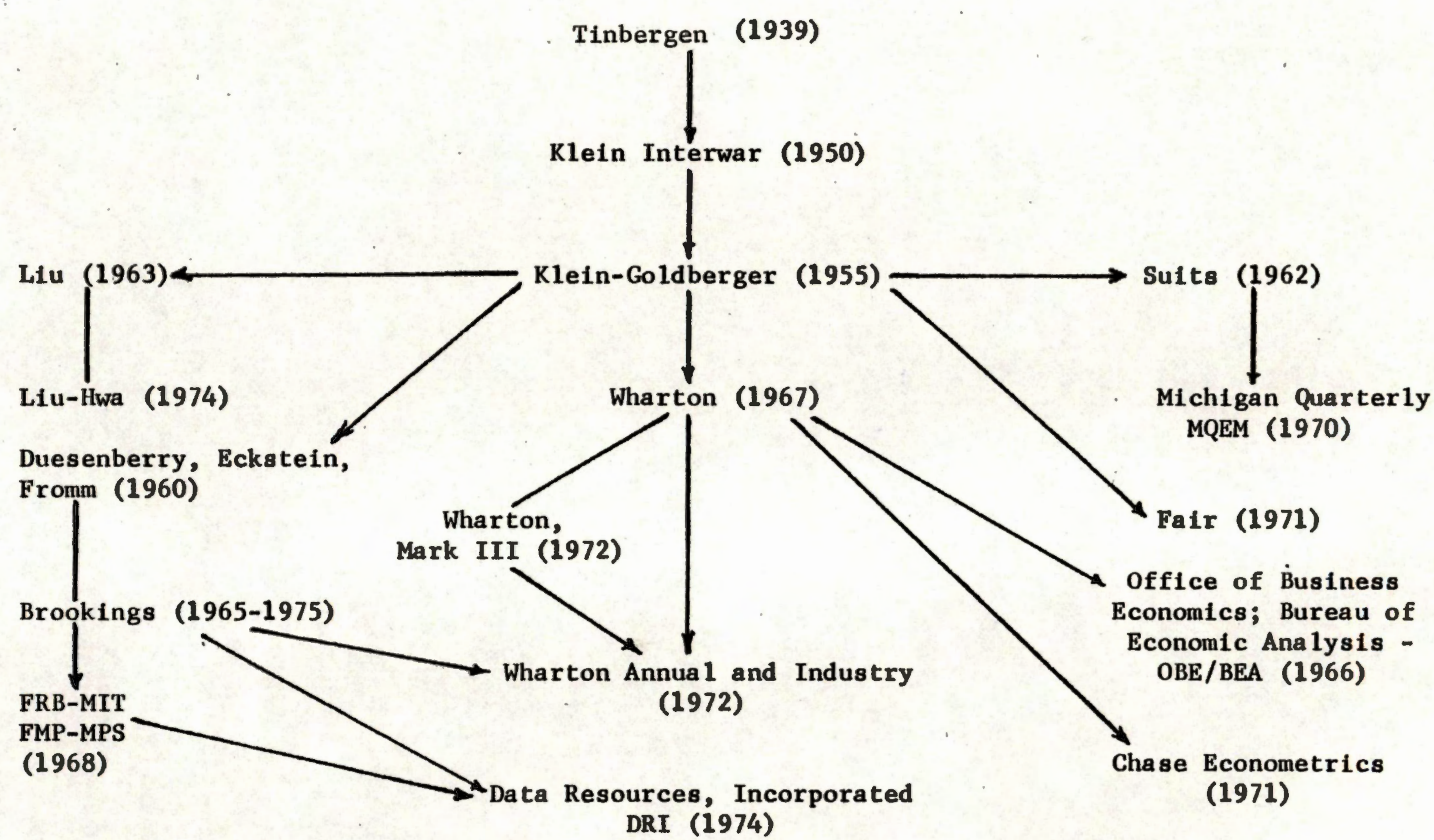

Figure 7. "Family Tree" of Macro-Econometric Models.

Source: (17)

Since the development of econometric techniques, there have been several applications to forest product industry analysis. Among the earliest was a study of the hardwood flooring market by Gregory in 1960. The model consisted of a demand, supply, and price equation, with housing starts playing the major role in the model. This model was important not only for its insight into the hardwood flooring market, but also for its substantiation of econometrics as an important tool for the forest economist.

In Gregory's words, "one might say that an experiment was made to test the hypothesis that modern econometric methods can yield significant results when applied to forest product market research. The hypotheses was substantiated" (13). The hypothesis has been re-substantiated several times since this early effort. Most of the econometric models developed since that time have concentrated on either the forest products industry as a whole, or on the softwood markets. Two examples of the latter are a study by Robinson (36) and one by Mills and Manthy (28). These models represent much more sophisticated efforts, although the basic three part (demand, supply, price) structure remains evident.

A comprehensive model of the entire forest products industry was developed by McKillop (26) in 1967. This model consisted of supply and demand functions for a broad range of forest products. A later effort, and one of particular relevance to this study, was reported by Adams and Blackwell (1) in 1973. Their model of the forest products industry was unique in that it represented and linked the principal structural components of the markets for lumber, plywood, sawlogs, veneer logs, and stumpage. The most noteworthy feature, however, is the fact that the demand for lumber and plywood was linked with the predictions of the U. S. economy from the Wharton Annual and Industry Forecasting Model Though this model explicitly takes into account both construction and non-construction uses, it is evident that hardwood markets, if accounted for, are masked by the domination of softwoods in the aggregates used.

II. THE WHARTON ANNUAL AND INDUSTRY FORECASTING MODEL

As shown in Figure 7, page 23, the Wharton Annual and Industry Forecasting Model is a variant of the original Wharton model. The original Wharton model was influenced by the Klein-Goldberger model but innovative in several respects. First, it is based on quarterly data rather than annual estimates. It was the first model designed explicitly for developing forecasts and provided a greater degree of disaggregation than its predecessors. The Wharton model was estimated using two-stage least squares and is used to provide forecasts up to eight quarters in advance (17).

The Wharton Mark III model differs from the original formulation in that the emphasis is placed on the financial sector, the non-manufacturing sector, and prices. The model allows for more detailed analysis of policy questions due to the incorporation of 25 policy instruments compared to 7 in the original formulation (17).

The macro-economic model upon which this study is based contains elements of both of the above models. The Wharton Annual and Industry

Forecasting Model was developed with an emphasis in industry, with disaggregated long-term forecasts of quantities and prices. The model uses an annual time framework in order to produce long-term forecasts as well as to take advantage of a more extensive data base. Another important influence on this model was the Brookings model which first explored the possibility of using, in the same model, data available both from the national income accounts and national interindustry matrix.

The unique structure of Wharton Annual and Industry model is based on the integration of a highly disaggregated (63 sectors) input-output matrix into a macro-model framework. Driving this matrix are 49 final demand categories including 11 consumption equations and 29 fixed capital formation equations (35). The model produces annual forecasts of up to 10 years on an industry basis. The premise of the model is that adequate treatment of both supply and demand sides of the economy is necessary to provide a realistic forecast of the economic environment five to ten years in the future. The incorporation of interindustry transactions provides a method of tracing the impact of alternative policies within the context of this general equilibrium framework (34).

The output from the Wharton long-term model consists of several statistics broken down by industry sectors. Among them are: fixed investment, real output, employment, employee compensation, wage rates, and sector prices. Components of Gross National Product, personal consumption expenditures, federal and state government spending, and other selected indicators are included also in each forecast.

III. THE TENNESSEE ECONOMETRIC MODEL

The Tennessee Econometric Model was formulated to fill the need for "a method of integrating the analysis of the various state and local governmental agencies by providing a consistent set of economic information upon which to base policy recommendations" (14). The method agreed upon to provide this information was the development of a large scale econometric model of the state that was linked to a model of the national economy. It has been only in the last decade that established models of the national economy have been available for this purpose. There have been, during this time period, numerous regional models formulated. Input-output and/or econometric models have been formulated for several states.[3] The justification for choosing the econometric approach for the Tennessee study is related to the advantages in performance, flexibility, research capabilities, and cost discussed above. The loss of detail due to aggregate rather than interindustry analysis would seem to be justified given these considerations.

In order to model output on a state level, an approximation of the Gross State Product (GSP) must be formulated. Conceptually, Gross State Product is equivalent to its national counterpart Gross National Product; however, the lack of data at the state level makes its approximation more tedious. The first concise method of formulating an approximation to

---

[3]For a list of state input-output models see Niemi, 1975, p. 100 (32); for a list of state econometric models see Gustely, 1978, p. 11-12, (14).

Gross State Product was proposed by Kendrick and Jaycox in 1965. There are three theoretically equivalent definitions of GSP: 1) gross state expenditures by sector, 2) gross state income by income type, and 3) gross state product by sector and industry. Each of the above formulations would quantify "the market value of the output of goods and services produced by a state's economy before deduction of capital consumption allowances but after deduction of 'intermediate products' used by business in the accounting period" (21). The gross expenditure approach of estimating GSP is not practically possible at the state level, due to lack of data. Both of the other approaches have been applied; however, the detailed breakdown by industry provided by the third approach is better suited to the needs of formulating a disaggregated state model.

The detailed application of the Kendrick-Jaycox approach to the Tennessee's GSP can be found in work by Kort (1976). Of particular interest in this study is the estimation of the gross manufacturing product. The basic Kendrick-Jaycox approach to estimating gross product originating consists of applying national ratios to the state income received data. The implicit assumption is that factor proportions within the state industries are similar to their national counterpart. When this assumption is violated a bias in the estimate results (31). In the estimation of the gross product of Tennessee, Kort identifies this bias and concludes that the assumptions of the Kendrick-Jaycox formulation preclude its application to Tennessee manufacturing. Further, the modifications proposed by Niemi (1972) were rejected in favor of the value-added data published by the Commerce Department in the Annual Survey of Manufactures. The following justification was used:

> "While it may be true that the Annual Survey of Manufacturers concept of value-added is an over-estimate because not all intermediate purchases are netted out, this problem is certainly not unique in regional analysis, given the availability of regional data. Input-output tables involve some double-counting, as an example. Moreover, since the value-added concept is utilized with respect to gross farm product by Kendrick and Jaycox, there is no reason why the same cannot apply to manufacturing. Where data are available which approximate the desired account, it makes more sense to use the data rather than to fabricate it" (23, p. 21).

Based on this conclusion the Tennessee Econometric Model uses value-added as the approximation of each industry's contribution to GSP. Real output is then defined as being value-added deflated by the national industry deflator. The disaggregation of the Tennessee Economy used in approximating GSP is shown in Table 1. The state lumber and wood products industry is currently included in the "Other Durables" category.

The Tennessee Econometric Model (TEM II) was developed and is maintained by the Center for Business and Economic Research in the College of Business Administration at The University of Tennessee, Knoxville. It was formulated by relating the historical trends in the state economy to national economic activity. The relationship was quantified using ordinary least squares, due to the fact that the preferable simultaneous equation estimation techniques require a greater degree of freedom than was available (14). TEM II was developed as an annual forecasting and simulation model of the state, with sub-models of the four metropolitan areas. National economic activity input comes from the Wharton Annual and Industry Forecasting Model described above. The remaining input consists of selected state policy variables.

TABLE 1

INDUSTRY DISAGGREGATION FOR TENNESSEE
GROSS STATE PRODUCT

Farm
Government
Federal
State and Local
Manufacturing
Durable
Furniture and Fixtures
Fabricated Metals
Nonelectrical Machinery
Electrical Machinery
Transportation Equipment
Other Durables
Nondurable
Food and Kindred Products
Textile
Apparel and Textile Products
Paper
Chemicals
Rubber/Plastics
Other Nondurables
Mining
Contract Construction
Wholesale and Retail Trade
Finance, Insurance and Real Estate
Transportation, Communications and Public Utilities
Services and Other

Source: (23).

TEM II is formulated emphasizing the output, employment and wage interactions of the firm. Output equations fall into one of two categories, depending upon the market being served. In general, the manufacturing sector is assumed to serve national markets. Therefore, Tennessee real output is expressed as a function of national real output in that sector, together with adjustment factors that reflect the cost of production differentials between the state and nation. Tennessee furniture output, for example, is expressed as a function of United States furniture output and the ratio of the state corporate tax rate to the national average corporate tax rate.

Generally, the employment equations are represented as functions of output and either real wages or a lagged employment variable. The lagged variable represents the fact that employment does not respond immediately to changes in output.

Wage rate equations are formulated explicitly to take into account the effect of the regional and national economics in the wage determination process. Specifically, the manufacturing equations include the national wage rate or compensation figures as explanatory variables (14).

The current model contains a component to delineate the state economy's effect on the metropolitan areas and a socioeconomic component that forecasts population and labor movements. The most visible result of the model has been the yearly publication of forecasts in the annual Economic Report to the Governor (4). The model's use as a research and simulation tool on an ongoing basis reflects its greatest value to the state.

CHAPTER III

FORMULATION OF THE TENNESSEE LUMBER AND WOOD PRODUCTS MODEL

Figure 8 illustrates the generalized procedure used in formulating an econometric model. The parameters defined by the interraction of economic theory, data availability, and statistical validity determine the structure of the general model. In this study most of the factors were predetermined by the decision to develop sector equations for an established econometric model. Chapter III identifies 1) the constraints of the model, 2) the characteristics of the data, and 3) the methodologies involved in formulating the equations.

I. CONSTRAINTS

Compatibility With TEM II

In order to accomplish the objective of producing a model compatible with the structure of the state econometric model, several limiting assumptions as to the general form of the model were required.

The specific restrictions necessary to produce a sector model of TEM II were as follows:

1) Use a compatible definition of the dependent variables.
2) Manufacturing output equations should reflect the relationship between the state and national industries.
3) Development of equations for output, employment and wages.

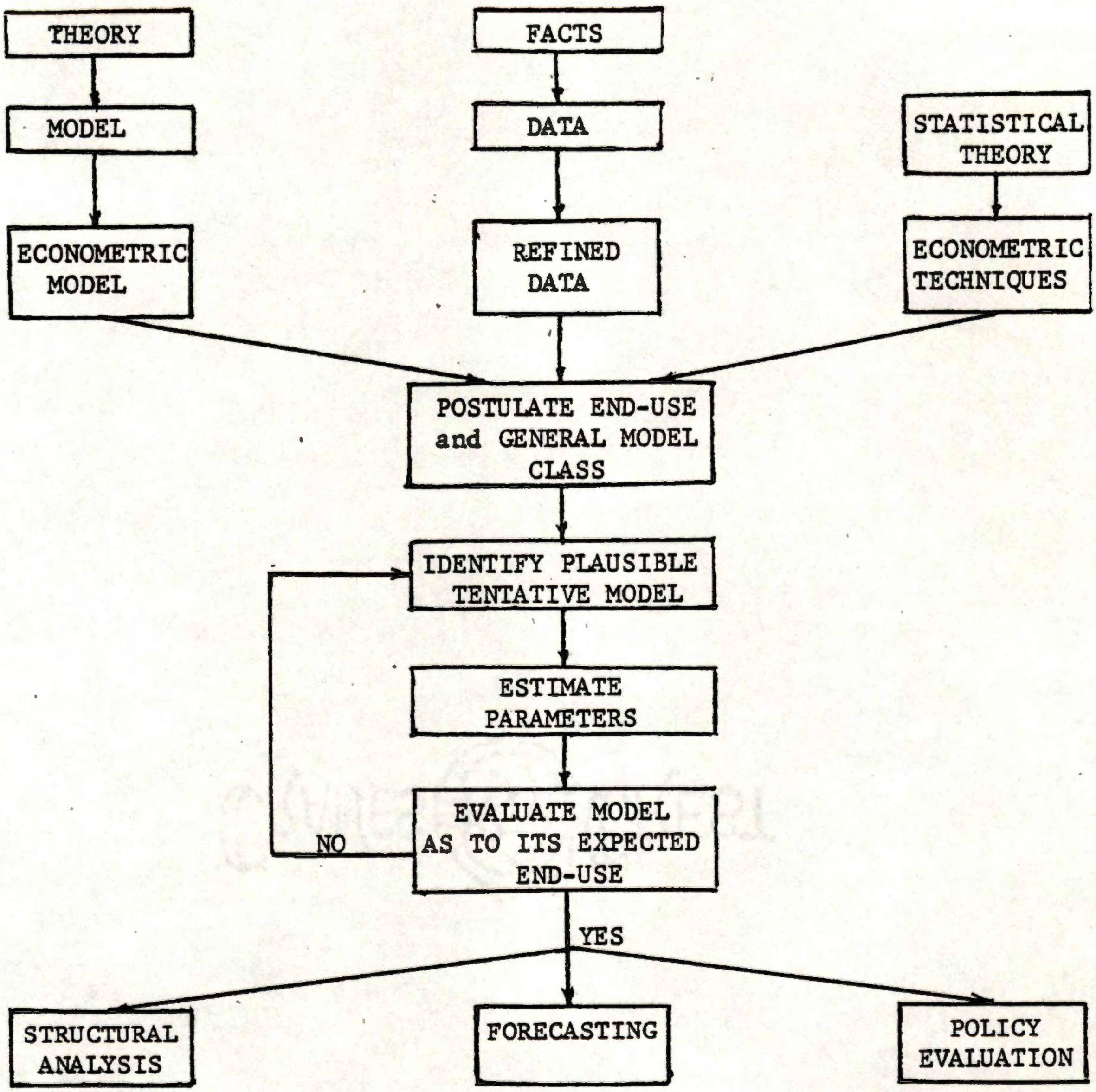

Figure 8. Generalized Procedure for Developing an Econometric Model.

Source: Adapted from (17)

4) Variables exogenous to the SIC 24 model should be endogenous to either the Wharton Annual and Industry Forecasting Model or TEM II.

5) Equation performance (in both statistical and economic terms) should be comparable to those included in TEM II.

Implications of the Differences Between the State and National Lumber Industry

Many of the constraints listed above are tenable only if certain similarities between the state and national variables are assumed. Though the restrictions do not preclude the development of a satisfactory lumber model, the validity of the assumptions in this formulation is questionable. Specifically, the domination of hardwoods in the state lumber industry implies different demand, supply, and price relationships than those found in the softwood dominated national industry. The structural differences between the two industries have particularly significant implications in light of three of the constraints mentioned above. They are: 1) using the TEM II definition of real output, 2) relating the state and national industries in the output equation, and 3) using only variables in the Wharton or TEM II data banks as exogenous variables.

The first problem concerns the definition of output in TEM II equations. This variable is defined as the state value added deflated by the national sector deflator. The problem arises in the implicit assumption that the structure and product mix of the state and national sectors are similar. For most sectors the state and national industries probably do not differ significantly. In those cases a published industry specific deflator would offer the best available proxy of the true state deflator. The differences between the hardwood and softwood industries, however, may be significant enough to affect the interpretation of the dependent variable (real output). These differences suggest reservations about the definition of real output used in this formulation.

The manufacturing output equations in TEM II relate the state industry to the national industry. An appropriate variable identifying cost differentials between the state and nation is included also. The justification for this approach is that the state manufacturing sectors serve national markets. It is postulated, therefore, that the performance of the state industry can be explained by the performance of the national industry and a measure of regional cost differentials.

Applying this methodology to the Tennessee lumber industry model, given the differences between the state and national sectors, indicates another significant concern in this formulation. Though Tennessee lumber is affected by the national industry (and definitionally a part of it), there are different markets that determine their respective performance. Historically, the national industry's fluctuations are determined by the performance of housing. Hardwood lumber traditionally is affected by the furniture industry. There is, of course, a relationship between the furniture and housing markets. Furniture industry performance, however, is more dependent upon disposable income than it is on the current performance of the housing market (38). As a result, there often are significant differences in the performance of the two industries. In addition to furniture, the pallet and railroad tie industries use significant amounts of hardwoods. It is questionable, therefore, that relating the state to the national industry with some measure of cost differential will be sufficient in terms of explaining the cyclical variation in Tennessee's lumber industry.

The third problem with the sectoral model is that the exogenous variables of TEM II are restricted to those forecast in the Wharton model with the exception of certain state policy assumptions. Though the Wharton model provides a great degree of disaggregation, the lumber variables at the national level are softwood dominated. Limiting the equation for output of Tennessee lumber to a function of these national variables and the state variables in TEM II provides little information as to the performance of hardwoods. In order to forecast with the model, exogenous variables must be forecast. Significant information as to the structure of the state industry, however, could be derived from a model that includes variables pertinent to hardwoods, whether or not they are forecast. There are several sources of hardwood time series data that may prove significant to an understanding of Tennessee's lumber and wood products industry.

The three considerations discussed above indicate serious problems in applying TEM II structural procedents to the lumber industry formulation. Strict application of the methodology in TEM II to any one set of equations would yield questionable results. Consequently, it was postulated that two sets of output equations would best meet the objectives of the study, one set to be developed primarily for forecasting within the TEM II framework. The second would be developed: 1) to provide for structural analysis, 2) to allow meaningful impact analysis, and 3) to take advantage of a larger data base. The structural equation also would allow for experimentation into alternative definitions of real output.

II. DATA CHARACTERISTICS

Data Availability

The primary sources of data for the study were the following:[1]

1) Wharton historical tables
2) Center for Business and Economic Research databank
3) Annual Survey of Manufactures (45)
4) Survey of Current Business, Business Statistics (43)
5) The Demand and Price Situation for Forest Products 1976-1977 (33)
6) Bureau of Labor Statistics (44)
7) Economic Report of the President (49)

Problems with the Data

Economic time series data usually are characterized by interrelationships among the variables. The problems (in regression analysis) associated with this characteristic are caused by two specific types of interrelationships: 1) multicollinearity (intercorrelation) and 2) autocorrelation (serial correlation).

---

[1] A more comprehensive list of variables and sources appears in Appendix II.

Multicollinearity. The intercorrelation of the independent variables in an equation is called multicollinearity. Due to the general interdependence of economic phenomena, multicollinearity is most apparent in economic time series analysis, where the series move closely together over the business cycle or over a secular trend (12).

The problems associated with the presence of multicollinearity can be summarized as follows:

1) The precision of coefficient estimation is affected so that it is impossible to disentangle the relative influences of the independent variables;
2) Correlation among the independent variables may lead to significant variables being incorrectly dropped from the model, since the true effect on the dependent variable cannot be ascertained; and
3) The estimates of the coefficients may become very sensitive to a particular set of sample data (19).

Though a large data base was accumulated for this model, the correlation matrix indicated that nearly all of the variables were correlated significantly among themselves. This was due to the fact that values of a vast majority of the variables increased over the time period studied. It should be noted that the presence of intercorrelation does not inhibit a good fit, nor does it hamper the prediction of new observations if the assumption holds that the relationship between the variables remains the same during the period for which the predictions are made (30, 17, 12). Since econometric forecasts by definition depend upon historical relationships, this assumption of constancy in the relationship of the variables does not affect significantly the validity of the forecast.

Intercorrelation among the independent variables does present, however, severe limitations to any structural or impact analysis with equations. The lack of significance in the coefficient values implies that the manipulation of the associated variables is also meaningless. This "lack of significance" characteristic of multicollinearity provides further justification for two separate equations. Whereas multicollinearity can be tolerated in the forecasting equations, the variables in the structural/simulation equation should exhibit minimal intercorrelation. Given little or no intercorrelation, the manipulation of the variables then can provide some information on the impact to the dependent variable.

Autocorrelation. The basic regression model assumes that the error term (the variation in the dependent variable not explained by the independent variables) is random. The error terms in time series models most often are correlated positively over time; this phenomena is known as autocorrelation or serial correlation.

The presence of autocorrelation in econometric analysis is due usually to one of two deficiencies in the model, the first being the omission of one or serval key variables from the model. If this missing variable is correlated positively over time, the error terms of the model will tend to be correlated positively, since the error terms contain the effects of the missing variable.

Another possible cause of serial correlation is a systematic coverage error in the dependent variable time series. These errors often tend to be correlated positively over time (30).

The problems associated with autocorrelation are summarized below:

1) The coefficients are unbiased, but no longer have the minimum variance property.
2) The Mean Square Error (MSE) will underestimate the variance of error term.
3) The calculated estimate of the standard deviation of the coefficient may underestimate the true standard deviation.
4) The validity of "t" and "F" statistics for confidence intervals of tests is questionable (30).

The technique employed to detect autocorrelation in this study was the Durbin-Watson test. The test statistic is obtained by fitting the regression and obtaining the residuals (e_t = observed - predicted). The statistic is then calculated as:

$$D = \frac{\sum_{t=2}^{n} (e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2}$$

where n is the number of observations. The statistic is compared to tabled critical values to detect autocorrelation.

If the autocorrelation is present, the chief remedy for the associated problems is the development of a model that explicitly takes into account its presence. The method used in this thesis is the iterative procedure as described in Neter and Wasserman (1974).

The iterative procedure basically adjusts the equation's parameters by the estimated value of the autocorrelation parameter ρ. The autocorrelation parameter is estimated by r, where:

$$r = \frac{\sum_{t=2}^{n} e_{t-1} e_t}{\sum_{t=2}^{n} e_{t-1}^2}$$

and the transformed variables are defined by:

$$Y_t' = Y_t - rY_{t-1}$$

$$X_t' = X_t - rX_{t-1}$$

where: Y_t = the value of the dependent variable in time period "t"

X_t = the value of the independent variable in time period "t".

The new model results from the application of ordinary least squares to these transformed variables. The Durbin-Watson D then is reestimated and if autocorrelation still exists, the procedure is repeated until a satisfactory model is formed. In this study, one iteration proved satisfactory.

Data for Forecasting Equations

In order to make forecasts of the dependent variables, it is necessary to make assumptions as to the future performance of the explanatory variables. As mentioned earlier, the Tennessee Econometric Model is "driven" by forecasts from the Wharton Annual and Industry Forecasting Model. The variables for the forecasting equation in the lumber and wood products model, therefore, are derived from the same source with the exception of state variables forecast in TEM II. In other words, for forecasting purposes the exogenous variables of the SIC 24 equations were the endogenous variables of the national and state models mentioned. The source of the dependent variables were:

1) Output was defined as the value-added figures for Tennessee SIC 24 in the Annual Survey of Manufactures, real output being this figure deflated by the implicit deflator for the lumber sector in the Wharton historical tables.
2) Employment data came from the Bureau of Labor Statistics (BLS) Employment and Earnings, 1939-1975 with consistent data for 1976 and 1977 being provided by the Center for Business and Economic Research (CBER).
3) Average normal wage and salary was derived by dividing the BLS estimate of annual total wage and salary (supplied by CBER) by the average annual employment figure above.

In all cases, the attempt was made to provide a continuous data series for the period 1956 to 1976. In most cases this was accomplished. The only exception among the dependent variables was the wage and salary figure for which the 1958 to 1976 period was used. Though the discontinuities were more numerous among the exogenous variables, they will be discussed only as to their effect on any particular equation.

Data for Structural/Simulation Equations

The data base for the structural/simulation output equation includes all of the variables for the forecasting equation, in addition to variables for which a continuous time series was available but which were not forecast in the Wharton or TEM II models. For the most part, these variables were selected to represent circumstances that were specifically pertinent to hardwoods and/or the Tennessee lumber industry. Examples include hardwood flooring orders and shipments from the Survey of Current Business (SCB) (43), wholesale price indexes and relative wholesale price indexes for hardwood from The Demand and Price Situation for Forest Products 1976-1972 (33), and the prices of #1 common 4/4 red oak lumber in the Southern and Appalachian regions from the Hardwood Market Report (16). A comprehensive list is provided in Appendix II table B.

III. FORMULATION OF THE FORECASTING EQUATIONS

Constant Dollar

Output. In this thesis, the equation for forecasting output was considered the primary objective and was the first to be developed. The techniques and procedures used to arrive at a final "best" equation were similar in each formulation of the equations for the model. These techniques are discussed in detail in this section. The formulation of the structural/simulation equations will be discussed only as to how it differed from these procedures.

Basically, the process of choosing the selected equation was accomplished in two stages. The first stage involved formulating several alternative equations by means of a mechanical data screening process. At this point minimum guidelines were established to determine which equations merited further consideration. Additional detailed statistics were calculated for those equations meeting minimum requirements. These statistics were used to identify the superior equations.

The data base of the constant dollar output equations consisted of any variable contained in either the Wharton or CBER databank postulated to be related to the state lumber industry. These variables (listed in Appendix II) usually fell into one of four broad categories: variables related to 1) the U. S. lumber industry, 2) the furniture industry (state and national), 3) demographic factors, and 4) money supply (disposable income, mortgage rates, etc.). The only major refinement of the data that was necessary was to deflate current dollar values to a 1972 dollar equivalent. All of the necessary deflators were available from the Wharton historical tables.

Screening the variables for inclusion in the ordinary least squares (OLS) output equation was accomplished by a combination of procedures. The first step involved the application of the stepwise procedure of the Statistical Analysis System (SAS). Four different stepwise routines were applied.

The forward stepwise routine involves introducing the single variable that produces the largest coefficient of multiple determination (R^2).[2] The rest of the variables are then tested at to their significance

---

[2] R^2 is the ratio of the regression sum of squares to the total sum of squares.

$R^2 \frac{SSR}{SST} = 1 - \frac{SSE}{SST}$ It measures the proportionate reduction of the total variation in the dependent variable associated with the set of independent variables.

if they were included in the model. The variable that represents the greatest contribution, if included, then is brought into the model. The procedure continues adding variables one by one until no variables left meet the specified level of significance.

The backward stepwise routine first performs calculations for a model including all of the independent variables. Then, one by one, the variables are deleted which show the smallest contribution to the model, until all of the remaining variables are significant at the required level.

The stepwise routine (within the stepwise procedure) is a modification of the forward selection technique. Variables are added in the same manner as the forward procedure. The difference lies in the fact that after any variable is added, all variables are checked for significance. Any variable not considered significant is dropped before any other additions are made. This process terminates when no variable meets the significance level required for inclusion or when the variable to be added is the one just deleted.

The maximum R^2 improvement routine is a more rigorous procedure that involves searching for the "best" one variable model, the "best" two variable model, etc. It starts by finding the one variable model with the highest R^2, then the variable that would yield the greatest increase in R^2 is added. Each variable in this model is then compared to every variable not in the model. For each comparison, the procedure determines whether substituting the excluded variable for the included variable would increase R^2. After all comparisons are made, the switch is made that produces the largest increase in R^2. A third variable is added according to the same criteria and the procedure is repeated (2).

Each procedure was rerun excluding variables "chosen" in the first iteration. For example, if the best equation from the stepwise run included independent variables B and C, the second iteration would include all variables except B, the third all except C, etc. The purpose was to determine if any of the variables included were masking the effects of other significant combinations. Iterations for the time periods 1961-1976, 1966-1976, and 1971-1976 were performed to identify variables whose importance had increased in more recent years.

The procedures were applied not only to yield tentative equations, but also to produce a smaller subset of variables for more rigorous analysis. The variables added and/or deleted to produce the best equation in each of the iterations were grouped together to form a smaller data set. All possible combinations of these variables were analyzed for up to a four variable model. The SAS procedure "RSQUARE" was used to produce all possible regressions.

The above process produced a substantial set of possible output equations, to which many more were added that were intuitively attractive due to past research and/or acquired knowledge of the industry. Detailed statistics for each of the equations were produced by the General Linear Models procedure in SAS.

In order to reduce the number of equations to a manageable level, the following flexible guidelines were applied:

1) The coefficients associated with the independent variables should be significantly different from zero (at the .05 level).

2) The variables' signs should be in agreement with economic theory.

3) The R^2 value should be above .90.

4) The equation should have four or less independent variables, since only incremental increases in R^2 were found at or above this level.

The above guidelines substantially reduced the number of equations under consideration. These remaining equations were further analyzed to provide detailed information as to their performance.

The following statistics were used in this stage of analysis:

1) adjusted R^2

2) mean square error

3) partial sum of squares

4) standardized regression coefficients

5) elasticities

6) graphical analysis

7) actual vs. predicted performance and/or dynamic simulation.

A deficiency of the R^2 statistic, used up to this point, is that it does not take into account the number of variables in the model. This statistic will increase always with the addition of another variable, thereby favoring the larger equations. A modified measure that recognizes the number of independent variables in the model is defined as:

$$\bar{R}^2 = 1 \left[\left(\frac{n-1}{n-p}\right)\left(\frac{SSE}{SST}\right)\right]$$

where: n = number of observations

p = number of independent variables

SSE = Error Sum of Squares

SST = Total Sum of Squares

The adjusted coefficient of multiple determination ($\bar{R}^2$) may become smaller with the addition of an independent variable when the decrease in variation does not offset the loss of a degree of freedom. It is, therefore, better for comparative purposes.

The use of $\bar{R}^2$ as a descriptive statistic is similar to examining the Mean Square Error (MSE). $\bar{R}^2$ measures the percentage of explained variation to total variation, whereas MSE measures the absolute level of the unexplained variation. Both of these statistics were calculated for comparing the remaining equations.

The presence of multicollinearity makes the quantitative delineation of the separate effects of the independent variables impossible. The standard regression coefficients and elasticities were calculated in order to gain a better understanding of each variable's role in the equation. They should be interpreted with the assumption that their values are dependent upon each of the other variables being included in the model. In other words, they show the effect of the independent variables on the dependent variable given the presence of the other independent variables.

As was mentioned earlier, the coefficients were tested for significance from zero. The test employed was the standard "t" test, which involves use of the standard deviation of the estimated coefficients.

The partial sum of squares associated with each independent variable in the equation provided some insight into the amount of variation explained by the independent variables. In order to gain some further measure of the relative importance of the variables, the standardized regression coefficients were calculated. The standardized coefficients remove the distortion in the coefficients caused by different units. The calculation was performed as follows:

$$Bk = b_k \left[\frac{(X_i - \bar{X})^2}{(Y_i - \bar{Y})^2}\right]^{1/2}$$

where: b_k = the estimated regression coefficient

Xi = ith observation of independent variable

$\bar{X}$ = mean of independent variable

Yi & $\bar{Y}$ = have similar meanings for the dependent variable.

The standardized coefficients reflect the change in the mean response (in units of standard deviations of Y) per unit change in the independent variable Xi (in units of standard deviations of Xi).

Another method of comparing the relative importance of the included variables is by calculating elasticities. The elasticities relate changes in the dependent variable due to changes in each of the independent variables.

The calculations were as follows:

if the equation is of the linear form

$$y = a + bx$$

the elasticity is defined as

$$dy/_{dx} \cdot x/_{y}$$

where

x = independent variable

y = dependent variable

$dy/_{dx}$ = the partial derivative or, in this case, the coefficient of x.

if the equation is in linear log form

$$\ln y = a + b \ln x$$

the elasticity is assumed constant and is equal to the coefficient b.

Since $dy/_{dx}$ is the coefficient (b) of the independent variable in linear models, the elasticity is influenced by multicollinearity. If the coefficients are unaffected by multicollinearity, a calculated elasticity above unity indicates that the dependent variable fluctuates more than the independent variable. For example if the elasticity between the Tennessee furniture industry and the national furniture industry were greater than one, the implication would be that the state industry would be more volatile--growing faster in expansions and declining faster in recessions--than the national industry.

In addition to the statistics listed above, the examination of the equation included a graphical analysis of the residual and predicted values. The examination of residuals involved the plotting of the residual values against time and against each of the independent variables. All of the plots were expected to show a random pattern (7).

The plot of the values predicted by the equation against the actual values, over the time period for which the equation was fitted, provided insight into the weaknesses of the particular equation. For example, several equations had descriptive statistics comparable to those finally selected; however, the poor performance of the predictions over the last five years eliminated many from further consideration.

Another method useful in determining the validity of a model is dynamic simulation. Dynamic simulation involves "forecasting" with a model over some time period for which the actual values are known. This type of analysis allows the systematic errors in the model to accumulate and thereby indicate the quantity and direction of any necessary constant adjustments.

In equations containing variables exogenous to the lumber model (the output, wage, and employment equations), dynamic simulation is similar to the examination of residuals discussed above. Equations containing variables endogenous to the model would be driven by the values of the endogenous variables "forecast" elsewhere in the model.

<u>Wages</u>. The formulation of the wage equation involved the simple regression of Tennessee annual average wage and salary in SIC 24 on the United States average wage rate for SIC 24. That is, Tennessee wages were postulated to be a function of U. S. wages in lumber. The forecast

was made in current dollars, which is the form used in the Wharton data series. For this reason, no constant dollar wage equation was developed.

Employment. The variables used to derive the employment equation included output figures, real wages, and employment in the previous year for the state lumber industry. In addition, employment levels in the national industry were considered as a possible explanatory variable. The selection process was similar to that described above for output, though considerably simplified by the fewer variables under consideration. It was considered important to include output as an explanatory variable for intuitive reasons and also to incorporate feedback into the system of equations.

Current Dollar

Essentially all of the analysis involved in determining the "best" equation was done in constant 1972 dollar terms. Current dollar versions of the equations consisted of using the undeflated values of the variables selected in the constant dollar model. In this respect, current dollar versions of the "best" two or three equations were formulated and their performance analyzed using the same methodology described above. The final decision on which equation to select could be made then by taking into consideration the performance of its current dollar counterpart.

IV. FORMULATION OF THE SIMULATION EQUATION

Constant Dollar - Output

The results of data screening for the forecasting equation provided input into the simulation equation formulation. The differences between the two formulations were due to the different end-uses to which the equations were to be applied. The fact that the simulation equation was to provide for meaningful impact analysis required that the following two guidelines be emphasized:

1) The variables included in the model should be intuitively meaningful, such that their manipulation would provide significant information on the response of the Tennessee lumber and wood products industry.
2) In order to be able to legitimately manipulate the variables, multicollinearity should be minimized.

The larger data base for the simulation equation was analyzed in two parts. The analysis of those variables used in the forecasting equation essentially was completed in the process of choosing the forecasting equation. The remaining variables (those not forecast in Wharton or TEM II) were screened using the same applications of stepwise and a computer routine that searches all possible combinations of the variables. The most important seven variables from this set were combined with the seven "best" from the forecasting analysis, and all possible combinations were examined. In order to be able to detect the presence of multicollinearity, emphasis was placed on finding a satisfactory two variable model. The matrix of the correlation coefficients was used to determine whether there was significant correlation among the independent variables. If a satisfactory two variable model could not be formulated, detection of multicollinearity would involve a more rigorous analysis of partial correlation coefficients. As in the forecasting model, several intuitively attractive models were analyzed also. The statistical and graphical analysis described above was applied to select one equation for simulation purposes.

Current Dollar Output

The current dollar simulation equation was formulated by refitting the above equation with nominal values of the variables substituted for their 1972 equivalent. The resulting equation was tested by examining the descriptive statistics and graphs described above.

CHAPTER IV

RESULTS

I. EMPIRICAL RESULTS

Output Forecasting Equation

Constant Dollar. The methodology described in Chapter III provided several equations for consideration in forecasting lumber output. After completing the first stepwise iteration, it became apparent that the U. S. lumber industry output variable and both the state and national furniture output variables explained significant amounts of the variation in the dependent variable.

Using the previously described criteria for selecting superior forecasting equations (page 47), the more detailed statistics and graphs associated with the potential equations were examined and those found inadequate were eliminated.[1] Two equations were left whose performance best met the statistical and economic requirements. Table 2 shows the two equations and the corresponding descriptive statistics. Equation one relates the output of the Tennessee lumber industry to: 1) the output of the U. S. lumber industry, 2) the output of the state furniture industry, and 3) the U. S. average mortgage rate on new homes.

---

[1]Additional equations that were considered are shown in Appendix III.

TABLE 2

ALTERNATIVE OUTPUT FORECASTING EQUATIONS

No.	Equation	R^2	$\bar{R}^2$	MSE	SE	DW	PERIOD
1	88.8304 + 11.9581 USLUM7 + .3653 TGPFUR7 - 15.3877 MTGRT (13.50) (3.70) (.096) (2.49)	.957	.948	57.49	7.58	2.53	58-76
2	77.9590 + 22.2981 USLUM7 - 15.2640 MTGRT + .0465 POST72 (11.52) (1.73) (2.41) (.011)	.959	.951	54.20	7.36	1.85	58-76

R^2 = Coefficient of Determination

$\bar{R}^2$ = Adjusted Coefficient of Determination

MSE = Mean Square Error

SE = Standard Error

DW = Durbin-Watson D

PERIOD = Available Time Series

USLUM7 = U. S. Lumber Output $72

TGPFUR7 = TN Furniture Output $72

MTGRT = U. S. Average Mortgage Rate New Homes

POST72 = Mobile Home Starts

The second equation also includes the U. S. lumber industry and mortgage rate variables. It differs in that the furniture variable is replaced by a variable representing U. S. mobile home starts for 1972 and the following years. The form of the mobile home variable reflects the addition of mobile homes to the definition of SIC 24 in 1972.

The presence of the U. S. lumber industry variable in the equations tends to indicate that although the state and national lumber variables differ, there are significant interrelationships in the performance of these two wood products markets. The general consensus is that hardwood markets follow the same trend as softwood, with hardwood fluctuations generally lagging the variations in the softwood market. Though some of the lag effect is undoubtedly hidden by the use of annual aggregates, the importance of the current value of the national lumber variable in this equation indicates that both industries respond similarly to the economic environment in any given year.

The significance of mortgage rates in the equation goes beyond the documented negative relationship between housing and mortgage rates. If mortgage rate fluctuations did nothing more than identify the status of housing in the equation, the variable probably would not have entered the model as significant in the presence of the U. S. lumber industry variable. In other words, since there is a significant relationship between housing and the national lumber industry, mortgage rates would not be able to explain any significant additional variation as a proxy of the housing market, given that U. S. lumber was already in the model.

Another indication that the mortgage rate variable is explaining more variation than is due to housing is the fact that none of the housing start variables were significant in its place.

Presently, a simple negative relationship between housing starts and mortgage rates does not exist. The constant presence of inflation in the economy has led to a changing definition of "high" interest rates. In recent years housing has remained strong in the presence of high mortgage rates. Given the expectations of continuing inflation, the real interest paid on the loans is sometimes quite low. Due to the built-in inflation factor in interest rates, the mortgage rate variable in these equations is probably a better proxy for the more general interactions between money markets and inflation than it is a representative of money available for housing. In any case, a negative relationship between lumber output and mortgage rates was expected.

The descriptive statistics in Table 2, page 56 show that the two equations exhibit very similar properties. The Durbin-Watson statistics indicate that neither of the equations exhibits significant autocorrelation. The period of fit for both of the equations was abbreviated by the absence of mortgage rate figures for 1956 and 1957 in Wharton's historical tables. The resulting loss in degrees of freedom, though detrimental, did not alter the superiority of the equations. Examining the statistics alone, one would conclude that equation two does a slightly better job of fitting the data.

The similarities in the graphic analysis of the equations provided little insight into which might be the better equation for forecasting purposes. Both of the equations exhibited a random pattern in the residual plots. Similarly, when plotted, both equations did a more than adequate job of tracing the historical pattern. Similarities in the performance of the current dollar counterparts and tentative forecasts prevented any choice of a "best" equation using these criteria.

Given that the two were both statistically valid equations, the decision as to which was preferable for forecasting was made on an economic and intuitive basis. The major difference between the two equations is the inclusion of a furniture variable in one case and a mobile home variable in the other. The decision as to which equation to use for forecasting was made by choosing the more meaningful explanatory variable to be included in the model.

Pre-fab wood buildings and mobile homes accounted for 14 percent of the lumber and wood products output in 1972. The 1978 Industrial Outlook ranks mobile homes as the number one industry in terms of expected real annual growth in the 1977-1982 period (51). These considerations led to the inclusion of the variable in the model databank. Mobile homes, undoubtedly, will play an increasingly important role in SIC 24 performance. However, mobile homes are not dependent upon the hardwood resource, except indirectly, in that most units are sold furnished.

The strength of furniture industry demand, on the other hand, is one of the major determinants of the fluctuations in the hardwood market. Further, the analysis of Tennessee output for the more recent time series indicates that the state furniture industry has been consistently important in explaining the variations in lumber output.

Given the above considerations and the hardwood resource base, equation one was determined to be a better equation for forecasting lumber and wood products output. The plot of the actual values for the 1956 to 1976 series with the predicted values from equation one is shown in Figure 9, with the associated numbers shown in Table 3.

The fit of the model to the data (Figure 9) is consistent, and generally the turning points are accurately predicted. The areas that do not fit the data usually can be explained in terms of inconsistencies in the relationship among the variables. For example, in the 1965-1966 time period the actual output in the state lumber industry increased, whereas the predicted value shows a decrease. The reason can be traced to the hardwood and softwood markets at the time and the subsequent lumber production figures. The Demand and Price Situation for Forest Products 1966 indicates that from 1965 to 1966 there was a significant increase in hardwood production, but no increase in U. S. softwood production. The housing market was depressed at the time, while the furniture, pallet, and railroad tie markets were strong (15). These factors are reflected in statistics in Table 3.

The value of the coefficient of the state furniture variable is influenced by the fact that the furniture and U. S. lumber industry variables usually move in the same direction. When this condition does not hold (as in this instance), the accuracy of the prediction suffers.

In order to gain a better understanding of the importance of the individual variables in the model, the standardized regression coefficients were calculated:[2]

---

[2]Variables defined on page 56.

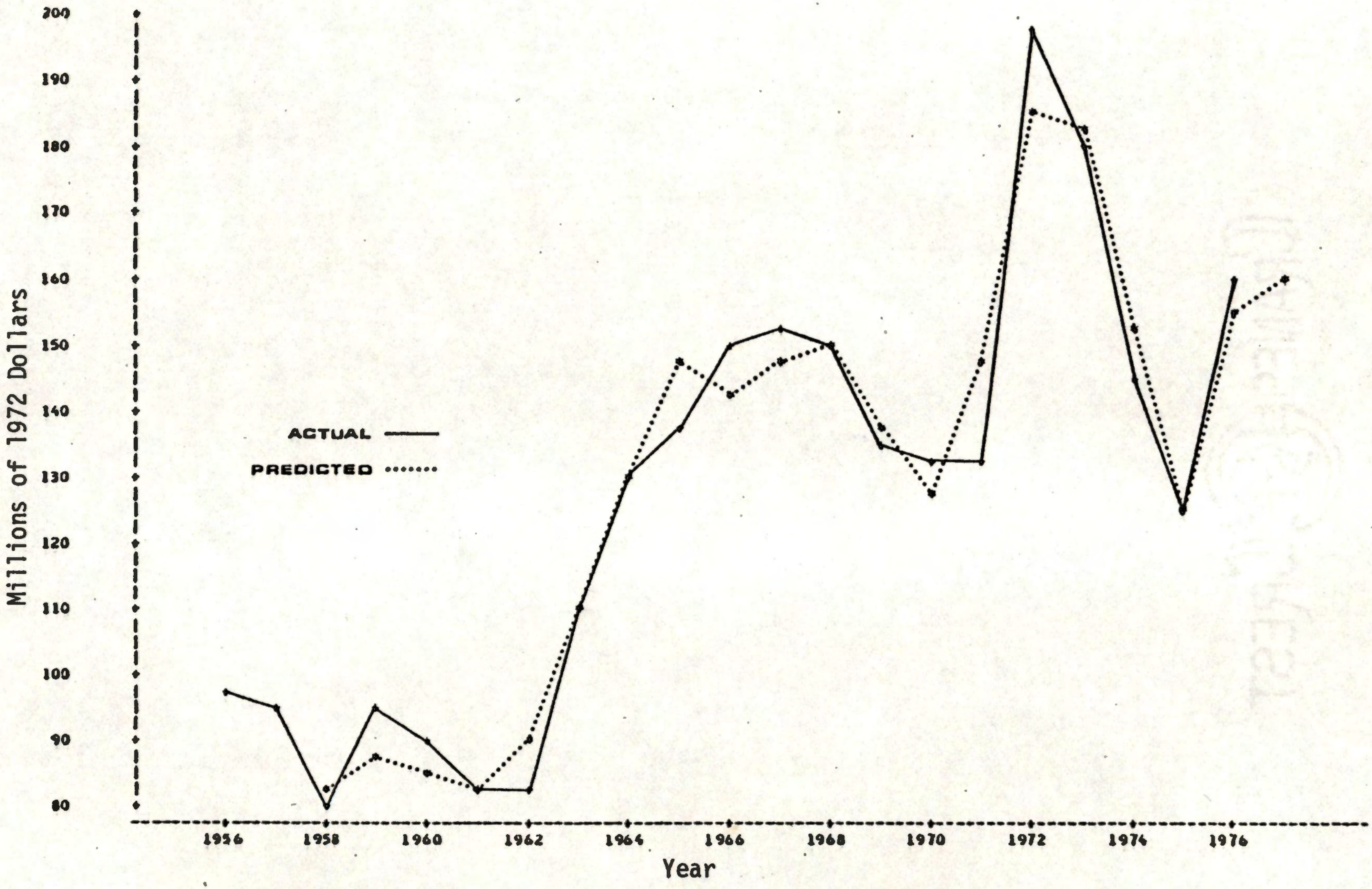

Figure 9. Constant Dollar Output Forecasting Equation, Actual and Predicted Values.

Source: TN SIC 24 Model

TABLE 3

OUTPUT FORECASTING EQUATION
TIME SERIES DATA

Year	Predicted	Residual	TGPLUM7	USLUM7	TGPFUR7	MTGRT
1956	*	*	97.901	4.7	82.381	*
1957	*	*	93.856	4.4	84.447	*
1958	81.474	-1.621	79.853	4.1	81.117	5.59
1959	87.577	8.133	95.711	4.8	93.022	6.02
1960	85.300	5.930	91.230	4.6	95.019	6.06
1961	82.827	-0.810	82.017	4.3	93.016	5.94
1962	89.358	-6.759	82.599	4.3	110.893	5.94
1963	111.231	-1.206	110.026	5.3	135.930	5.89
1964	130.782	-1.842	128.940	6.6	143.945	5.82
1965	147.898	-9.202	138.696	7.3	167.463	5.81
1966	143.371	7.615	150.986	7.2	176.879	6.25
1967	147.713	5.485	153.198	7.5	187.789	6.46
1968	150.864	-1.444	149.419	7.8	208.076	6.97
1969	138.081	-2.001	136.080	7.7	211.320	7.80
1970	127.530	4.970	132.500	8.0	199.996	8.45
1971	147.620	-16.095	131.525	8.0	225.085	7.74
1972	184.843	11.457	196.300	8.9	291.200	7.59
1973	182.719	-1.479	181.240	9.0	297.276	7.95
1974	153.555	-8.370	145.185	9.0	258.300	8.92
1975	124.831	0.893	125.724	8.1	212.924	9.01
1976	154.691	6.346	161.037	9.1	261.085	8.99
1977	159.182	*	*	9.3	267.675	9.01

TGPLUM7 = TN SIC 24 output in millions of 1972 dollars.
USLUM7 = U. S. SIC 24 output in billions of 1972 dollars.
TGPFUR7 = TN SIC 25 output in millions of 1972 dollars.
MTGRT = U. S. Average Mortgage Rate, New Homes.
Missing values are represented by "*".

USLUM7 = .677 TGPFUR7 = .800 MTGRT = .593

The indication from these figures is that the predicted value of Tennessee lumber output would be affected more by changes in the state furniture variable (in terms of standard deviations) than by either the national lumber or mortgage rate variables. These values also show that the variables play a more balanced role in the model than would be expected from looking at the estimated coefficient values alone.

Another measure that takes into account the individual variables is the elasticity of the relationship between the dependent variable and the independent variables. Though the validity of the elasticity measure is compromised by the presence of multicollinearity, their calculation does give some indication of the interrelationships in the equation. Table 4 contains the values as calculated at the mean from the final linear form of the model as well as an estimate from a logarithmic version of the model.

TABLE 4

ELASTICITIES FROM THE OUTPUT FORECASTING EQUATION
(DEPENDENT-INDEPENDENT VARIABLE)

	TGPLUM7-USLUM7	TGPLUM7-TGPFUR7	TGPLUM7-MTGRT
Final Linear Form	+ .6427	+ .5085	- .8625
Log Form	+ .6748	+ .3838	- .6973

If valid (i.e. unaffected by multicollinearity), these elasticities would lead to the conclusion that the Tennessee lumber industry performance is not as volatile as the key factors (in this model) which influence its performance; i.e., it exhibits an inelastic response. This conclusion is supported by the past performance of the Tennessee lumber industry as a whole, though particular segments by comparison may be quite volatile. Note that the elasticity figures indicate a greater sensitivity to changes in mortgage rates than is shown by the standardized regression coefficients.

Current Dollar. The nominal dollar counterpart of the output forecasting equation and the associated descriptive statistics are shown in Table 5. The actual and predicted values are shown in Figure 10.

Output Structural/Simulation Equation

Constant Dollar. In contrast to the forecasting equation formulation, the mechanical data screening process did not yield any satisfactory simulation equations. The need for an equation whose independent variables were uncorrelated proved to be a very restrictive criterion. Furthermore, due largely to multicollinearity in the data, the performance of many of the "hardwood" variables in the equations was often contrary to economic expectations.

One way of including important variables in an equation which would otherwise be intercorrelated is to transform the variables into ratios that do not exhibit the same interrelationships.

TABLE 5

CURRENT DOLLAR OUTPUT FORECASTING EQUATION

Equation	R^2	$\bar{R}^2$	MSE	SE	DW
106.4835 + 15.6965 USLUM + .2950 TGPFUR -19.9565 MTGRT (20.01) (2.98) (.096) (4.17)	.973	.968	81.55	9.03	2.0

USLUM = U. S. SIC 24 Output Current Dollars

TGPFUR = TN SIC 25 Output Current Dollars

MTGRT = U. S. Average Mortgage Rate New Homes

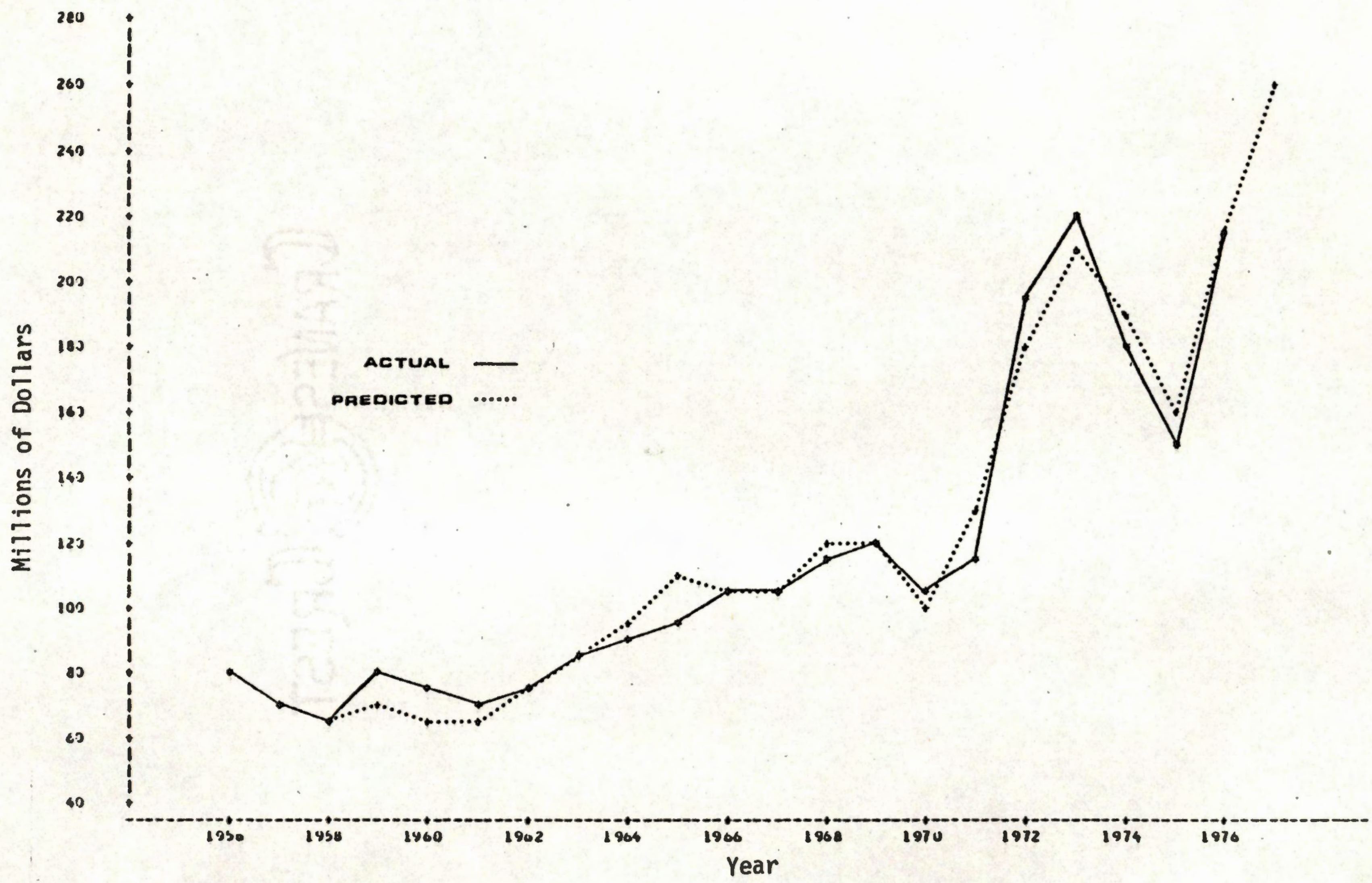

Figure 10. Current Dollar Output Forecasting Equation, Actual and Predicted Values.

Source: TN SIC 24 Model

Since furniture manufacturing is one of the primary markets for hardwoods, it was postulated that variables important to furniture industry performance would provide insight into possible combinations or transformations useful to the Tennessee lumber and wood products model.

Insight into the variables important to the performance of the furniture industry was provided by Dr. Michael Sherman of the National Association of Furniture Manufacturers (38). His information on past research into the performance of hardwood prices led to testing the importance of the interrelationships between fixed investment in residential structures and the furniture industry as factors in hardwood market fluctuations.

The resulting equation and descriptive statistics are shown in Table 6.

The correlation coefficient between the independent variables is -.211, which was not significant at the .05 level.

Though the use of the ratio allowed an acceptable model to be produced, the interpretation of its precise definition is complex. Basically, the model relates the output of the Tennessee lumber industry to the housing sector and to the performance of the furniture industry relative to housing.

Note that even though there was a much larger data base for this equation, the final form consists of variables taken from the Wharton databank. Therefore, this equation has the potential to forecast the dependent variable, given the forecast from the Wharton system.

TABLE 6

CONSTANT DOLLAR OUTPUT SIMULATION EQUATION

Equation	R^2	$\bar{R}^2$	MSE	SE	DW	Period
-148.4276 + 3.5565 FXIVRS7 + 1422.2983 NAFM2 (28.14) (.327) (246.2)	.880	.867	146.3	12.1	1.41	56-76

FXIVRS7 = U. S. Fixed Investment in Residential Structures \$72

NAFM2 = USFUR7/FXIVRS7 where USFUR7 = U. S. Furniture Sector Output \$72.

Figure 11 shows the actual lumber output values and the predicted values using the simulation equation: Table 7 contains the numbers from which the figure was derived.

As is shown, the predicted values for the last four years have been consistently high. If predictions were to be made with this model, this would be an indication that constant adjustments may be necessary. When data becomes available from the 1977 Census of Manufacturers, the additional information could be used to better analyze model performance.

Before examining the effects of the individual variables, it should be reiterated that multicollinearity has not been eliminated from the model; it has simply been reduced to a manageable level. The statistics that identify the effects of the individual variables, therefore, should be taken in the context of this particular equation.

An examination was made of the partial and sequential sums of squares associated with the independent variables. This indicated that most of the variation in the dependent variable was explained by fixed investment in residential structures.

This assessment is substantiated further by the standardized regression coefficients (shown in Table 8). The indication is that the dependent variable responds more to changes in FXIVRS7 (in terms of standard deviations) than to the ratio NAFM2.

In terms of a percentage response (elasticity), the same relationship holds (Table 9).

The elasticities indicate that the dependent variables response to a percentage change in residential investment is elastic and near unity in response to the relative performance of furniture.

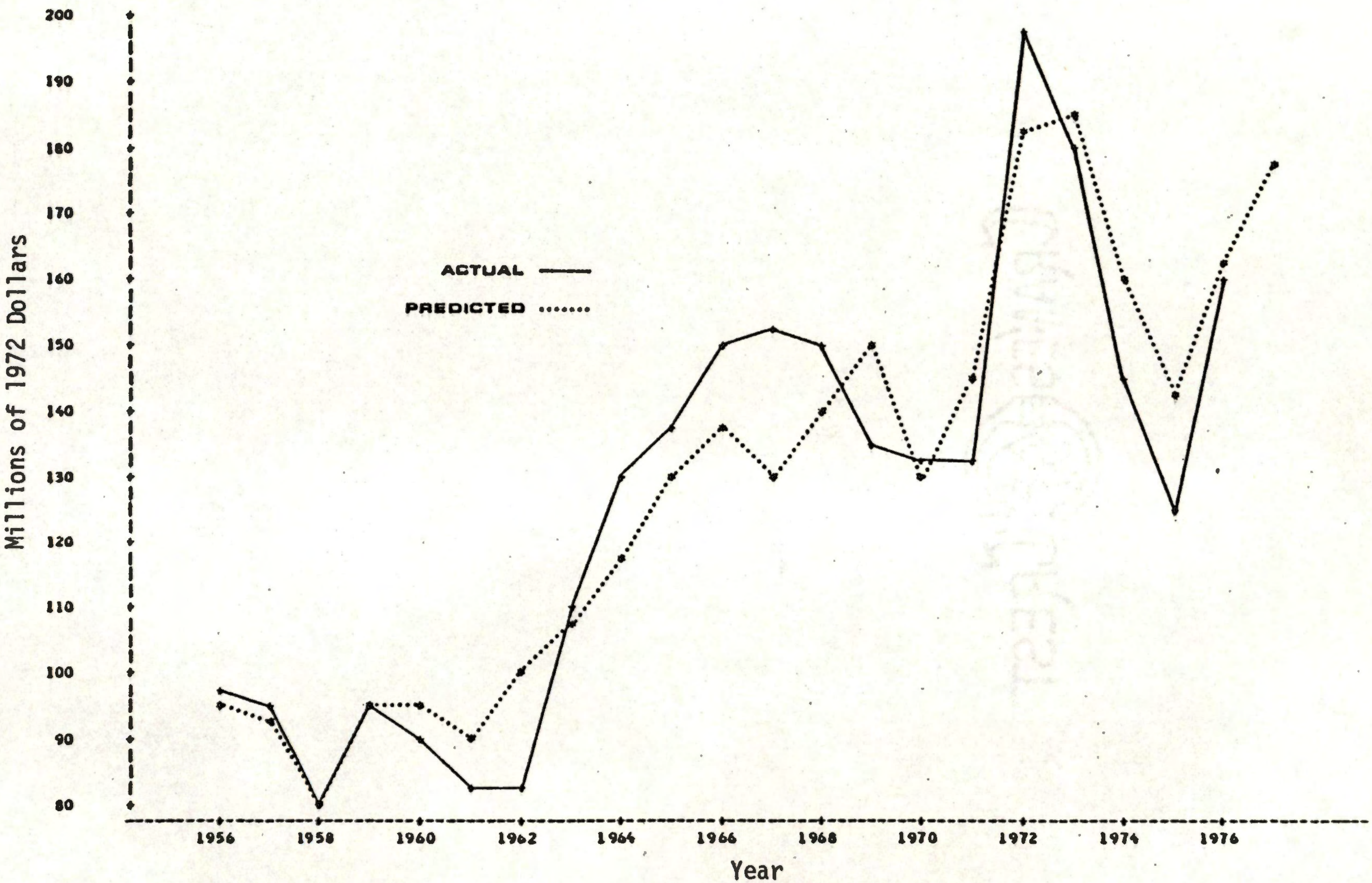

Figure 11. Constant Dollar Output Simulation Equation, Actual and Predicted Values.

Source: TN SIC 24 Model

TABLE 7

OUTPUT SIMULATION EQUATION
TIME SERIES DATA

Year	Predicted	Residuals	TGPLUM7	FXIVRS7	NAFM2
1956	94.323	3.578	97.901	31.9	0.090909
1957	91.288	2.569	93.856	29.7	0.094276
1958	81.249	-1.395	79.853	30.6	0.084967
1959	95.332	0.379	95.711	38.1	0.076115
1960	93.896	-2.666	91.230	35.0	0.082857
1961	89.864	-7.846	82.017	35.1	0.079772
1962	99.257	-16.658	82.599	38.4	0.078125
1963	107.274	2.752	110.026	43.2	0.071759
1964	117.752	11.188	128.940	43.8	0.077626
1965	130.321	8.375	138.696	43.2	0.087963
1966	136.267	14.719	150.986	38.5	0.103896
1967	129.161	24.037	153.198	37.2	0.102151
1968	140.037	9.383	149.419	42.8	0.095794
1969	150.075	-13.995	136.080	43.2	0.101852
1970	129.034	3.466	132.500	40.4	0.094059
1971	146.208	-14.682	131.525	52.2	0.076628
1972	182.186	14.114	196.300	62.0	0.077419
1973	185.395	-4.156	181.240	59.7	0.085427
1974	160.164	-14.979	145.185	45.0	0.104444
1975	143.523	-17.799	125.724	38.8	0.108247
1976	161.420	-0.383	161.037	47.8	0.098326
1977	177.564	*	*	57.7	0.084922

TGPLUM7 = TN SIC 24 output in millions of 1972 dollars
FXIVRS7 = U. S. Fixed Investment in Residential Structures in billions of 1972 dollars
NAFM2 = U. S. SIC 25 output in millions of 1972 dollars/FXIVRS7
Missing values are represented by "*"

TABLE 8

STANDARDIZED REGRESSION COEFFICIENTS FROM THE OUTPUT SIMULATION EQUATION

FXIVRS7	NAFM2
+.955	+.471

FXIVRS7 = Fixed Investment in Residential Structures in U. S.

NAFM2 = U. S. Furniture Output/FXIVRS7

TABLE 9

ELASTICITIES IN THE OUTPUT SIMULATION EQUATION (DEPENDENT - INDEPENDENT VARIABLE)

TGPLUM7 - FXIVRS7	TGPLUM7 - NAFM2
+1.191	+.998

Current Dollar. The current dollar version of the structural equation is shown in Table 10. The definitions of the variables are the same, the only difference being the use of nominal values.

The predicted and actual values associated with the equation are plotted in Figure 12.

Final Form of the Employment and Wage Equations

Employment. One of the objectives in formulating the employment equation was to incorporate feedbacks in the system of equations. Specifically, the objective was to establish the relationship between output and employment in the state lumber industry.

One interesting phenomenon shown in the graph of employment (Figure 13) is the fact that the 1977 and 1957 employment figures are not substantially different. The implication is that the increase in output over this time period can be attributed largely to productivity increases. Using value added per employee as a proxy of productivity, Figure 14 shows the productivity growth over the 20 year study period.

The nearly continuous rise in productivity in the period is consistent with the documented shift to larger, more efficient mills from 1960 to 1970. Since output was being used to explain employment, the significant changes in output per worker during the 1960's caused problems in the regression analysis. Consequently, the latter part of the study period was emphasized as being more indicative of probable future trends.

TABLE 10

CURRENT DOLLAR OUTPUT SIMULATION EQUATION

Equation	R^2	$\bar{R}^2$	MSE	SE	DW
-52.6521 + 3.2764 FXIVRS + 490.8978 NAFM3 (23.3) (.180) (218.3)	.949	.944	137.9	11.74	1.43

FXIVRS = U. S. Fixed Investment in Residential Structures in Current Dollars.
NAFM3 = USFUR/FXIVRS where USFUR = U. S. SIC 25 Output in Current Dollars.

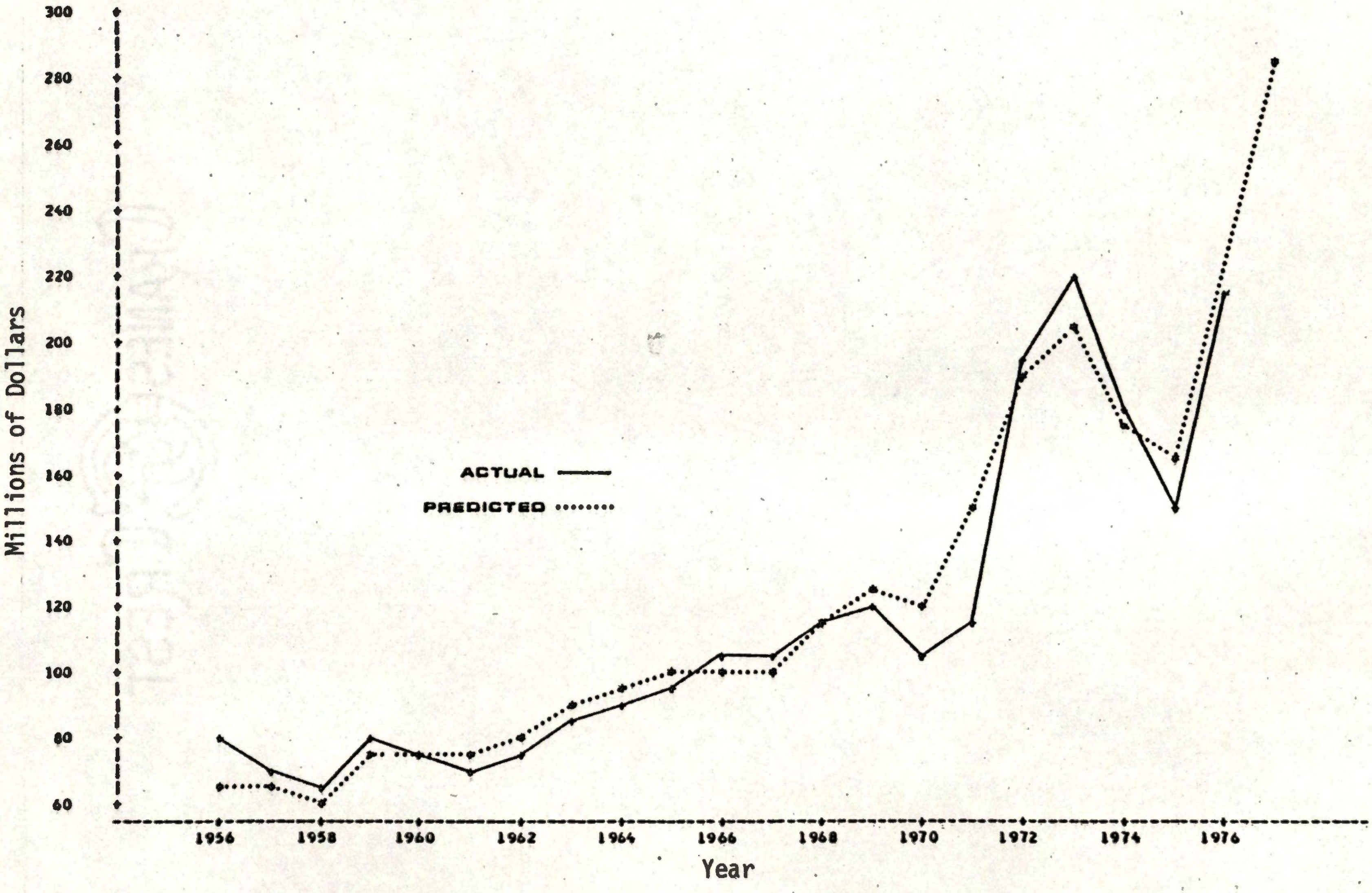

Figure 12. Current Dollar Output Simulation Equation, Actual and Predicted Values.

Source: TN SIC 24 Model

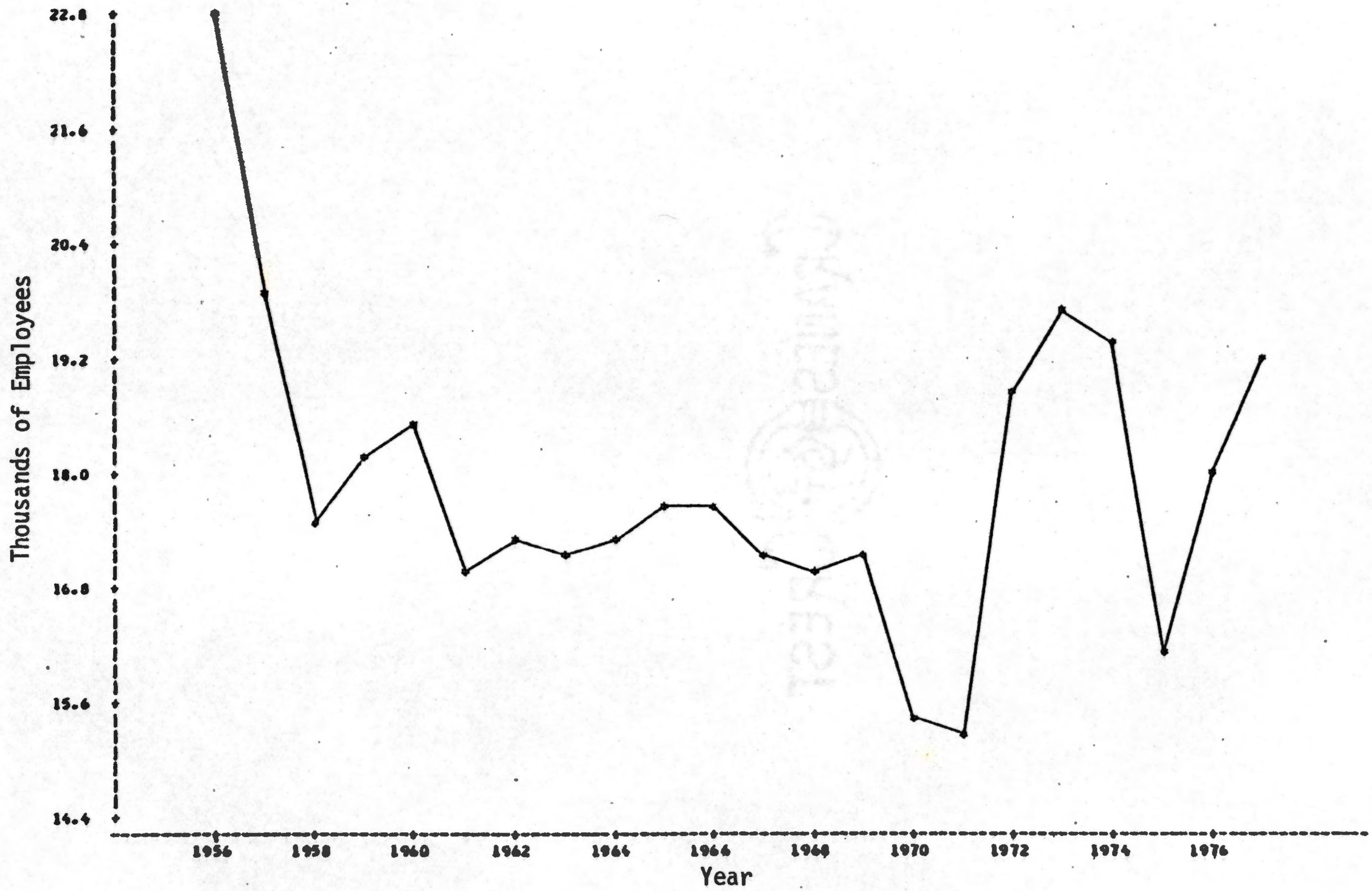

Figure 13. Tennessee SIC 24 Employment.

Source: (BLS, CBER)

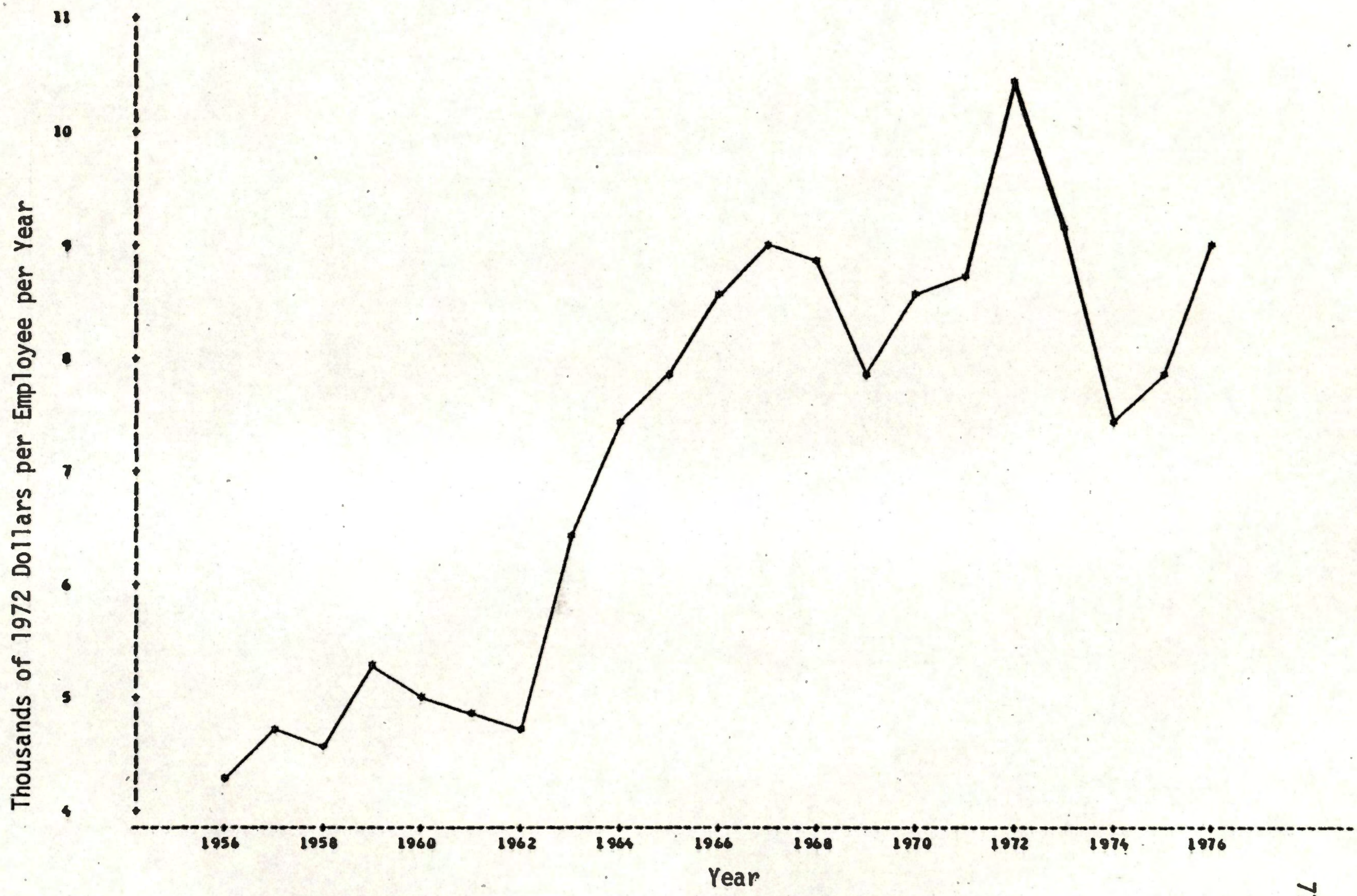

Figure 14. Tennessee SIC 24 Productivity.

Source: TN SIC 24 Model

In 1967 the significant increases in productivity growth began to level off. It was postulated that the fluctuations in output and employment after that year would best identify the probable future relationship of the two variables. As a result, the equation was fitted for the 1967 to 1976 time period.

A lagged dependent variable was included in the model to account for the fact that employment does not fluctuate as readily as output might. The final form of the equation is shown in Table 11.

TABLE 11

EMPLOYMENT FORECASTING EQUATION

Equation	R^2	$\bar{R}^2$	MSE	SE	DW
-.7278 + .0608 TGPLUM7 + .5144 TELLAG1	.804	.748	.620	.787	2.93
(3.93) (.012) (.0175)					

TGPLUM7 = TN SIC 24 Output $72.

TELLAG1 = TN Employment SIC 24 lagged 1 year

The actual and predicted values are shown in Figure 15. Note that, except for the 1969 and 1970 predictions, the turning points and magnitude of change are for the most part correctly predicted. Tables 12 and 13 contain the values associated with the productivity and employment graphs respectively. The elasticities associated with the equation are shown in Table 14.

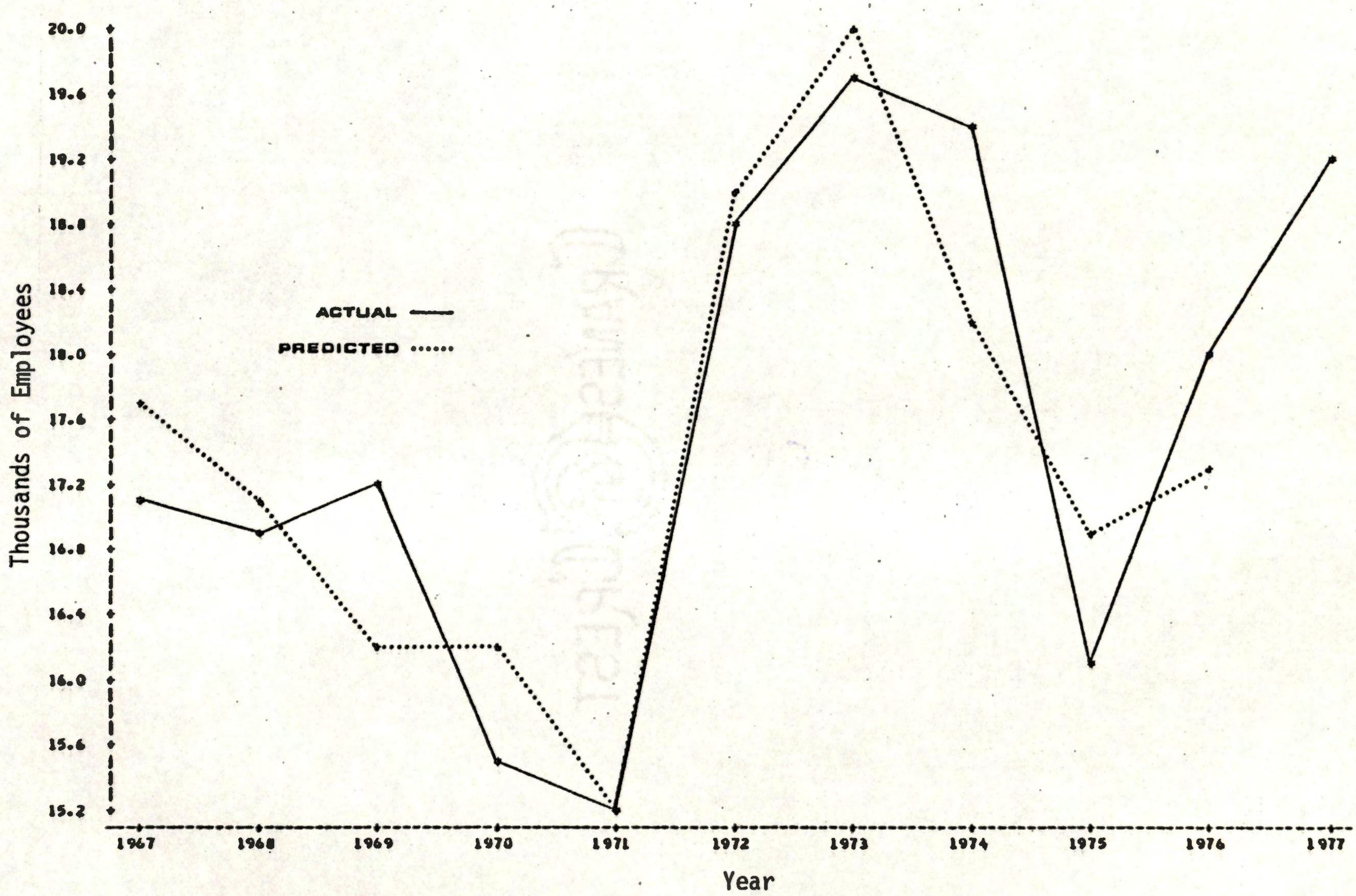

Figure 15. Employment Forecasting Equation, Actual and Predicted Values.

Source: TN SIC 24 Model

TABLE 12

TENNESSEE SIC 24 PRODUCTIVITY
TIME SERIES DATA

Year	TGPLUM7	TELUM	Productivity
1956	97.901	23.0	4.2566
1957	93.856	19.8	4.7402
1958	79.853	17.5	4.5631
1959	95.711	18.2	5.2588
1960	91.230	18.5	4.9314
1961	82.017	17.0	4.8245
1962	82.599	17.3	4.7745
1963	110.026	17.2	6.3968
1964	128.940	17.3	7.4532
1965	138.696	17.6	7.8804
1966	150.986	17.7	8.5303
1967	153.198	17.1	8.9589
1968	149.419	16.9	8.8414
1969	136.080	17.2	7.9116
1970	132.500	15.5	8.5484
1971	131.525	15.2	8.6530
1972	196.300	18.8	10.4415
1973	181.240	19.7	9.2000
1974	145.185	19.4	7.4837
1975	125.724	16.1	7.8089
1976	161.037	18.0	8.9465
1977	*	19.2	*

TGPLUM7 = TN SIC 24 Value Added
TELUM = TN SIC 24 Employment
Productivity = TGPLUM7/TELUM, Value Added (in thousands of dollars) per Employee per year
Missing values are represented "*"

TABLE 13

EMPLOYMENT FORECASTING EQUATION
TIME SERIES DATA

Year	TELUM	Predicted	Residual	TGPLUM7	TELLAG1
1967	17.1	17.6850	-0.58500	153.198	17.7
1968	16.9	17.1468	-0.24681	149.419	17.1
1969	17.2	16.2334	0.96658	136.080	16.9
1970	15.5	16.1702	-0.67019	132.500	17.2
1971	15.2	15.2366	-0.03655	131.525	15.5
1972	18.8	19.0181	-0.21809	196.300	15.2
1973	19.7	19.9547	-0.25470	181.240	18.8
1974	19.4	18.2268	1.17316	145.185	19.7
1975	16.1	16.8900	-0.79005	125.724	19.4
1976	18.0	17.3384	0.66164	161.037	16.1
1977	19.2	*	*	*	18.0

TELUM = TN SIC 24 Thousands of Employees
TGPLUM7 = TN SIC 24 Value Added
TELLAG1 = TN SIC 24 Employment in the previous year
Missing values are represented "*"

TABLE 14

ELASTICITIES FROM THE EMPLOYMENT FORECASTING EQUATION
(DEPENDENT - INDEPENDENT VARIABLES)

TELUM - TGPLUM7	TELUM - TELLAG1
+.529	+.514

TELUM = TN SIC 24 Employment

TGPLUM7 = TN SIC 24 Output $72

TELLAG1 = Dependent Variable Lagged 1 year

As is shown, an inelastic relationship exists between both the independent variables and employment. The practical interpretation from the above would be that, given the variations in output, the resulting fluctuations in employment are less pronounced.

Since the exogenous variables for the employment equation were endogenous to the SIC 24 model, the relationship between output and employment might be refined using dynamic simulation. In this instance, values were estimated for employment for 1973 through 1976 using the output equation's predicted output values. The differences between these values and the actual figures exhibited alternate signs; that is, there were no consistent under or over-estimation of the actual values. Therefore, it was impossible to draw any conclusions as to possible adjustments necessary to the equation.

Wage and Salary. The average annual wage and salary in Tennessee SIC-24 was postulated to be a function of the U. S. SIC 24 wage rate. This simple relationship was hypothesized due to the influences of factors outside the state economy on the wage rates of the industry. Though the absolute level may be below the U. S. average, the variables should exhibit similar fluctuations.

The first regression of the two variables yielded a satisfactory equation in all respects, except that the Durbin-Watson statistic indicated the presence of autocorrelation.

Rather than change the structure of the model, the original formulation was transformed (via the described iterative procedure) to yield a satisfactory equation. One iteration proved satisfactory in accounting for the autocorrelation without substantially changing the coefficient values. Both of the formulations are shown in Table 15.

The time series data used to derive the equations are shown in Table 16. The actual and predicted values for the wage equation are plotted in Figure 16.

The elasticity of Tennessee wages and salary to the U. S. wage rate in lumber was calculated using the adjusted form of the equation. The elasticity was estimated to be +.098, implying that Tennessee wages exhibit a slightly inelastic response to the national lumber wage rate.

II. FORECASTING RESULTS

Structural Considerations

After selection of the "best" forecasting equations, the production of forecasts of Tennessee's SIC 24 parameters involved simply

TABLE 15

WAGE AND SALARY FORECASTING EQUATION

Equation		R^2	R^2	MSE	SE	DW
Uncorrected	466.3305 + 1154.1999 USLUMWG	.946	.943	127730.1	357.4	.99
Final Form	408.5519 + 1176.2528 USLUMWG	.946	.943	128789.0	358.9	1.54

USLUMWG = U. S. SIC 24 Average Annual Wage Rate

TABLE 16

WAGE AND SALARY FORECASTING EQUATION
TIME SERIES DATA

Year	TAASWLUM	Predicted	Residual
1956	*	2478.66	*
1957	*	2537.47	*
1958	2573.71	2631.57	-57.86
1959	2769.07	2713.91	55.16
1960	2672.16	2819.77	-147.61
1961	2835.65	2855.06	-19.41
1962	3035.20	2949.16	86.04
1963	3172.15	3055.02	117.13
1964	3312.43	3231.46	80.97
1965	2870.57	3313.80	-443.23
1966	3669.21	3454.95	214.26
1967	3823.98	3654.91	169.06
1968	4223.02	3984.26	238.75
1969	4575.87	4254.80	321.07
1970	4992.97	4595.91	397.05
1971	5005.39	4819.40	185.99
1972	4490.69	5042.89	-552.20
1973	4612.08	5513.39	-901.31
1974	5245.00	5878.03	-633.03
1975	6539.69	6348.53	191.16
1976	7097.78	6866.08	231.69
1977	7664.01	7489.50	174.51

TAASWLUM = TN SIC 24 Average Annual Wage and Salary
Missing values are represented "*"

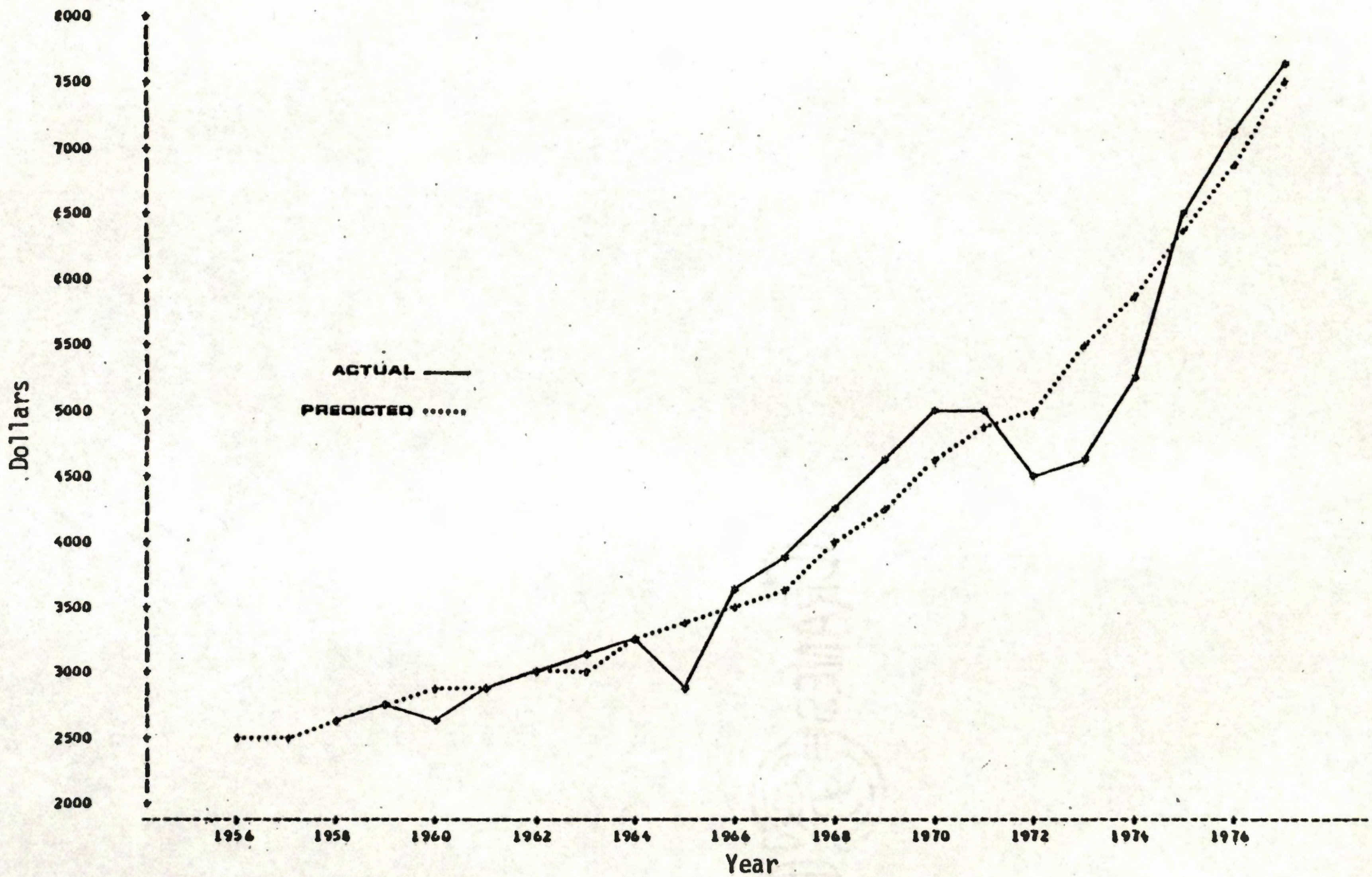

Figure 16. Wage and Salary Forecasting Equation, Actual and Predicted Values.

Source: TN SIC 24 Model

substituting the forecasts of the independent variables into the system of equations. Though the results would be more meaningful in the context of the state econometric model, the secular trends that are expected for the state lumber industry can be identified by using the equations as a satellite model.

The exogenous assumptions relevant to the Tennessee lumber industry model consist of the assumptions used to formulate the particular Wharton forecast that is used to drive the lumber model. The forecasts in this thesis are based on the April 11, 1979 Wharton forecast. This forecast is dependent upon the basic assumption that the President's Energy Plan (primarily oil price decontrol) would pass Congress substantially intact, but that the windfall profits tax would not be enacted.

The energy situation appears to be the most volatile of the policy issues affecting the forecasts of national economic activity. Though Wharton appears to be accurate in its assumptions on oil prices, the April forecast used in this formulation obviously does not take into account the recent changes in the President's energy policies.

The discussion of forecasting results is divided into two parts: 1) the short-term forecast (1978-1981) and 2) the long-term forecast (1982-1986). This is due to the fact that the short-term national outlook is much more sensitive to the exogenous assumptions than the long-term. The short-run "shocks" introduced into the model by alternative policy assumptions tend to converge over the long-run due to the secular trends implicit in the model structure.

Since the output forecasting equation includes variables from both the Wharton model (USLUM7, MTGRT) and TEM II (TGPFUR7), a valid forecast is possible only when compatible solutions of the two models are being used. This means that the forecast of the exogenous variable, Tennessee furniture output, must be based on the same Wharton forecast being used in the lumber industry equation.

Short-Term Forecast (1979-1981)

U. S. Outlook. The Wharton forecast used in this formulation calls for slow-to-moderate growth in real GNP for the 1979-1981 period. The growth rates from 1979 to 1980 and from 1980 to 1981 being 1.5 and 2.2 percent, respectively. The rate of inflation (as measured by change in the GNP deflator) is expected to reach a peak of 8.0 percent in 1979 and level off to 7.3 percent by 1981. Real per capita disposable income (1972 dollars) is expected to show minimal growth, with an increase from 4,555 dollars in 1979 to 4,694 dollars in 1981. The forecast of the prime rate shows a large drop from 10.07 percent in 1979 to a value of 8.93 percent in 1980, and a further decrease to 8.44 percent in 1981. Unemployment, on the other hand, is expected to increase from a 1979 value of 6.15 percent to 7.69 percent in 1981.

These selected indicators show that the 1979 to 1980 years are expected to be fairly stagnant in terms of real growth in the economy, with an expected upturn in 1981.

Output Forecast. The forecast of the national economy was the source of the forecast values of the exogenous variables and the subsequent forecast for the lumber industry shown in Table 17.

TABLE 17

SHORT-TERM OUTPUT FORECAST

Year	USLUM7	TGPFUR7	MTGRT	TGPLUM7
1978*	9.9	283.0	9.69	161.5
1979	10.4	297.4	10.47	160.7
1980	10.7	297.7	9.99	171.8
1981	11.2	304.5	9.55	187.0

USLUM7 = U. S. SIC 24 Output in billions of $72.

TGPFUR7 = TN SIC 25 Output in millions of $72.

MTGRT = U. S. Average Mortgage Rates - New Homes.

TGPLUM7 = TN SIC 24 Output in millions of $72.

1978* values are estimated from actual exogenous values.

The graph of the forecast values for both the short- and long-term forecast is shown in Figure 17. The 1978 figure is shown as a forecast because the actual values have not been published yet. As is shown, there has been a leveling off in Tennessee lumber output since 1976. The short-term forecast indicates that 1979 will continue the no-growth trend. The outlook for 1980 and 1981 shows that an upswing can be expected, the impetus being a drop in long-term interest rates and improved performance of the national industry.

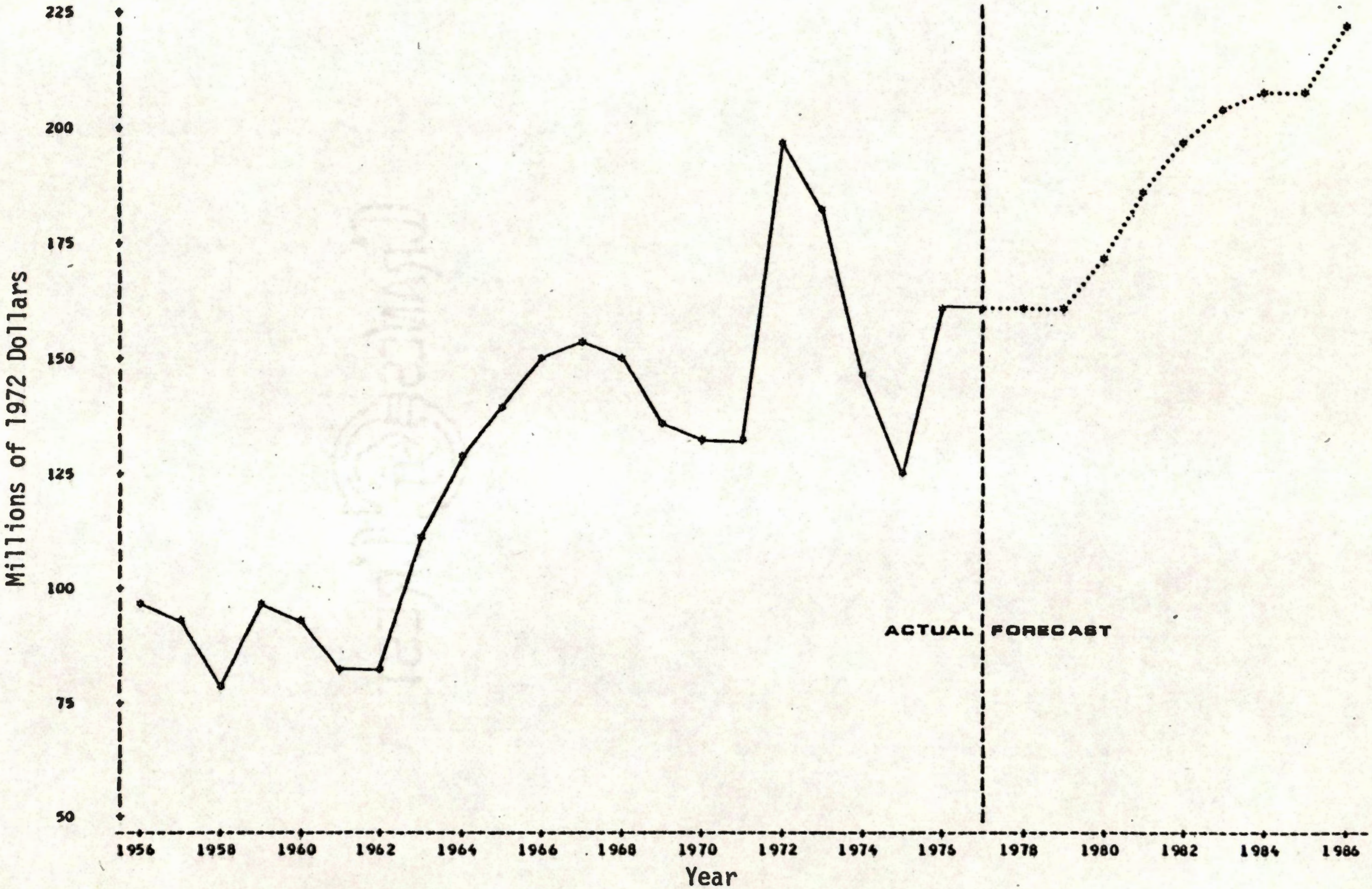

Figure 17. Output Forecasting Equation, Forecast Results.

Source: TN SIC 24 Model

The forecast growth is even greater in 1981 as the state furniture industry begins its recovery and provides additional impetus to the upturn in lumber production.

Employment Forecast. The forecast for employment is driven by the output forecast derived above. The values for the 1978-1981 period are shown in Table 18.

TABLE 18

SHORT-TERM EMPLOYMENT FORECAST

Year	TGPLUM7	TELUM
1978	161.5	19.0
1979	160.7	18.8
1980	171.8	19.4
1981	187.0	20.6

TELUM = Employment in Tennessee SIC 24.

Figure 18 shows that the leveling off in output in the 1978-1979 period implies a dropping off in employment. This would agree with economic logic and past performance in the industry in that increasing productivity would maintain a constant output during periods of dropping employment.

Wage and Salary Forecast. The forecast for nominal wages is totally dependent on Wharton's forecast for U. S. lumber sector wages.

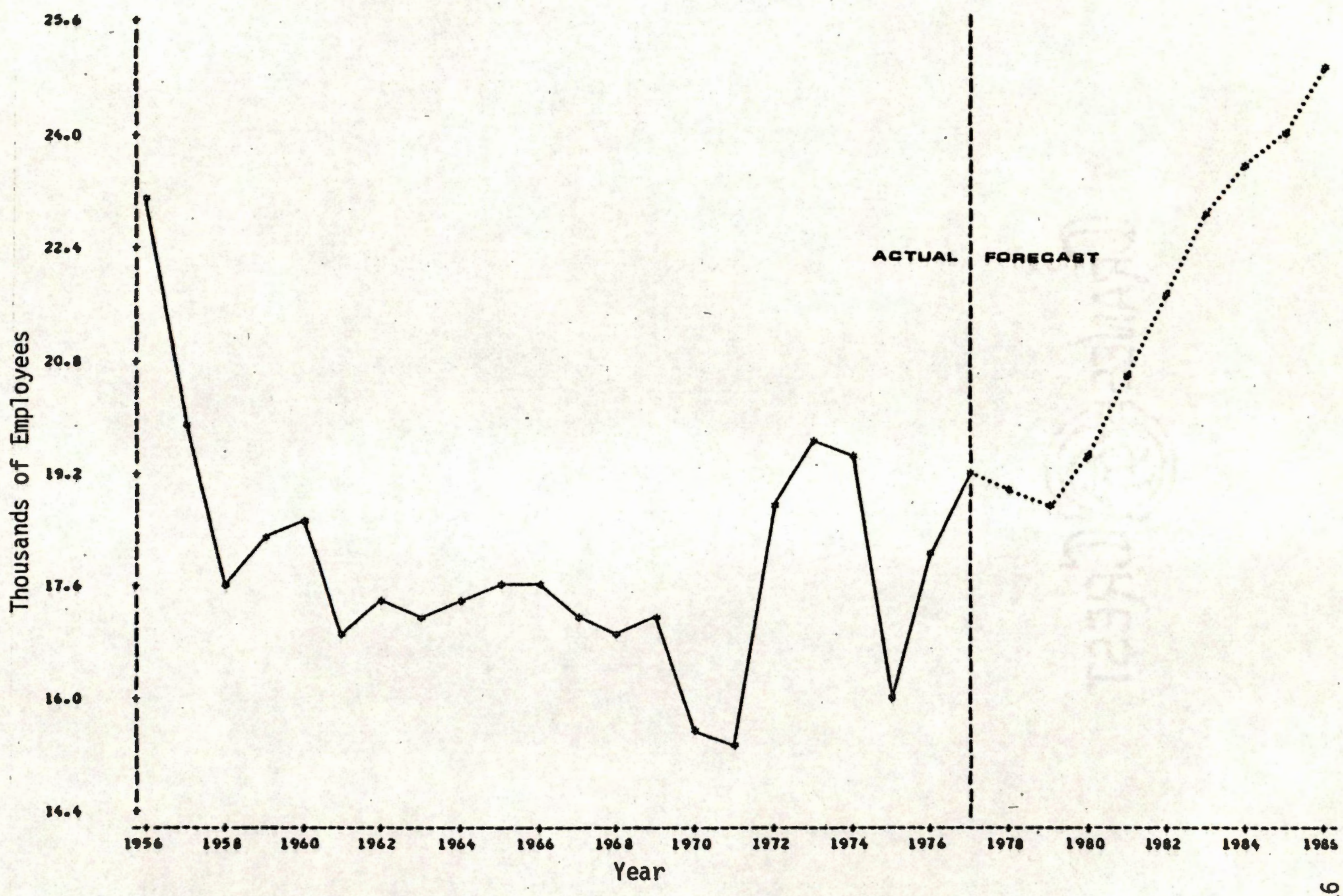

Figure 18. Employment Forecasting Equation, Forecast Results.

Source: TN SIC 24 Model

The statistics in Table 19 show the forecasts of the two wage variables.

TABLE 19

SHORT-TERM WAGE AND SALARY FORECAST

Year	TAASWLUM	USLUMWG
1978	7948.2	6.41
1979	8665.7	7.02
1980	9489.1	7.72
1981	10406.6	8.5

TAASWLUM = Tennessee SIC 24 annual average wage and salary

USLUMWG = U. S. SIC 24 annual average wage rate

Figure 19 illustrates that nominal wages are expected to maintain their upward trend.

Long-Term Forecast (1982-1986)

U. S. Outlook. Selected indicators of the Wharton forecast for 1982 to 1986 indicate a period of continuous moderate growth with a slight slowdown in 1984-1985. Real GNP growth is expected to average about 3 percent during the period, with inflation moderating from a high of 7.1 percent in 1982 to low of 5.9 percent in 1986. The average increase in real per capita disposable income is just over 2 percent, ranging from a 2.4 percent increase from 1985 to 1986 to a 1.7 percent increase from 1984 to

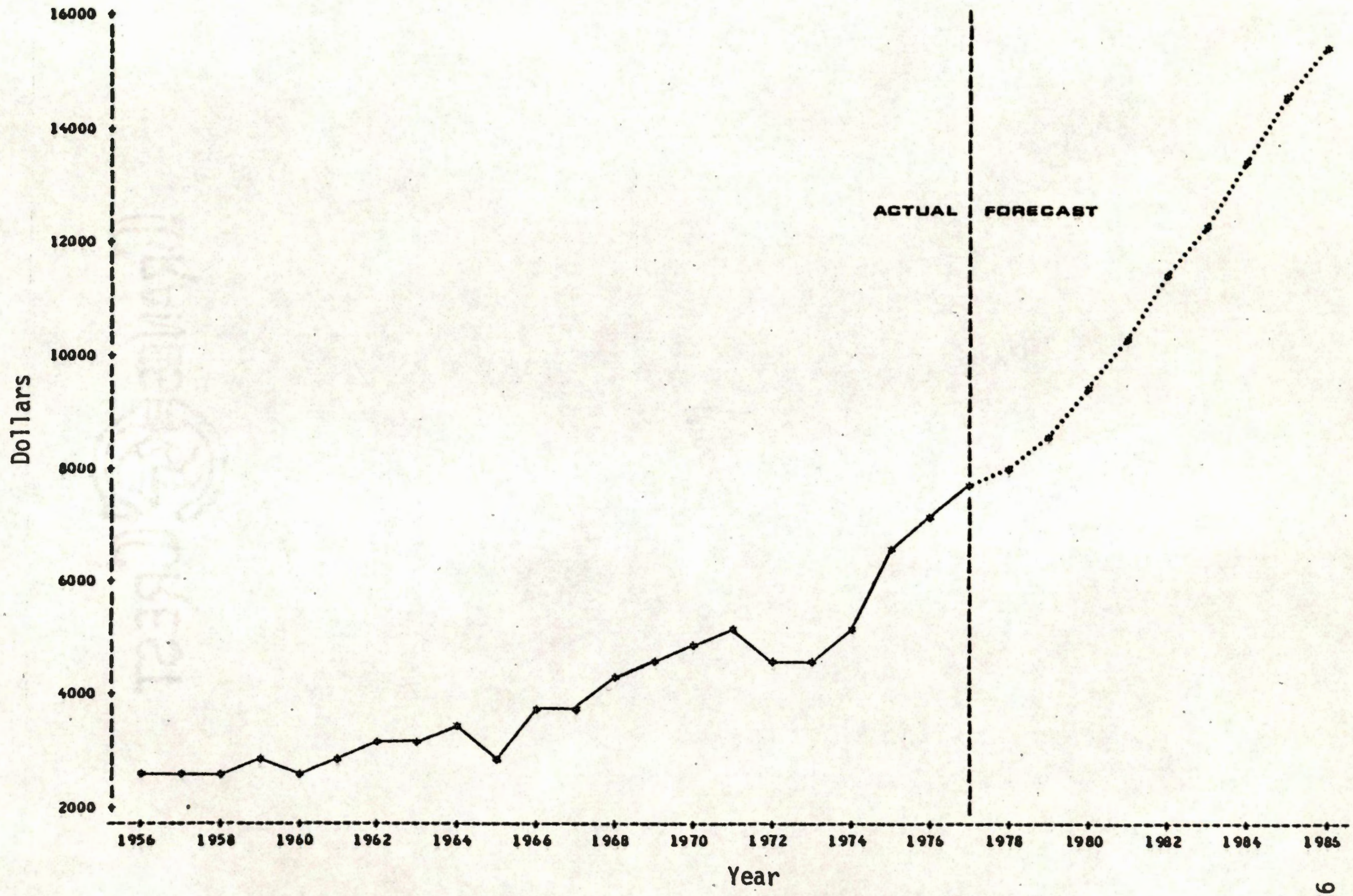

Figure 19. Wage and Salary Forecasting Equation, Forecast Result.

Source: TN SIC 24 Model

1985. The prime rate is expected to continue its decline from a high in 1979, averaging about 8 percent during this time period. The projected growth in real GNP is reflected in a continuing decrease in unemployment from its expected peak in 1981.

Output Forecast. The implications of the forecast slow-growth in the national economy for the 1984-1985 period are reflected in the long-term forecast for the Tennessee lumber industry. Table 20 contains the pertinent statistics that translate the national performance to Tennessee's SIC-24 industry's performance.

TABLE 20

LONG-TERM OUTPUT FORECAST

Year	USLUM7	TGPFUR7	MTGRT	TGPLUM7
1982	11.7	313.4	9.65	194.7
1983	12.1	323.3	9.67	202.8
1984	12.3	329.2	9.74	206.3
1985	12.2	330.2	9.71	205.9
1986	12.7	348.0	9.60	220.1

Referring back to Figure 17, page 89, the long-term outlook is for moderate growth until 1984, at which time the state lumber industry will enter a period of either slow or no growth.

Employment Forecast. Table 21 contains the forecasts for employment over the 1982-1986 period and the corresponding output forecast.

TABLE 21

LONG-TERM EMPLOYMENT FORECAST

Year	TGPLUM7	TELUM
1982	194.2	21.7
1983	202.8	22.8
1984	206.3	23.5
1985	205.9	23.9
1986	220.1	24.9

The plotted values in Figure 18, page 91, show that after the decline in 1978-1979, employment in the Tennessee lumber industry increases rapidly. It should be noted that even with the rapid increase in employment, it will be 1983 before employment is forecast to reach its 1956 level.

Wage and Salary Forecast. Wages are expected to show the least variations of the forecast variables. Table 22 contains the forecast values of the U. S. lumber industry wages and the Tennessee annual average wage and salary.

TABLE 22

LONG-TERM WAGE AND SALARY FORECAST

Year	USLUMWG	TAASWLUM
1982	9.29	11,335.8
1983	10.13	12,323.9
1984	11.02	13,370.8
1985	11.94	14,452.9
1986	12.87	15,546.8

The near linear rise in nominal wages is shown in Figure 19, page 93.

Forecast Summary

Table 23 consolidates the long-term and short-term forecasts. In addition, tentative forecasts of Tennessee gross state product, U. S. Gross National Product, U. S. lumber output, and Tennessee furniture output are shown for comparative purposes. In the context of the other variables included in Table 23, the unadjusted forecast for Tennessee's lumber and wood products industry seems optimistic.

III. STRUCTURAL/SIMULATION RESULTS

One of the goals of formulating the structural/simulation equations was to provide an instrument for valid impact analysis outside the context of the Wharton and TEM II models. An important implication for the model, therefore, was that key variables should be included such that their manipulation provided useful information.

The final form of the structural simulation equation contains two "key factors" for analysis: 1) the housing market (represented by the fixed investment in residential structures) and 2) the furniture market (represented by the ratio of furniture output to fixed investment in residential structures). Both of these variables are forecast in the Wharton long-term model; therefore the impact analysis is enhanced by the ability to forecast the "impacts" into the future.

TABLE 23

FORECAST OF TENNESSEE SIC 24 PARAMETERS AND SELECTED INDICATORS

Description*	1978	1979	1980	1981	1982	1983	1984	1985	1986
U. S. GNP $72	1385.3	1429.2	1450.3	1482.3	1533.8	1586.1	1627.9	1666.0	1723.8
% Change	3.9	3.2	1.5	2.2	3.5	3.4	2.6	2.3	3.5
TN GSP $72	25468.6	26198.1	26593.3	27248.4	28003.1	28815.8	29580.6	30217.0	31192.1
% Change	4.4	2.9	1.5	2.5	2.8	2.9	2.7	2.2	3.2
U. S. SIC 24 Output	9.9	10.4	10.7	11.2	11.7	12.1	12.3	12.2	12.7
% Change	7.2	4.3	3.6	4.1	4.7	3.4	1.4	-.7	4.3
TN SIC 25 Output	283.0	297.4	297.7	304.5	313.4	323.3	329.2	330.2	348.0
% Change	5.7	5.1	.1	2.3	2.9	3.2	1.8	.3	5.4
TN SIC 24 Output	161.5	160.7	171.8	187.0	194.7	202.8	206.3	205.9	220.1
% Change	1.5	-.5	6.9	8.8	4.1	4.2	1.7	-.2	6.9
TN SIC 24 Employment	19.0	18.8	19.4	20.6	21.7	22.8	23.5	23.9	24.9
% Change	-1.0	-1.1	3.2	6.2	5.4	5.1	3.1	1.7	4.2
TN SIC 24 Wages	7948.2	8665.7	9489.1	10406.6	11335.8	12323.9	13370.8	14452.9	15546.8
% Change	3.7	9.0	9.5	9.7	8.9	8.7	8.5	8.1	7.6

*U. S. GNP and U. S. SIC 24 are measured in Billions of 1972 dollars.
TN GSP, TN SIC 25, and TN SIC 24 are measured in Millions of 1972 dollars.
TN SIC 24 Employment is measured in Thousands of jobs.
TN SIC 24 Wages are measured in Current dollars.

Figure 20 illustrates the forecast using the simulation equation, given the U. S. industrial outlook and the policy assumptions of the April 11, 1979 Wharton forecast described above. The short-term outlook differs substantially from the forecast values shown in Figure 17, page 89, whereas the long-term forecast converge into a similar pattern. It is suggested that this is due to the structural relationships built into the Wharton model.

The value of the structural equation comes from both the "static" information it provides (i.e. the elasticities in Table 9, page 72) and the dynamic analysis it allows. Use of the equation for dynamic analysis could be approached in the following manner. The forecast of the Wharton model would provide a "control" solution. The particular policy assumptions used in making the Wharton forecast then would be analyzed. The impact analysis would consist of identifying alternative policy scenarios and postulating the effect on the forecast values of the housing and furniture variables. The statistical qualities of the equation would allow the independent variables to be manipulated separately or in combination. The "revised" solution then could be compared to the "control" solution to provide some indication of the resulting impact on Tennessee lumber and wood products.

This type of analysis would allow the researcher greater freedom in developing "independent" outlooks for the lumber and wood products sector. Rather than being totally dependent upon the Wharton forecast, other information or hypotheses could be incorporated into a modified forecast.

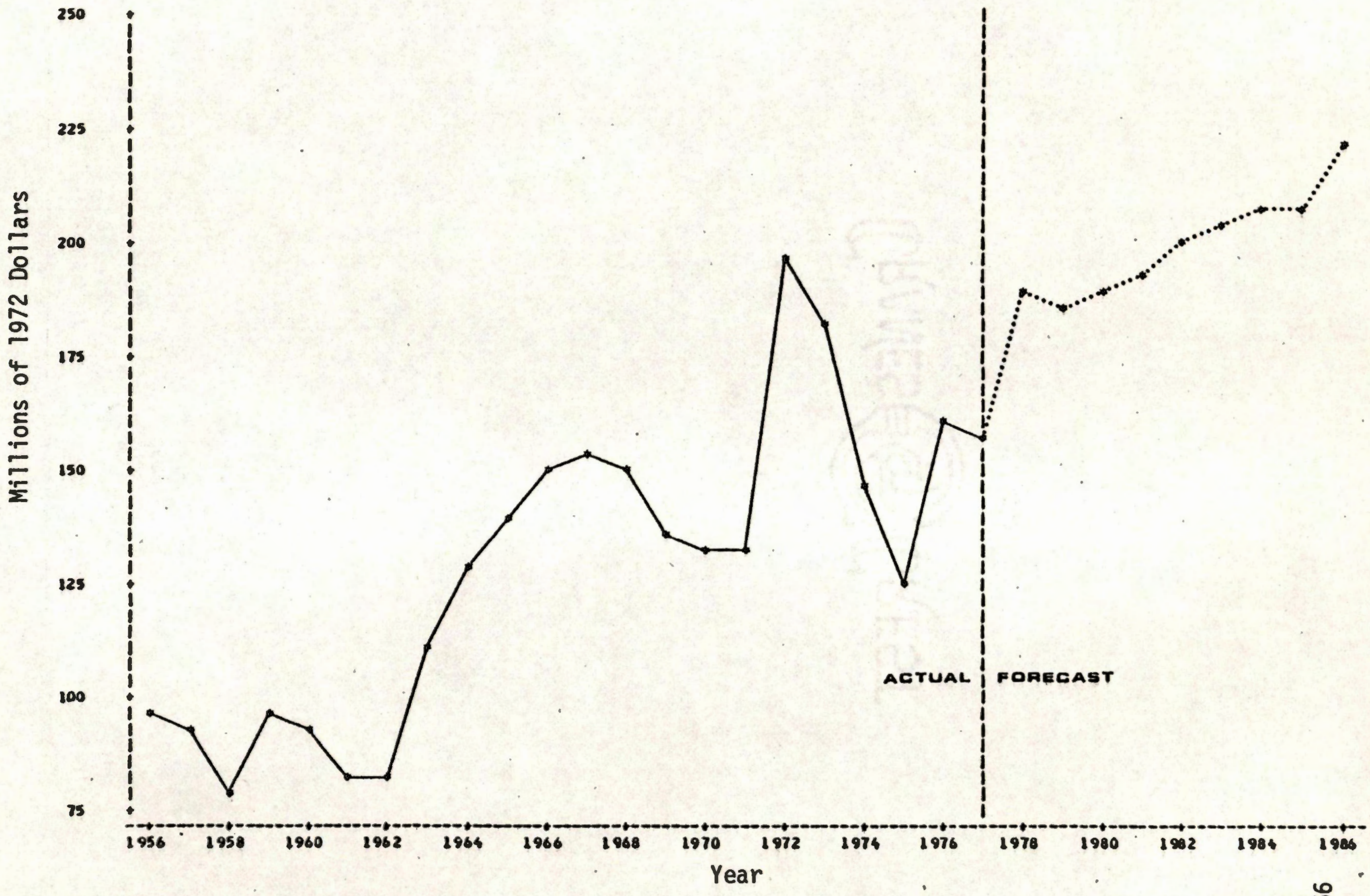

Figure 20. Output Simulation Equation, Forecast Results.

Source: TN SIC 24 Model

CHAPTER V

SUMMARY AND CONCLUSIONS

The general objective of this study was to provide a better measure of the contribution of the Tennessee lumber and wood products industry to the state economy. The objectives were accomplished by contructing equations that related the performance of Tennessee's lumber industry in terms of output, employment, and wages to variables forecast in national and state econometric models.

By developing equations within the structural constraints of the state econometric model, the equations essentially disaggregate the Tennessee lumber and wood products industry as a separate sector of the Tennessee Econometric Model (TEM II).[1] Though the equations are valid for forecasting as a separate satellite model, the forecasts would be more meaningful, by design, were the equations to be incorporated as components of the state model.

Refinements in the equations may be beneficial before they are incorporated in the model. Such adjustments should provide a better understanding of the interactions of the exogenous variables. Specifically, the importance of the mortgage rate variable in the output forecasting equation needs to be clarified. The fact that the predictions

[1]Tennessee lumber and wood products is currently included in the "Other Durables" sector of TEM II.

of the output equation are equally sensitive to mortgage rates as they are to the U. S. lumber industry and the state furniture industry variables has not been satisfactorily explained.

Other refinements in the equations could be accomplished after the equations were incorporated into TEM II. One of these would be the use of the interrelationships of the state model to better indicate the magnitude of constant adjustments needed in the forecasting equations.

The mechanical processes of examining systematic errors in the residuals and/or using dynamic simulation proved unsatisfactory in providing information as to the sign and magnitude of possible adjustments in this study. A look at the future expectations for lumber in the context of other TEM II and Wharton forecasts (Table 23, page 97) indicates that the state SIC 24 forecasts probably should be adjusted downward. Specifically, the 1980 and 1981 forecasts seem overly optimistic. This type of comparison would be enhanced by the use of the lumber equations as a sector in the state model.

Another obvious advantage to using the equations as a sector in the model is the in-place support structure and developed audiences for the state econometric model. Since the development of the SIC 24 equations was intended to better indicate the importance of the industry, dissemination of the resulting information to decision-makers in the public and private sector is obviously necessary to complete the process.

The benefits of adding the lumber equations to the state model are not limited to the lumber and wood products side of the relationship. The further disaggregation of the state model that would result from use of the equations is the obvious benefit to TEM II. Since all of exogenous variables come from Wharton or CBER, the additional computational load, once the equations are incprporated, would be minimal. The SIC 24 forecasting equations appear to be comparable, in both economic and statistical terms, to those currently used in the state econometric model. In this sense, the study appears to have accomplished its objective.

Another objective in this study was the development of an output equation for structural and/or impact analysis. The resulting equation provides only limited structural information in that only two variables (housing and furniture) are included in the model. The statistical qualities of the equation, however, are compatible with the objectives in that the significance of the estimated coefficients was enhanced by a reduction in multicollinearity.

An additional objective of developing the structural/simulation equations was to formulate equations not limited by the structural constraints of sector equations in TEM II. The conclusion reached after development of the equation is that the aforementioned constraints were not as restrictive as first thought. The larger data base of variables specifically related to hardwoods for the most part performed unsatisfactorily in the equations. As a result, the final form of the equation contains variables in the Wharton databank.

The definition of real output was another restriction that was postulated to compromise the validity of the forecasting equations. Real output in TEM II is defined as the state industry value-added, deflated by the national sector deflator. In the lumber industry model, this consisted of deflating a hardwood dominated industry by a softwood dominated deflator. An alternative estimate of real output in Tennessee's SIC 24 industry was postulated to be value-added deflated by the Wholesale Price Index for hardwood lumber. The differences in the two deflators are illustrated in Figure 21.

Tests for models that fit this alternative definition of real output were performed simultaneous to the formulation of the structural/simulation equations. No adequate models were identified. The poor fit of these models prevented any conclusions from being drawn about the better proxy of real output. It was impossible to determine whether the models were deficient due to: a) inadequacies in the definition of the dependent variable; b) incorrect specification of the model; or c) some combination thereof. Though the process seems to substantiate the use of the TEM II definition, it was not considered an integral part of the analysis.

As in most large-scale studies, this initial application of econometrics to the analysis of Tennessee's lumber and wood products industry identified many areas worthy of further study. One broad deficiency that was apparent was the general lack of research available on the national hardwood industries. A partial explanation may be the data problems encountered in this study. The data problems do not seem insurmountable, however, and the multitude of econometric applications to softwood market analysis would seem to indicate that the methodology has been refined adequately.

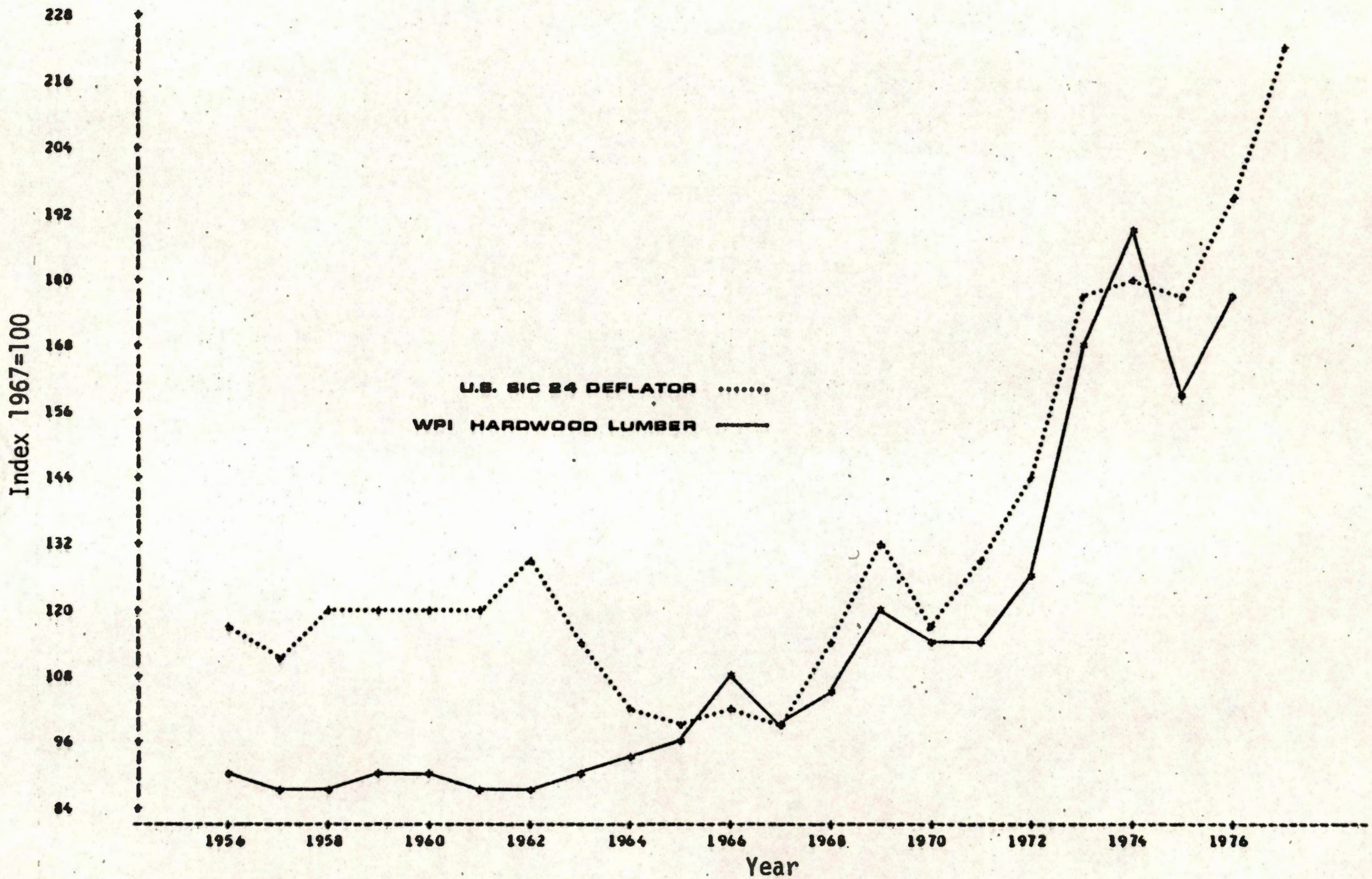

Figure 21. Performance of Alternative Output Deflators.

Source: (WEFA, CBER)

Viewing this thesis as a feasibility study into the development of a more detailed model of the industry, the conclusion would be favorable. In order to better incorporate price relationships into the model, data availability for a quarterly time frame model should be investigated. Quarterly data may identify better the relationships in the hardwood data that were hidden in the annual aggregates used in this analysis.

Further study is needed also into the relationship of hardwood stumpage and lumber prices. Given that the productive capacity of the industry is limited, the tendency of stumpage prices to exhibit large fluctuations in response to changing demand may affect the relationship of prices and value-added. The lack of quantitative analysis into the relationship between the hardwood product and factor markets would need to be corrected before or during development of a more detailed hardwood model.

The most logical next step in this project, (whether or not the equations are incorporated into the state model), would be an analysis of the aggregate wood products industries in Tennessee. By combining the three primary wood using sectors in TEM II (SIC 24, 25, 26), conclusions could be drawn regarding both the historic trends and future expectations of the industry. This type of analysis, in conjunction with more traditional structural and inventory analysis, could indicate policy issues and/or inconsistencies. In this type of application the model would provide an additional tool for policy analysis, as well as a feedback mechanism to judge tentatively the effect of alternative policy scenarios.

In conclusion, the development of the Tennessee SIC 24 model was a necessary first step in the process of providing the current detailed information that is required to accurately assess the "importance" of Tennessee's wood products industries. In addition, the format of the study allows for an indication of the future expectations for the important parameters of the industry (i.e. output, employment, and wages). This type of information has not been available for the state lumber and wood products industries. This study, therefore, provides the decision-maker in both the public and private sectors with two valuable assets: current data about the lumber industry in Tennessee and an objective assessment of future expectations.

The study was also valuable in that it represents a cooperative effort between the Center for Business and Economic Research and the Department of Forestry, Wildlife and Fisheries. This analysis reflects only part of the potential mutual benefits of such efforts. To the Center for Business and Economic Research this thesis basically represents a feasibility study. That is, specialized knowledge of the SIC 24 industry was applied to the development of a sector in the state model. From the forestry viewpoint, it represents the application of econometric techniques in identifying the "importance" of lumber and wood products industry in a dynamic context. In either instance, continued cooperation will be necessary for optimal application and utilization of the study results.

LIST OF REFERENCES

LIST OF REFERENCES

1. Adams, F. Gerald, and John Blackwell. 1973. "An Econometric Model of the United State's Forest Product Industry." In: Forest Science, vol. 19 #2, p. 82-96.

2. Barr, Anthony J., James H. Goodnight, John P. Sall, and Jane T. Helwig. 1976. A User's Guide to SAS - 76. SAS Institute, Inc., Raleigh, North Carolina, 329 pp.

3. Bertelson, Daniel F. 1971. Tennessee forest industries. USDA Forest Service, Resource Bulletin SO-30, Southern Forest Experiment Station, 27 pp.

4. Center for Business and Economic Research. 1979. An Economic Report to the Governor of the State of Tennessee. College of Business Administration, The University of Tennessee, Knoxville, Tennessee. 246 p.

5. Convery, Frank J. 1973. Unit planning and local economic impacts of alternative forest management practices. School of Forestry, Technical Paper, No. 1, Duke University, Durham, NC, 27 pp.

6. Czamanski, Stanislaw, and Emil E. Malizia. 1969. "Applicability and Limitations in the Use of National Input-Output Tables for Regional Studies," in: Regional Science Association Papers, Vol. 23, p. 65-78.

7. Draper, N. R., and H. Smith. 1966. Applied Regression Analysis. John Wiley & Sons, Inc., New York.

8. Eckstein, Otto. 1976. "Econometric Models and the Formation of Business Expectations." In: Challenge, March/April 1976, p. 12-19.

9. Elrod, Robert H., Kemal M. Sheshai, and William A. Schaffer. 1972. Interindustry study of forestry sectors for Georgia economy. Georgia Forest Research Council. Report No. 31, 18 pp.

10. Esteban-Marquillas, J. M. 1972. "A Reinterpretation of Shift-Share Analysis." In: Regional and Urban Economics. vol. 2 #3, p. 249-255.

11. Fromm, Gary, and Lawrence R. Klein. 1973. "A Comparison of Eleven Econometric Models of the United States." In: American Economic Review, Vol. 63 #2, p. 385-393.

12. Goldberger, Arthur S. 1968. Topics in Regression Analysis. The Macmillan Co., New York, pp. 144.

13. Gregory, G. Robinson. 1960. "A Statistical Investigation of Factors Affecting the Market for Hardwood Flooring." In: Forest Science, Vol. 6 #2, 134 pp.

14. Gustely, Richard D. 1978. Forecasting Regional Economic Activity: The Tennessee Econometric Model (TEM) II. Center for Business and Economic Research, College of Business Administration, The University of Tennessee, Knoxville, 331 pp.

15. Hair, Dwight, and Alice H. Ulrich. 1967. The Demand and Price Situation for Forest Products - 1966. USDA Forest Service, Misc. Pub. 1045, U. S. Government Printing Office, Washington, D. C.

16. Hardwood Market Report. Various Issues, 1963-1977. Memphis, Tennessee.

17. Intriligator, M. D. 1978. Econometric Models, Techniques and Applications. North-Holland Publishing Co., Amsterdam, 638 pp.

18. Johnson, Maxine. 1972. "The Wood Products Industry" Montana Business Quarterly, Spring 1972, Missoula, MT., p. 10-41.

19. Johnston, J. 1972. Econometric Methods. Second Edition. McGraw-Hill Book Co., New York, 436 pp.

20. Kaiser, Harold F. Jr. 1969. Input-Output Analysis of the southern forest economy. USDA Forest Service, Research Paper SO-43, Southern Forest Experiment Station.

21. Kendrick, John W., and C. Milton Jaycox. 1965. "The Concept and Estimation of Gross State Product," In: The Southern Economic Journal, vol. 32 no. 2, p. 153-168.

22. Klein, Lawrence R. 1969. "The Specification of Regional Econometric Models." In: Regional Science Association Papers, Vol. 23, p. 105-115.

23. Kort, John R. 1976. Estimating Gross State Product: An Analysis and Application to the Tennessee Economy. Center for Business and Economic Research, College of Business Administration, The University of Tennessee, Knoxville, 57 pp.

24. Lee, Tong Hun, John R. Moore, and David P. Lewis. 1967. A Report on the Tennessee Interindustry Study. Center for Business and Economic Research, College of Business Administration, University of Tennessee, Knoxville, 243 pp.

25. Maki, Wilbur R., Con H. Schallau, and John H. Beuter. 1968. Importance of timber-based employment to the economic base of the Douglas-fir region of Oregon, Washington, and northern California. USDA Forest Service Research Note PNW-76, 6 pp.

26. McKillop, W. L. M. 1967. Supply and demand for Forest Products - an econometric study. Hilgardia 38: 132 pp.

27. Miernyk, William. 1969. "Comments on Czamanski and Malizia," in: Regional Science Association Papers, Vol. 23, p. 81-82.

28. Mills, T. J., and R. S. Manthy. 1974. An econometric analysis of market factors determining supply and demand for softwood lumber. MSU Research Report 238, Michigan State University, East Lansing, Michigan. 59 pp.

29. Murphy, Paul A. 1972. Forest Resources of Tennessee. USA Forest Service, Resource Bulletin SO-35, Southern Forest Experiment Station, New Orleans, Louisiana, 33 pp.

30. Neter, John, and William Wasserman. 1974. Applied Linear Statistical Models. Richard D. Irwin, Inc. Homewood, Illinois, 842 pp.

31. Niemi, Albert W., Jr. 1972. "A Re-examination of the Kendrick-Jaycox Method of Estimating Gross State Product," In: Review of Regional Studies (Spring 1972), p. 123-131.

32. Niemi, Albert W., Jr. 1975. Gross State Product and Productivity in the Southeast. Chapel Hill, North Carolina: University of North Carolina Press.

33. Phelps, Robert B. 1977. The Demand and Price Situation for Forest Products 1976-1977. USDA Forest Service, Misc. Pub. 1357, U. S. Government Printing Office, Washington, D. C.

34. Preston, R. S. 1972. "The Wharton Annual and Industry Forecasting Model," Economics Research Unit, Department of Economics, University of Pennsylvania.

35. Preston, R. S. 1975. "The Wharton Long-Term Model: Input-Output within the context of a macro forecasting model." In: International Economic Review, vol. 16 no. 1, p. 3-19.

36. Robinson, Vernon L. 1974. "An Econometric Model of Softwood Lumber and Stumpage Markets, 1947-1967." In: Forest Science, Vol. 20 #2, p. 171-179.

37. Schaffer, William A., and Kong Chu. 1969. "Nonsurvey Techniques for Constructing Regional Interindustry Models," In: Regional Science Association Papers, Vol. 23, p. 83-101.

38. Sherman, Michael. Personal Correspondence of March 16, 1979.

39. Shuster, Ervin G., Charles R. Hatch, and William D. Koss. 1975. Location quotients, excess employment and short run economic base multipliers for Idaho's forest products industry. Information Series: No. 10, Forest, Wildlife and Range Experiment Station, University of Idaho, 25 pp.

40. Tennessee Dept. of Economic and Community Development. 1978. Tennessee directory of manufacturers. Nashville, TN. 551 pp.

41. Terfehr, Thomas R. 1976. The Economic Contribution of Forestry to Mississippi: An Application of Input-Output Analysis. M. S. thesis, Mississippi State University, Mississippi State, 105 pp.

42. Tiebout, Charles M. 1962. The Community Economic Base Study. Supplementary Paper No. 16, Committee for Economic Development, 86 pp.

43. U. S. Bureau of Economic Analysis. 1978. 1977 Business Statistics. U. S. Dept. of Commerce. U. S. Government Printing Office, Washington, D. C.

44. U. S. Bureau of Labor Statistics. 1977. Employment and Earnings, States and Areas 1939-1975. U. S. Dept. of Labor, U. S. Government Printing Office, Washington, D. C.

45. U. S. Bureau of the Census, 1956-1976. Annual survey of manufactures. U. S. Dept. of Commerce, U. S. Government Printing Office, Washington, D. C.

46. U. S. Bureau of the Census. 1966. 1963 Census of manufactures. vol. III U. S. Dept. of Commerce, U. S. Government Printing Office, Washington, D. C.

47. U. S. Bureau of the Census. 1976. 1972 Census of manufactures. Vol. III U. S. Dept. of Commerce, U. S. Government Printing Office, Washington, D. C.

48. U. S. Forest Service. 1973. The outlook for timber in the United States. USDA Forest Service, Forest Resource Report No. 20, U. S. Government Printing Office, Washington, D. C. 367 pp.

49. U. S. Government. 1978. Economic Report of the President. U. S. Government Printing Office, Washington, D. C.

50. U. S. National Oceanic and Atmospheric Administration. Various Issues, 1956-1977. "Climatological Data." U. S. Dept. of Commerce, Environmental Data Service, Asheville, N. C.

51. U. S. Industry and Trade Administration. 1978. 1978 U. S. Industrial Outlook. U. S. Dept. of Commerce, U. S. Government Printing Office, Washington, D. C.

52. U. S. Technical Committee of Industrial Classification. 1972. Standard Industrial Classification Manual. Executive Office of the President, Bureau of the Budget, Washington, D. C. 649 pp.

53. Wilson, Charles M. 1968. An Interindustry Analysis of Tennessee with Emphasis on Agriculture. Ph.D. dissertation, University of Tennessee, Knoxville, 142 pp.

APPENDIXES

APPENDIX I

AN APPLICATION OF SHIFT-SHARE ANALYSIS TO THE TENNESSEE LUMBER AND WOOD PRODUCTS INDUSTRY

One of the important features of shift-share analysis is its ability to provide insight into regional growth from easily attainable statistics. The lack of data at the sub-national level for growth analysis has thwarted the application of many of the techniques applied to national economic analysis.

In this particular application of shift-share analysis, the Esteban-Marquilles formulation will be used. Its formulation is as follows:

$$X'_{is} - X_{is} = X_{ix}r_n + X_{is}(r_{in} - r_n) + X_{is}(r_{is} - r_{in}) + (X_{is} - X_{is})(r_{is} - r_{in}) \qquad \text{(10, p. 249-275. 23, p. 27)}$$

where X' = output in the terminal period

X = output in the initial period

$X_{is} = (X_{in}/X_n)X_s$ Esteban-Marquilles' "homothetic effect"

r = rate of growth from initial to terminal period

the subscripts i and s refer to the industry and state respectively, and the subscript n represents the nation-

The four components of the right side of the above equation are defined as: 1) the national growth effect, 2) the industrial mix effect, 3) the competitive effect, and 4) the allocative effect, respectively.

Applying the above formulation to the Tennessee lumber industry produced the following results.

TENNESSEE LUMBER AND WOOD PRODUCTS INDUSTRY

Time Period	Change	National Growth	Industrial Mix	Competitive	Allocation
56-76	63	88	4	-19	-10
66-76	10	45	-6	-24	- 5

For the period 1956 to 1976 Tennessee's lumber industry output in real dollars increased by 63 million dollars. If the state's industry had kept pace with the growth of the national industry, one would have expected it to have increased by 88 million dollars. The small positive figure for the industrial mix effect means that the national lumber industry grew slightly faster than GNP. The negative sign for the competitive effect indicates that the growth in Tennessee was below that of the nation or that the state was at a competitive disadvantage over this time period. The allocative figure of -10 reflects the fact that Tennessee is specialized in lumber relative to the nation, although it is at a competitive disadvantage. The figures for the 1966-1976 decade show similar trends, although during this time period the national lumber industry grew slightly slower than GNP.

APPENDIX II

TABLE II-A

DATABANK FOR FORECASTING EQUATIONS

No.	Label	Description	Units	Source*
1	CAPCOST	US LUMBER SECTOR COST OF CAPITAL	PERCENT	WHARTON
2	CONLAGI	TGPCON7 LAGGED 1 YEAR	CONSTANT $72	TRANS
3	CORINCTX	CORPORATE INCOME TAX ALL STATES	EFFECTIVE RT	WHARTON
4	CPILAGI	CPI67BS LAGGED 1 YEAR	67=100	TRANS
5	CPI67BS	CONSUMER PRICE INDEX ALL ITEMS	67=100	WHARTON
6	DISPINC7	REAL PER CAPITA DISPOSABLE INCOME	CONSTANT $72	WHARTON
7	DUMMY1	DUMMY VARIABLE FOR CHANGE IN SIC DEFINITION 1972	ZERO-ONE	DUMMY
8	FAMILIES	NUMBER OF FAMILIES	MILLIONS	WHARTON
9	FXINVOL7	FIXED INVESTMENT PRICE DEFLATOR	72=100	WHARTON
10	FXIVLUM7	FIXED INVESTMENT LUMBER	CONSTANT $72	WHARTON
11	FXIVRSDL	FIXED INVESTMENT RESIDENTIAL STRUCTURES DEFLATOR	72=100	WHARTON
12	FXIVRS7	FIXED INVESTMENT RESIDENTIAL STRUCTURES	CONSTANT $72	WHARTON
13	GNPLAGI	USGNP7 LAGGED 1 YEAR	CONSTANT $72	TRANS
14	HSHLDS	NUMBER OF HOUSEHOLDS	MILLIONS	WHARTON
15	HSMLAGI	HSPRM LAGGED 1 YEAR	THOUSANDS	TRANS
16	HSPLAGI	HSPR LAGGED 1 YEAR	THOUSANDS	TRANS
17	HSPLAG2	HSPR LAGGED 2 YEARS	THOUSANDS	TRANS
18	HSPR	PRIVATE HOUSING STARTS	THOUSANDS	WHARTON
19	HSPRM	PRIVATE HOUSING STARTS MULTIPLE UNITS	THOUSANDS	WHARTON
20	HSPRMOB	PRIVATE HOUSING STARTS MOBILE HOMES	THOUSANDS	WHARTON
21	HSPR1	PRIVATE HOUSING STARTS SINGLE UNITS	THOUSANDS	WHARTON
22	HSSLAG1	HSPR1 LAGGED 1 YEAR	THOUSANDS	TRANS
23	LUMLAG1	USLUM7 LAGGED 1 YEAR	CONSTANT $72	TRANS
24	MTGRT	HOME MORTGAGE RATES NEW HOMES	PERCENT	WHARTON
25	NAFM2	USFUR7 DIVIDED BY FXIVRS7	CONSTANT $72	TRANS
26	NAFM3	USFUR DIVIDED BY FXIVRS	CURRENT $	TRANS
27	NFLATION	(CPI67BS-CPILAGI)/CPILAG1	PERCENT	TRANS

TABLE II-A (CONTINUED)

No.	Label	Description	Units	Source*
28	PCEDG	GNP PERSONAL CONSUMPTION EXPENDITURES DUR GDS	CURRENT $	WHARTON
29	PCEDG7	GNP PERSONAL CONSUMPTION EXPENDITURES DUR GDS	CONSTANT $72	WHARTON
30	PCEFNHS7	PERSONAL CONSUMPTION EXPENDITURES FUR & HSHLD FQ	CONSTANT $72	WHARTON
31	PDPCDG7	PRICE DEFLATOR PERS CONSUMPTION EXP DURABLE GOODS	72=100	WHARTON
32	PDPGFH7	PRICE DEFLATOR PERS CONSUMPTION EXP FUR & HSHLD EQ	72=100	WHARTON
33	PERCON7	PERSONAL CONSUMPTION PRICE DEFLATOR	72=100	WHARTON
34	POPUL	TOTAL POPULATION AGED 25-34	MILLIONS	TRANS
35	POP25-29	TOTAL POPULATION AGES 25-29	MILLIONS	WHARTON
36	POP30-34	TOTAL POPULATION AGES 30-34	MILLIONS	WHARTON
37	POST72	DUMMY! MULTIPLIED BY HSPRMOB	THOUSANDS	TRANS
38	PRIMERT	US PRIME RATE	PERCENT	WHARTON
39	PRODUCT	PRODUCTIVITY MEASURE TGPLUM7 DIVIDED BY TELUM	CONSTANT $72	TRANS
40	REALSAL	TAASWLUM DEFLATED BY CPI67BS	CONSTANT $67	TRANS
41	REALWAG	TWLUM DIVIDED BY USLUMPR7	CONSTANT $72	TRANS
42	TAASWLUM	TWLUM DIVIDED BY TELUM	CURRENT $	TRANS
43	TAXADJ	TNTXCE DIVIDED BY CORINCTX	RATIO	TRANS
44	TELUM	TN EMPLOYMENT LUMBER & WOOD PRODUCTS	THOUSANDS	BLS CBER
45	TGPCON7	TN GROSS STATE PRODUCT CONTRACT CONSTRUCTION	CONSTANT $72	CBER
46	TGPFUR	TN NOMINAL OUTPUT SIC 25	CURRENT $	CBER
47	TGPFUR7	TN GROSS STATE PRODUCT FURNITURE	CONSTANT $72	CBER
48	TGPLUM	TN GROSS STATE PRODUCT LUMBER VALUE ADDED	CURRENT $	ASM
49	TGPLUM7	TGPLUM DEFLATED BY USLUMPR7	CONSTANT $72	TRANS
50	TWLUM	TN WAGE & SALARY LUMBER & WOOD PRODUCTS	CURRENT $	CBER
51	USCTRLUM	US CORPORATE TAX RATE LUMBER	PERCENT	WHARTON
52	USELUM	US EMPLOYMENT LUMBER	THOUSANDS	WHARTON
53	USFUR	US NOMINAL OUTPUT SIC 25	CURRENT $	WHARTON
54	USFURPR	US FURNITURE SECTOR PRICES IMPLICIT DEFLATOR	72=100	WHARTON
55	USFUR7	US REAL OUTPUT SIC 25 GNP ORIGINATING	CONSTANT $72	WHARTON

TABLE II-A (CONTINUED)

No.	Label	Description	Units	Source*
56	USGNP	US GROSS NATIONAL PRODUCT	CURRENT $	WHARTON
57	USGNP7	US GROSS NATIONAL PRODUCT	CONSTANT $72	WHARTON
58	USLUM	US NOMINAL OUTPUT SIC 24	CURRENT $	WHARTON
59	USLUMCP	US LUMBER COMPENSATION	CURRENT $	WHARTON
60	USLUMPR7	US LUMBER SECTOR PRICES IMPLICIT DEFLATOR	72=100	WHARTON
61	USLUMWG	US LUMBER WAGE RATE	CURRENT $	WHARTON
62	USLUM7	US REAL OUTPUT SIC 24	CONSTANT $72	WHARTON
63	WAGEADJ	TWLUM DIVIDED BY USLUMCP	RATIO	TRANS

*CBER - Center for Business and Economic Research, University of Tennessee, Knoxville.
ASM - Annual Survey of Manufacturers (45)
BLS - Bureau of Labor Statistics (44).
Wharton - Wharton Historical Tables
TRANS - Transformation

TABLE II-B

DATABANK FOR SIMULATION EQUATIONS

No.	Label	Description	Units	Source*
64	CDTLAG1	CDTOUT7 LAGGED 1 YEAR	CONSTANT $72	TRANS
65	CDTOUT	INSTALLMENT CREDIT OUTSTANDING END OF YEAR	CURRENT $	SCB STAT
66	CDTOUT7	CDTOUT DEFLATED BY PERCON7	CONSTANT $72	TRANS
67	CPTDG67	CONSUMER PRICE INDEX HOUSEHOLD DURABLES	67=100	REPT PRES
68	DPTLAG1	TNDEPTM7 LAGGED 1 YEAR	CONSTANT $72	TRANS
69	FLNLAG1	HWDFLUN LAGGED 1 YEAR	THS BD FT	TRANS
70	HLNLAG1	HMIMPLN7 LAGGED 1 YEAR	CONSTANT $72	TRANS
71	HMIMPLN	HOME IMPROVEMENT LOANS OUTSTANDING	CURRENT $	SCB STAT
72	HMIMPLN7	HMIMPLLN DEFLATED BY PERCON7	CONSTANT $72	TRANS
73	HWDFLNO	US HARDWOOD FLOORING NEW ORDERS	THS BD FT	SCB STAT
74	HWDFLUN	US HARDWOOD FLOORING UNFILLED ORDERS END OF PERIOD	THS BD FT	SCB STAT
75	HWDLAG1	HWDSTMPG LAGGED 1 YEAR	CONSTANT $67	TRANS
76	HWDLAG2	HWDSTMPG LAGGED 2 YEARS	CONSTANT $67	TRANS
77	HWDSTMPG	AVG EASTERN HDWD STMPGE PRICE SAWTIMBER IN NAT FDR	CONSTANT $67	USFS
78	NETVCD	NET INVESTMENT IN CONSUMER DURABLES	CURRENT $	REPT PRES
79	NETVCD7	NETVCD DEFLATED BY FXINVDL7	CONSTANT $72	TRANS
80	OAKLAG1	OAKSTMPG LAGGED 1 YEAR	CONSTANT $67	TRANS
81	OAKSTMPG	AVG RED & WHITE OAK STMPGE PR SAWTIMBER IN NAT FORST	CONSTANT $67	USFS
82	PTCLEBD	PARTICLEBOARD CONSUMPTION INDEX	67=100	USFS
83	RDOAKAPP	#1 COMMON RED OAK PR 4/4 FOB MILL JONCTY APLCH MKT	CURRENT $	HMR
84	RDOAKAP7	RDOAKAPP DEFLATED BY USLUMPR7	CONSTANT $72	TRANS
85	RDOAKSO	#1 COMMON RED OAK PR 4/4 FOB MILL TEX & LA STHRN MKT	CURRENT $	HMR
86	RDOAKSO7	RDOAKSO DEFLATED BY USLUMPR7	CONSTANT $72	TRANS
87	SFTLAG1	USSFTWDP LAGGED 1 YEAR	MIL BD FT	TRANS
88	STKLAG1	USHWDSTK LAGGED 1 YEAR	MIL BD FT	TRANS
89	TNBLR	TN COMMERCIAL BANKS LOAN RATE	PERCENT	FDIC CBER

TABLE II-B (CONTINUED)

No.	Label	Description	Units	Source*
90	TNDEPTM	TN DEPOSITS OF INSURED COMMERCIAL BANKS-TIME	CURRENT $	CBER
91	TNDEPTM7	TNDEPTM DEFLATED BY PERCON7	CONSTANT $72	TRANS
92	TNDINC7	TN DISPOSABLE PERSONAL INCOME	CONSTANT $72	CBER
93	TNHOUS	TN NEW HOUSING UNITS AUTHORIZED	THOUSANDS	CBER
94	TNINTLB	TN INTEREST RATE ON LOANS IN COMM BANKS	PERCENT	CBER
95	TNINTLSL	TN INTEREST RATE ON LOANS IN S & L	PERCENT	CBER
96	TNLOAN	TN LOANS TO INDIVIDUALS OF INS COMMERCIAL BANKS	CURRENT $	CBER
97	TNLOAN7	TNLOAN DEFLATED BY PERCON7	CONSTANT $72	TRANS
98	TNRAIN	DEC-MAY DAYS GTR .5 IN. RAIN WID BY REG STMBR VOL	DAYS	NOAA
99	TNSLMTG	TN SAVINGS AND LOAN MORTGAGE LOANS	CURRENT $	CBER
100	TNSLMTG7	TNSLMTG DEFLATED BY FXIVRSDL	CONSTANT $72	TRANS
101	TNTXCE	TN TAX RATE CORPORATE EXCISE	PERCENT	CBER
102	TRNLAG1	TNRAIN LAGGED 1 YEAR	DAYS	TRANS
103	UDGLAG1	UNFILDG7 LAGGED 1 YEAR	CONSTANT $72	TRANS
104	UHSLAG1	UNFILHS7 LAGGED 1 YEAR	CONSTANT $72	TRANS
105	UNFILDG	UNFILLED ORDERS END OF PERIOD DUR GDS UNADJ SEAVAR	CURRENT S	SCB STAT
106	UNFILDG7	UNFILDG DEFLATED BY PDPCDG7	CONSTANT $72	TRANS
107	UNFILHS	UNFILLED ORDERS END OF PERIOD HSHLD DUR GDS ADJ SV	CURRENT $	SCB STAT
108	UNFILHS7	UNFILHS DEFLATED BY PDPCDG7	CONSTANT $72	TRANS
109	USHWDP	US HARDWOOD PRODUCTION	MIL BD FT	SCB STAT
110	USHWDSTK	US STOCKS GROSS MILL END OF PERIOD HARDWOOD	MIL BD FT	SCB STAT
111	USSFTWDP	US SOFTWOOD PRODUCTION	MIL BD FT	SCB STAT
112	USTPLUM	US TOTAL PRODUCTION LUMBER ALL TYPES	MIL BD FT	SCB STAT
113	WPIALL67	WHOLESALE PRICE INDEX ALL COMMODITIES	67=100	USFS
114	WPIDG	WHOLESALE PRICE INDEX DURABLE GOODS	72=100	CBER
115	WPIFURHS	WHOLESALE PRICE INDEX FURN & HSHLD DURABLES	72=100	CBER
116	WPIFUR67	WHOLESALE PRICE INDEX HOUSEHOLD FURNITURE	67=100	SCB STAT

TABLE II-B (CONTINUED)

No.	Label	Description	Units	Source*
117	WPIHWD67	WHOLESALE PRICE INDEX ALL HARDWOOD LUMBER	67=100	USFS
118	WPILUM67	WHOLESALE PRICE INDEX LUMBER & WOOD PRODUCTS	67=100	SCB STAT
119	WPIPOP67	WHOLESALE PRICE INDEX #1 COMMON POPLAR	67=100	USFS
120	WPISFT67	WHOLESALE PRICE INDEX SOFTWOOD LUMBER	67=100	USFS

*CBER - Center for Business and Economic Research, University of Tennessee, Knoxville.
SCBSTAT - Survey of Current Business, Business Statistics (43)
USFS - U. S. Forest Service, Demand and Supply Situation for Forest Products, 1976-1977 (33).
HMR - Hardwood Market Report (16)
REPT PRES - Economic Report of the President, 1978 (49)
TRANS - Transformation
NOAA - National Oceanic and Atmospheric Administration (50)

APPENDIX III

ALTERNATIVE OUTPUT FORECASTING EQUATIONS

The process of screening the data and formulating the equations (described in Chapter III) provided several tentative equations for forecasting Tennessee SIC 24 output. The variables identified as significant in explaining the variations in Tennessee lumber output were grouped together as a separate subset of the total databank. Using the SAS "RSQUARE" procedure, all possible combinations of these variables were analyzed and ranked as to their R^2 value. That is each variable was ranked by its R^2 value for a one variable model, then all possible combinations of two variables were ranked, etc., for up to a four variable equation. These combinations were then analyzed by starting at the highest R^2 value in each classification and identifying the combinations that met the criteria described on page 47. Using this approach, combinations of the variables not selected in the stepwise procedure or by intuitive means could be identified.

The process of selecting the one equation to be used for forecasting output was necessarily subjective. The relative strengths and weaknesses of the equations made the decision as to which was the "superior" equation a somewhat arbitrary one. In addition to the two output equations identified in the text, the equations listed below had properties that merited consideration. Their relative strengths and the justification for rejecting them are briefly discussed.

Equation 1

$$TGPLUM7 = \underset{(16.2)}{44.6320} + \underset{(3.3)}{51.7594}\ USFUR7 + \underset{(.014)}{.0437}\ HSPRI - \underset{(.133)}{.7215}\ USLUMPR7$$

$R^2 = .945$ $\bar{R}^2 = .936$ S.E. = 8.41 D.W. = 2.27 PERIOD = 56-76

Equation 1 relates output in Tennessee SIC 24 to: 1) real output in the U. S. furniture industry (USFUR7), 2) U. S. single family housing starts (HSPR1), and 3) U. S. SIC 24 sector prices, (USLUMPR7). The equation's descriptive statistics are all satisfactory and the graph of predicted and actual values provided a good fit. The weakness of this equation relate to the negative sign associated with the lumber price variable. One would expect a positive relationship between prices and output. The negative sign above is undoubtedly due to interrelationships among the independent variables. Though this factor alone is not significant enough to reject the equation, it is an important flaw. Further, the price variable is the U. S. SIC 24 sector deflator, which is dominated by softwood prices; and therefore is questionable as an explanatory variable for a hardwood dominated industry. Given these weaknesses, and the slightly better fit attained by the selected equation, the equation was rejected.

Equation 2

$$\text{Ln } TGPLUM7 = \underset{(.38)}{2.9344} + \underset{(.22)}{.6748}\ \text{Ln } USLUM\ 7 + \underset{(.15)}{.3839}\ \text{Ln } TGPFUR7 - \underset{(.14)}{.6973}\ \text{Ln } MTGRT$$

$R^2 = .956$ $\bar{R}^2 = .948$ S.E. = .061 D.W. = 2.08 PERIOD = 58-76

Equation 2 relates the natural logarithm of Tennessee SIC 24 output to the natural logarithm of 1) U. S. SIC 24 real output (USLUM7), 2) TN SIC 25 real output (TGPFUR7), and 3) U. S. Average Mortgage Rate on New Homes. Basically, this equation is the logarithmic counterpart of the final selected equation. One advantage is that the coefficients can be interpretated as the constant elasticities. The logarithmic equations in TEM II, however, often exhibit questionable performance in the long-run forecast. Since the descriptive statistics are no better than its linear counterpart, this equation was rejected.

Equation 3

$$\underset{}{TGPLUM7} = \underset{(20.9)}{71.9800} + \underset{(3.28)}{42.4440}\ USFUR7 - \underset{(.21)}{1.2652}\ USLUMPR7 + \underset{(10.78)}{43.0369}\ DUMMY1$$

$R^2 = .955$ $\bar{R}^2 = .947$ S.E. = 7.65 D.W. = 1.91 PERIOD = 56-76

Equation 3 relates Tennessee lumber and wood products output to: 1) the U. S. furniture industry real output (USFUR7), 2) U. S. lumber sector prices (USLUMPR7), and 3) a zero-one dummy variable included to account for the change in SIC 24 definition in 1972 (DUMMY1). Though this equation appears statistically valid, its performance in fitting the actual data for the latter part of the study period was unacceptable. Though the dummy variable is significant, in each of the equations in which it was used the predicted values for the 1974-1976 time period were significantly in error. In addition, the equation included the lumber sector deflator and the associated weakensses discussed above.

Equation 4

$$27.7843 + 45.8534\ USFUR7 + .0317\ HSPRI - 1.2470\ USLUMPR7 + 34.8360\ DUMMY1$$
$$(23.06)\quad (2.97)\qquad (.010)\qquad (.174)\qquad (9.40)$$

$R^2 = .971$ $\bar{R}^2 = .963$ S.E. = 6.36 D.W. = 2.06 Period = 56-76

Equation 4 quantifies the same relationships found in equation 1 above, with the addition of the dummy variable for the change in SIC 24 definition. Though the descriptive statistics indicate a better fit to the data, the predicted values for 1975 and 1976 were substantially different from the actual values. The inferior performance in the latter part of the study period, coupled with the weaknesses described for equation 1, led to rejection of the equation.

Equation 5

$$.5757 + 46.2698\ USFUR7 + .0254\ HSPRI - .8357\ USLUMPR7 + .0411\ POST72$$
$$(25.99)\quad (3.99)\qquad (.015)\qquad (.133)\qquad (.019)$$

$R^2 = .957$ $\bar{R}^2 = .946$ S.E. = 7.67 D.W. = 1.70 Period = 56-76

Equation 5 has the same variables found in equation 1 above, with the addition of the mobile home starts variable (POST72). The equation has the same weaknesses as equation 1 and; in addition, the housing starts and mobile home coefficients are not significant from zero at the .05 level.

VITA

Robert C. Abt, son of Mr. and Mrs. Peter Abt, was born in Tuscaloosa, Alabama, on August 14, 1955. He was raised and attended elementary schools in Albany, Georgia. In 1973, he graduated from Deerfield High School in Albany.

The author entered Georgia Institute of Technology, Atlanta, in June of 1973. In September 1976, he received the degree of Bachelor of Science with a major in Industrial Management. That same month he entered The University of Tennessee, Knoxville, and began his background studies in Forestry. His undergraduate and initial graduate studies were funded by a scholarship from the Robert Brent trust. In September 1977, he was awarded a graduate research assistantship.

In June of 1978, the author joined the staff of the Department of Forestry, Wildlife, and Fisheries at the University of Tennessee, as senior research assistant in socio-economic research.

While a student at The University of Tennessee the author was named to membership of Xi Sigma Phi and Gamma Sigma Delta honorary societies. He is also a member of the Society of American Foresters and the American Forestry Association.

The author was married to Dona B. Dowling on May 6, 1978, at Albany, Georgia.