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Estimates of Emergency Operating Capacity in U.S. Manufacturing and Nonmanufacturing Industries

Volume 1 - Concepts and Methodology

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Prepared for
the Federal Emergency Management Agency
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ESTIMATES OF EMERGENCY OPERATING CAPACITY IN U.S. MANUFACTURING AND NONMANUFACTURING INDUSTRIES

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SUMMARY

To develop integrated policies for mobilization preparedness, planners require estimates of available productive capacity during national emergency conditions. This two-volume report presents estimates for emergency operating capacity (EOC) for 446 manufacturing industries at the 4-digit SIC level of aggregation and for 24 key nonmanufacturing sectors.

This volume lays out the general concepts and methods used to develop the emergency operating estimates. The procedure for estimating the manufacturing EOC basically follows that used in a previous study for the Federal Emergency Management Agency (FEMA) in 1984. The key data input is the set of historical capacity utilization measures collected by the Bureau of the Census in its Survey of Plant Capacity. These utilization measures are used in conjunction with output measures to develop estimates of "practical" capacity by 4-digit SIC industry. Data collected in the Survey of Plant Capacity on weekly plant hours are used to estimate the additional output that may be expected should the plant operate 7 days per week, 24 hours per day. The resulting emergency capacity estimates are adjusted to account for required maintenance and the loss of productivity from greater reliance on shift work.

The historical analysis of capacity extends from 1974 through 1986. Projections of emergency capacity are provided through 1992. The projection methodology relies on establishing a relationship between the capital stock and capacity output, then using forecasts of investment, by industry, to augment the capital stock, and finally using these forecasts of capital to project capacity. Tabular and graphical results of the historical analysis and the projections of EOC by 4-digit SIC industry are shown in Volume 2.

This study also developed estimates of emergency capacity for a number of nonmanufacturing industries. In addition to mining and utilities, which were addressed in the 1984 study, key industries in transportation, communication, and services were analyzed to derive estimates of EOC. Given the diversity of the nonmanufacturing sector, it was necessary to address each of the nonmanufacturing industries by first defining an appropriate concept for measuring output and the corresponding measure of capacity, and then determining the availability of data to implement these measures. Also, unlike the manufacturing sector, there is no general survey of capacity and capacity utilization in the nonmanufacturing sector. Thus, a measure of EOC was developed for each industry. Industry specific EOC measures fell into two types, measures of physical capacity and measures of efficient production. The estimates for the nonmanufacturing industries are shown in this volume.

This study includes the results of some exploratory work that was performed to investigate the potential contribution of "frontier" production function analysis to the estimation of emergency capacity. The frontier approach seeks to measure maximum physical capacity by examining the industry under the most efficient use of fixed inputs (such as capital stock) and variable inputs (such as labor, materials, or fuel), then estimating the maximum

output obtainable from the currently available capital stock, assuming that variable inputs are unconstrained. Several variants of this technique, which has gained more recognition in the academic literature in the past decade, were tested and comparative analysis performed.

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1.0 INTRODUCTION

Development of integrated mobilization preparedness policies requires planning estimates of available productive capacity during national emergency conditions. Such estimates must be developed in a manner to allow evaluation of current trends in capacity and the consideration of uncertainties in various data inputs and in engineering assumptions.

This study developed estimates of emergency operating capacity (EOC) for 446 manufacturing industries at the 4-digit Standard Industrial Classification (SIC) level of aggregation and for 24 key nonmanufacturing sectors.

1.1 BACKGROUND

In 1983, FEMA contracted for the development of estimates of EOC in the manufacturing, mining, and utilities industries. The overall study (conducted during 1984) that produced these estimates also included detail on the potential for increasing labor force utilization and on investment lead time for manufacturing industries. Pacific Northwest Laboratory was responsible for the EOC estimation task in the study.

The EOC estimates from the 1984 study were provided for approximately 180 manufacturing sectors, 7 mining sectors, and the electric utility industry. A principal use of these estimates within FEMA has been in the Resolution of Capacity Shortfalls (ROCS) model. This model has been used in trade investigation studies and mobilization planning exercises. The EOC estimates were also used by other government agencies and consulting firms in studies related to mobilization and planning.

1.2 SCOPE OF CURRENT STUDY

In addition to updating the estimates of EOC from the 1984 study, the current study also extends the earlier work in several important ways. First, in manufacturing, the industry disaggregation extends to the 4-digit SIC level of aggregation. Based upon the industry production database provided by the Office of Business Analysis in the Department of Commerce, 446 manufacturing sectors were analyzed. The 4-digit disaggregation allows more targeted analyses by FEMA and other agencies and allows maximum flexibility for generating more aggregate models.

Second, more intensive analysis was performed relating to the potential of increasing operating hours within various manufacturing sectors. Two issues were examined: 1) the loss of worker productivity resulting from operating multiple shifts, and 2) approximate maintenance requirements by typical manufacturing establishments.

Third, some exploratory work was performed to investigate the potential contribution of "frontier" production function analysis to the estimation of emergency capacity. Several variants of this technique, which has gained more recognition in the academic literature in the past decade, were tested and comparative analysis performed.

Finally, this report extends the previous work in a major way in providing estimates of EOC for key nonmanufacturing sectors. Key sectors in transportation, communications, and services were analyzed to develop estimates of EOC.

1.3 ORGANIZATION OF REPORT

The overall report is organized in two volumes. This report, Volume 1, presents the overall methodology and concepts. It also includes full documentation and results of the EOCs in nonmanufacturing. Volume 2, Summary Report for 4-Digit Manufacturing Industries, contains one-page summary reports of EOC estimates and related data for each 4-digit manufacturing sector.

The remainder of this volume is divided into seven chapters and four appendices. Chapter 2 presents general concepts and a summary of the approaches used in the manufacturing and nonmanufacturing portions of the study. The next three chapters relate to the estimation of manufacturing EOC. Chapter 3 provides detailed documentation of the methodology used to generate the EOC estimates. Chapter 4 discusses shift factors that are used in attempts to estimate the increase in output that could be achieved by increasing plant operating hours. Chapter 5 explains the industry summary reports that are contained in Volume 2.

Chapters 6 and 7 are devoted to the nonmanufacturing portion of the study. Chapter 6 discusses concepts and methods; Chapter 7 summarizes the industry specific methodologies and final results.

Chapter 8 covers the production function analysis. The first part of the chapter explains the concept of frontier production functions in general terms. The chapter then discusses the empirical investigations conducted using these techniques.

Appendix A lists the industries for which EOC estimates were made and industry concordances that were used as part of the manufacturing EOC estimation. Appendix B documents the imputations made for missing practical capacity utilization rates, as published by the Census Bureau. Appendix C discusses in detail the industry-specific methodologies to estimate the nonmanufacturing EOCs. The final appendix, D, presents technical details concerning production and cost frontiers.

Accompanying the two-volume study report are diskettes with manufacturing EOCs and related information.

2.0 CONCEPTS AND GENERAL APPROACH

Estimates of emergency capacity were constructed by Pacific Northwest Laboratory, under contract to the Federal Emergency Management Agency (FEMA). The emergency capacity estimates cover 446 four-digit SIC manufacturing sectors and 24 nonmanufacturing sectors.[a] The project was conducted, in part, to support FEMA's Resolution of Capacity Shortfalls (ROCS) model.

The major research conclusion of the study has been that although both concepts and measures of capacity abound, the concepts become less precise the further they are removed from the establishment level and the measures become less meaningful as they are applied to broader industry aggregates. For a homogenous industry such as primary aluminum, capacity is an easily defined concept and is straightforwardly measured: it is the amount of aluminum that can be produced over a given time period without construction of additional plants, assuming that no material or labor restrictions apply. But for a less homogenous industry, such as secondary nonferrous metals, capacity has no straightforward measure, even though it can be defined and measured for any specific plant within this industry. Although we have become more fully aware of this difficulty in the course of this project, we have completed the study as we originally proposed. In so doing, we have relied on the only available data sources with a sufficient level of industry detail.

2.1 MANUFACTURING: GENERAL APPROACH

This section begins with a review of the concepts of emergency capacity as they have been articulated in the literature. Among these concepts the only available measures of capacity with sufficient detail to be used in estimating manufacturing capacity at the 4-digit SIC level are those generated by the Census Bureau in its annual Survey of Plant Capacity (SPC). The proposed method of moving from the SPC to an estimate of emergency capacity relies on establishing a relationship between the capital stock and capacity output. Forecasts of investment, by industry, are then used to augment the capital stock. Finally, these forecasts of capital stock are used to project capacity.

From the perspective of emergency management, the fundamental concern with regard to capacity is the ability of the economy to respond at sustained levels in the event of a national emergency. How rapidly can the industrial sector come up to speed and what may be the most critical bottlenecks? If damage is sustained at the onset of this emergency, what reduction in output would be expected? These and related questions do not fit neatly into any of the categories of capacity measures normally discussed in the literature. So

(a) Industry titles are shown in Appendix A.

one of the first chores of this section is to describe each of these concepts and show how the focus on capacity from the vantage of an emergency manager differs from other concepts.

2.1.1 Definitions of Capacity

Statistical measures of industrial capacity are widely regarded as indicators of short-run supply potential and are used in FEMA's ROCS model to specify output constraints. The theoretical counterpart to these statistical measures plays a major role in the literature on business investment and is important in discussions of sustained economic growth. Because of the importance of these concepts, there has been no shortage of theoretical considerations for the measurement of capacity. These theoretical underpinnings can be collected under at least three different headings: economic capacity, engineering capacity, and feasible capacity. When the translation from theory to measurement takes place, yet another definition of capacity is evidenced--practical capacity. We will first define these concepts, then relate them to emergency capacity, a concept more pertinent to the concerns of an emergency manager.

Economic Capacity. Economic capacity applies to a firm or establishment and denotes a short-run optimal, or preferred, output level with fixed capital equipment. In the neoclassical tradition, one views short-run production optimality with fixed capital stock as that level of output that is achieved at the optimal long-run capital-output ratio--heuristically, this is the minimum point on the average cost curve. In the Keynesian Tradition, one views prices as factors and products as fixed, then optimal capacity is defined as the profit maximizing level of output--the output level at which marginal cost equals price. When these concepts are translated into statistical measures, the Keynesian concept is the more appropriate one, since surveys indicate that firms typically operate well below capacity, and usually well below those rates that are preferred. If these data were interpreted strictly in the neoclassical tradition, the indicated under-utilization would imply disinvestment, which is only rarely observed. Moreover, the Keynesian concept is more amenable to a discussion of changes in capacity as economic incentives change over the cycle.

Engineering Capacity. Engineering capacity denotes a limit to production that reflects the physical or technologically determined potential of plant and equipment. These limits are typically discussed without reference to economic considerations or availability of other factors, so they reflect a theoretical maximum output. This concept is most appropriate at the process level--rated horsepower, template ratings of boilers, etc. The least ambiguous application of this concept might be to continuous process industries: basic steel, aluminum, pulp and paper. Moreover, the concept applies to an industrial process; the organization of a production facility is an exercise in combining these processes so that the capacity of the facility in not unduly restricted by any particular process.

Feasible Capacity. Since the concept of capacity typically applies to a firm or a process, difficulties arise when the concept is applied to aggregates of firms. At the industry level, one tends to view capacity as that level of output that is feasible or achievable. This level is typically less than the sum of all firms' engineering capacity because the factor supply curves an industry faces are less elastic than those a firm faces--a basic result of price theory. When considering a single firm, it is customary to assume that all the variable factors needed can be acquired to make full use of capital equipment. But if all firms in the industry pursue this policy, shortages of materials and manpower will rapidly occur. So aggregate measures of capacity require accounting for all factors that might limit production, including resource constraints influenced by the availability of foreign supplies. The "production-based" capacity measures--e.g., the Wharton index, the FRB capacity indexes--are the statistical measures that most closely correspond to this concept.

Practical Capacity. When survey methods are used to construct a statistical measure of capacity, it is important to understand the concept that respondents have in mind. The most relevant concept from the respondent's point of view appears to be that of "maximum practical capacity" or practical capacity for short. Practical capacity, as defined by the Census survey, is the greatest level of output the plant can achieve within the framework of a realistic work pattern. Further instructions suggest that the respondent take into account what is achievable for the particular industry under local conditions, that no effective material or resource constraints apply, and that capacity be limited to plant and equipment currently in place.

2.1.2 Concepts and Proposed Method

This study follows the 1984 study in utilizing practical capacity from the SPC as the basis for constructing EOC in the manufacturing sector. The approach is to establish a historical relationship between the capital stock and capacity output; then use forecasts of investment, by industry, to augment the capital stock; and finally, use these forecasts of capital to project capacity.

Emergency capacity is extrapolated from practical capacity on the basis of the number of additional hours that plants could operate over a specific time period (one week). The SPC collects data on the number of days per week and hours per day that plants are currently operating and would expect to operate at practical capacity.

Since the SPC has a number of flaws that had to be circumvented, applying these methods to the available data was not straightforward. Over much of the period for which the SPC has been collected, the sample was not large enough to provide the rich set of data needed to conduct this study. This problem was manifested with missing data, by industry, based primarily on disclosure criterion. Another problem with the SPC was changes in the survey sample in 1979 and 1984. With these sample changes, it was sometimes difficult to reconcile the data from prior periods with more recent data. Chapter 3 describes these difficulties and provides an overview of how these difficulties were reconciled.

2.2 NONMANUFACTURING: GENERAL APPROACH

The following (SIC) industrial categories define the set of nonmanufacturing industries used for this analysis:

- transportation, communications, electric, gas, and sanitary services
- wholesale trade
- retail trade
- finance, insurance, and real estate
- services.

Appendix A shows a more detailed breakdown of industries (to the 2-digit SIC level). This set excludes manufacturing, extractive industries, construction, and public administration. This set of industries is commonly termed "the service sector." However, narrowly defined, the service sector refers only to one of the categories listed here. For the purposes of this analysis, the service sector will refer to those industries included in SIC Division I "Services" and the terms nonmanufacturing or non-goods producing industry will refer to the set of categories listed here.

The above categories represent a number of diverse industries with very different characteristics. The service sector (narrowly defined) includes such diverse industries as personal services (laundry, clothes repair, barbers, shoe repair, funeral services, etc.); business services (advertising, building maintenance, computer programming and data processing, etc.); medical services; engineering and research, etc. In some cases, specific industries may be minimally affected by a military build-up (except through an increase in aggregate demand). In other cases, specific industries would be called upon to support a mobilization, directly or indirectly. For example, within the laundry, drycleaning, and garment industry sector is the industrial laundry industry, which provides cleaning services for working clothing such as clean-room apparel, protective clothing, mats and rugs, etc. Computer services, engineering services, research and development services could all support a military build-up.

Given the diversity of the nonmanufacturing sector, it was necessary to address each of the nonmanufacturing industries by defining an appropriate concept for measuring output and the corresponding measure of capacity, and determining the availability of data to implement these measures. Also, unlike the manufacturing sector, there is no general survey of capacity and capacity utilization in the nonmanufacturing sector. Thus, we developed a measure of EOC for each industry. Industry-specific EOC measures fell into two types, measures of physical capacity and measures of efficient production.

In some industries, there is a specific measure of physical capacity that constrains potential output in the short run. This is particularly true in transportation and public utility industries. For example, the maximum amount of cargo that the railroads can carry is constrained by the number of available freight cars; the distance the cargo is to travel; and the time required to load, unload, and haul the freight cars. For these industries, it is possible to estimate this maximum capacity from available data.

The alternative to measuring maximum physical capacity is to measure the output of an industry under the most efficient use of fixed inputs (such as capital stock) and variable inputs (such as labor, materials, or fuel), then estimate the maximum output obtainable from the currently available capital stock, assuming that variable inputs are unconstrained. Production frontier analysis is used to estimate efficient output. In addition, production frontiers can simultaneously determine capacity utilization of the fixed inputs.

3.0 ESTIMATION OF CAPACITY IN MANUFACTURING: CONCEPTS AND METHODS

3.1 DESCRIPTION OF CENSUS SURVEY APPROACH

Our development of normal and emergency capacity measures for manufacturing industries relied heavily on the Bureau of Census Survey of Plant Capacity (SPC) conducted annually in the fourth quarter of the year. This survey is conducted at the plant level from a probabilistically determined sample of approximately 7000 establishments. Unlike any other capacity measure, additional information is collected on the hours, days and shifts currently being used. Moreover, it is the only capacity measure reported at the 4-digit SIC level. But there are temporal problems with these data that must be resolved before we can construct our measures of normal and emergency capacity.

The first step we take is to shift the measure of capacity from the fourth quarter of the year to an annual average so that the capacity data are aligned with the product and price data available at the industry level. Following the methodology of the 1984 study, quarterly capacity utilization measures from the Federal Reserve Board were used to adjust the Census data.

The second step is to apply the "annualized" practical capacity utilization measures to production data available from the Office of Business Analysis (OBA) of the Department of Commerce. This yields a measure of capacity output by industry.

The third step in our analysis is to smooth these measures by regressing emergency capacity against capital stock data--also available from OBA. This step provides us with capacity measures that are purged of cyclical influences and allows a basis for forecasting. With historical capital stock, estimated rates of depreciation, and forecasts of industry investment, the capital stock can be updated to provide a basis for forecasting capacity output for the years 1989 through 1992. This smoothing technique provides another benefit as well. The difference between the constructed capacity output measures and the smoothed capacity output measures provides an estimate of the error associated with the capacity estimates.

We then adjust the practical capacity output by shift factors to derive a first approximation of emergency capacity. The shift factors take into account required maintenance times and the loss of productivity because of multiple shifts.

The final step in this proposed analysis is an examination of the speed at which industries move from economic to emergency capacity. Another advantage of using the Census survey is that it includes questions about how rapidly the respondents could move from current production levels to practical capacity. With assumptions about the ability of the non-respondents to accelerate their output to emergency levels, these data are used to alter the capacity output levels so that industries have different levels of capacity at different periods after the onset of an emergency. Specifically, the peak output surveys are used to construct different levels of capacity: three months after the onset of an emergency, six months after the onset of an emergency, and a year after the onset of an emergency.

3.1.1 Problems and Modifications to Methods

Three major problems uncovered in the course of this study required modification to the proposed method of analysis articulated in the previous section. These problems fall under three headings: gaps in the data, incompatibilities in the SPC because of a change in the sample, and measurement error in the major economic series. Each of these will be discussed in turn. First, however, a description of the data sources will help set the stage for the discussion to follow.

The Survey of Plant Capacity is a survey of over 7000 firms in nearly 450 4-digit SIC industry categories. If each SIC is sampled uniformly, then about 15 plants in each SIC will be surveyed. Because not all SICs contribute equally to output, the sample must be weighted properly; thus, some industries will be sampled more than others. Indeed, some SICs may have only one or two respondents where the industry comprises a very small number of firms. This would give rise to disclosure problems, since the nonresponding firms would be provided valuable information about the operating conditions of their competitors.

While both the SPC and the Annual Survey of Manufactures (ASM) are collected by the Census Bureau, they are collected at different points in time, the questions are structured to cover a different time period, and the sample coverage is different. In short, they are different data sets. That they are so different has been a source of frustration during this project. We now turn to the specific problems that had to be resolved.

Missing Data

During the first several years of the SPC, the sampling procedures resulted in missing values for many of the 4-digit SIC industries. Since the information from this survey is the basic building block on which this study is constructed, a procedure had to be developed to fill in these missing values. As it turned out, not one but three methods were used to fill in these missing values, with the method selected to fit the circumstances of the particular industry. These procedures are explained in the third section of this chapter. Most of these missing values were for the period 1974-1978; since 1979, the sample has been changed so that most of the disclosure problems have been resolved. However, this has given rise to a different problem.

Sample Change

A survey of plants such as those sampled for the SPC, gains integrity over time if the respondents remain the same or if the sample changes only slowly. These gains accrue as the firms build into their corporate memory a history of previous responses against which the current response can be compared. But if the sample changes, as it did for the SPC in 1979 and 1984, discontinuities in the data series may occur as different individuals and plants interpret and respond to the questionnaire for the first time. Unfortunately, there were other abrupt shifts in the data that were more disconcerting. These were evinced in some industries when output measures and capacity measures moved in different directions. These contrary movements are possible; however when they imply that capacity output decreases by half during a cyclical upturn and there is no commensurate change in capital stock, they are hardly believable.

Measurement Error

Relying on one data source for capacity and separate data sources for other measures of economic activity presents problems of comparable data. The lack of correspondence between these data sets may arise because of different samples, because of different respondents within the same plant, because the sampling covers different time periods, or because of a variety of other reasons. Whatever the reason for these disparities, combining the two data sets sometimes produces results that lack credibility.

Moreover, sufficient data are not available to resolve these disparities between capacity and the data series used for other measures of economic activity. To give substance to this charge, consider the previous example -- declines in capacity output during periods of cyclical upturns. The capacity output measure is constructed by dividing fractional capacity utilization into output as measured by shipments. Corroborating evidence might be available from a measure of capital stock, constructed via a perpetual inventory technique. The investment data used to construct the stock of capital and the shipments data are from one sample, the measure of capacity from another. Consider just some of the possible sources of error that might give rise to a sharp decline in capacity output:

- Timing: capacity utilization drops sharply in the fourth quarter but year-average shipments are high

- Stock Measure: interpolation of data between complete census years does not pick up the sudden closing of plants

- Measurement Errors: any of a variety of other problems, such as an unrepresentative sample for this particular industry, confusion in responding to the questionnaire, etc.

A survey through the 4-digit SIC industry reports (contained in Volume 2) will reveal examples of these problems. Where they most affect our proposed methodology, we have made a number of modifications. The most substantive of these is the technique used to smooth and forecast industry measures of capacity. In brief, we relied on a regression approach to calculate the effect of capital stock on capacity. With this brief introduction, we now turn to a detailed description of the methods used to construct the manufacturing emergency capacity measures.

3.2 STEPS TO IMPLEMENT THE CENSUS SURVEY APPROACH

The development of emergency capacity estimates for the manufacturing sectors involved a complex sequence of data processing steps using a number of industry data sets. These steps are described in the following sections.

3.2.1 Step 1: Imputations of Missing Values for Fourth Quarter Practical Utilization Rates

As described in the previous section, the industry disaggregation required in this study necessitated the use of the SPC conducted by the Census Bureau. This survey provides two measures of capacity utilization--"preferred" and "practical"--for 4-digit SIC industries for the fourth quarter of each year. Data used in this study spans the years 1974 through 1988. As discussed previously, the practical utilization rate is the one upon which this study has focused; at this level of industry detail, this practical utilization measure is the empirical measure that comes the closest to measuring engineering capacity within the context of normal shift practices.

This step involved considerably more than simply keypunching the practical utilization rates from the Census publications. Although the census survey covers approximately 7000 establishments, insufficient coverage in many small 4-digit industries resulted either in many data values withheld due to proprietary disclosure reasons, or in insufficient sample size. Before embarking upon subsequent analysis, imputations for these missing values were developed. In some cases, no statistical analysis could have been performed without the use of imputed values in the statistical analysis; this approach was judged preferable to simply dropping these years.

Several methods were employed to impute the missing values. In a few cases, data were published for a 3-digit aggregate and all but a single 4-digit industry within this aggregate. If Census data on shipments are used as weights, the values of the utilization rate for the missing 4-digit sector can be estimated that will yield the correct weighted average at the higher 3-digit level. A second procedure was to choose a similar industry and use the relative year-to-year movements of its utilization rate to fill in missing data. A third approach, an extension of the second approach, was to run a formal regression of the utilization rates of the 4-digit series with missing values, against the utilization rates of the 4-digit series with missing values, against the utilization rates of one (or more) industries judged to be similar. In many cases the regression was against the corresponding 3-digit SIC for which data were published for the entire period, 1974 through 1988. The regression equation was a simple double log form:

$$u = a + b \qquad (3.1)$$

where u = practical capacity utilization rates in industry i, and for which u was not published for one or more years.

U = practical capacity utilization rates in similar 4-digit or more aggregate industry series for which data was available for the entire sample, 1974-1988.

Missing values were then imputed, based on the predicted values of the equation. The imputation of missing values using these procedures was required primarily over the 1974-78 time period. Data for 1979-88, later made available by the Bureau of Census specifically for this project, provided information for many previous unpublished capacity utilization rates at the 4-digit SIC level. Appendix B documents the sectors for which imputations were made, the specific years imputed, and the type of imputation method used.

3.2.2 Step 2: Development of Annual Practical Utilization Rates

The SPC has been conducted each year since 1974. The survey requests manufacturers to report their operating rate only for the fourth quarter rather than for the year. The aim of Step 2 is to develop an interpolation scheme that will provide estimates on an annual basis.

In the effort to generate estimates of average annual utilization rates it became immediately apparent that simple linear interpolation between successive fourth quarter values would introduce serious biases. The cyclical behavior of the economy in the 1980-82 period illustrates this most graphically. The economy rebounded rapidly throughout most of 1981 from the recession low in the third quarter of 1980. However, this expansion was one of the briefest in post-war history; and by the fourth quarter of 1981, production in many parts of the economy was turning downward. Looking only at utilization rates for the fourth quarter of 1980 and 1981 would not provide an accurate picture of activity that occurred during the course of calendar year 1981.

To provide more realistic estimates of utilization rates for the missing quarters, a regression-based interpolation approach was followed. The first step in this approach was to run the following regression for each 4-digit SIC industry.

$$U^{i} = a + b\ U^{FRB} + e \qquad (3.2)$$

where U = SPC practical utilization rate for industry i

U^{FRB} = Federal Reserve Board Capacity Utilization rate for the most similar industry aggregate (generally, at the 2-digit SIC classification)

e = regression error

The constant term, a, in this regression crudely captures the difference in absolute utilization rates over this time period. Coefficient b reflects the sensitivity of the individual 4-digit industry's capacity utilization rate to the broader aggregate measure provided by the Federal Reserve Board.

Obviously, by substituting the estimated values of a and b in Equation (3.2), along with the FRB measure and the value of the regression error, we can match the actual SPC value for each fourth quarter. The interpolation method that was actually used involved a multiplicative rather than an additive procedure. The first step was to compute the ratio of the actual practical capacity utilization rate to its predicted value for each of the (fourth quarter) observations in the regression equation. These ratios were then interpolated linearly between the fourth quarter observations. The interpolated ratios were then multiplied by the first, second, and third quarter predicted capacity utilization values to generate final estimates of practical utilization rates. Annual series were finally constructed as simply the averages over the four calendar year quarters of the estimated practical utilization rates.

Table 3.1 illustrates the results of this procedure for SIC 3542, Machine Tools, Metal Forming Types. The first column shows the FRB utilization measures for 2-digit SIC industry 35, Nonelectrical Machinery. Column two shows the SPC practical capacity for SIC 3542. Based upon the specification in Equation (3.2), the predicted values from the equation are shown in column three. In this case the coefficients in Equation (3.2) were a = -35.4 and b = 1.35, indicating that the utilization rate in this industry was, in general, somewhat greater than the broader 2-digit industry. The ratio of the actual to the predicted practical utilization rate is shown in column four. As described above, these ratios were interpolated for the intervening quarters and then multiplied by the predicted values from Equation (3.2). The annual values from this procedure are shown in column five. The last column shows annual values based upon simple interpolation of the practical utilization rates directly.[a]

The final two columns contrast the annual values of utilization rates derived from the regression approach as compared to the simple linear interpolation. As expected, in stable periods of economic activity, the two measures are reasonably close. During the cyclical troughs and peaks, however, the values from the two approaches may differ by several percentage points or more. As illustrated in this case, the largest divergences were generally observed in 1975, 1979, and 1981-1982. For the purpose of accounting for some of the within-year variation in utilization rates to improve the accuracy of the annual estimates, the results of the methodology employed here appear to be satisfactory.

(a) The simple interpolation used the so-called "5/8" rule, where the previous year's fourth quarter value was multiplied by 3/8 and the current year's fourth quarter was multiplied by 5/8. This conceptually puts the resulting weighted average at a July 1 date, which is taken to be the annual average.

TABLE 3.1 Illustration of Methodology to Calculate Annual Utilization Rates

	FRB[a] (4THQ)	SPC[b] (4th Q)	Predicted[c] (4th Q)	Ratio[d] (4th Q)	Predicted[e] Annual	INTERP[f] Annual
1974	84.7	66.0	78.8	0.84	68.7	
1975	70.6	74.0	59.8	1.24	66.7	71.0
1976	74.5	71.0	65.0	1.09	71.7	72.1
1977	79.7	72.0	72.0	1.00	71.8	71.6
1978	84.3	75.0	78.3	0.96	73.3	73.9
1979	81.8	72.0	74.9	0.96	75.0	73.1
1980	79.1	75.0	71.2	1.05	72.7	73.9
1981	75.9	66.0	66.9	0.99	71.3	69.4
1982	63.4	45.0	50.0	0.90	51.3	52.9
1983	70.1	38.0	59.1	0.64	39.8	40.6
1984	77.1	71.0	68.5	1.04	60.3	58.6
1985	74.7	69.0	65.3	1.06	69.9	69.8
1986	71.9	61.0	61.5	0.99	63.8	64.0
1987	76.8	80.0	68.1	1.17	72.1	72.9
1988	82.9	81.0	76.4	1.06	82.8	80.6

(a) FRB capacity utilization rate.
(b) SPC practical utilization rate.
(c) Predicted value of SPC utilization from Equation 3.2.
(d) Ratio of actual to predicted on 4th quarter observation.
(e) Annual values from interpolation methodology.
(f) Annual values based on linear interpolation between 4th quarter observations.

3.2.3 Step 3: Estimates of Implied Practical Capacity by 4-Digit SIC Industry

Step 3 involves the development of estimates of practical capacity by 4-digit SIC industry. The measure of capacity used in this report is the value of production by SIC in constant 1982 dollars. This measure is computed simply by dividing the series of annual industry production values by the practical utilization rates derived in Step 2.

The production data used were developed by the Office of Business Analysis (OBA) within the Department of Commerce. These data were available for 4-digit SIC manufacturing industries for the period 1958-1986. These data are not based on physical production data as are the Federal Reserve indexes; rather, they rely on Census of Manufactures and Annual Survey of Manufactures (ASM) information on value of shipments and inventory change, subsequently deflated by appropriate 4-digit SIC deflators. The present OBA data base contains the information in current dollars and in 1982 constant dollars.

The OBA data were extended through 1988 by using Federal Reserve Board production indexes. A concordance was developed between 112 FRB production indexes and the 446 4-digit SIC sectors of the OBA. This concordance is shown in Appendix A.

Practical capacity measures were then computed by dividing the actual production measures by the annual utilization rates. This procedure of course assumes that the two establishment-based surveys, the ASM and the SPC, represent the economic conditions within a 4-digit SIC industry with a comparable degree of accuracy. As pointed out at the beginning of this section and as will be shown in Step 5, this comparability, at least as it manifests itself in year-to-year changes in the implied capacity, appears to be not as close as one would desire.

3.2.4 Step 4: Capital Stocks and Investment

Estimates of capital stocks and investment are essential components in the overall study methodology. First, capital stocks and investment provide information for a means of smoothing the implied capacity estimates derived in Step 3. Second, only by relating changes in capacity to investment activity is there a justifiable way of forecasting capacity for future years.

As for the output measures, the capital stocks and investment were provided by the OBA. The capital stocks are from the 1990 revision to the Capital Stock Data Base, undertaken by Jack Faucett and Associates.

The 1990 revision to the OBA capital stock data base is significant in two respects. First, investment and capital stock estimates are developed at the 4-digit SIC level. Second, the capital stock estimates use information on the book value of capital assets from the *Census of Manufactures*. The use of book value data is a sharp departure from the perpetual inventory method that has been used previously. In general, the book value data are better able to account for industries in which capital stock may be declining.

Two types of stock measures are developed with the historical investment series. Gross stocks represent the gross book value of accumulated investment unadjusted for depreciation or loss of efficiency. Net stocks represent an estimate of the productive value of the gross stocks; in computing net stocks, the productivity of capital items is assumed to decline before they are discarded. Both types of stocks are available in historical, current, and constant dollar valuations. Separate series are constructed for plant and equipment.

3.2.5 Step 5: Forecasting Capacity by 4-Digit SIC Industry

This step utilizes the output, implied capacity, and capital stock measures, developed in the previous steps, in a regression-based methodology to forecast (practical) capacity by 4-digit SIC industry. Investment forecasts by industry are used to extend the capital stock series which, in turn, are used to project practical capacity.

In the 1984 study, net equipment stocks, valued in 1972 constant dollars, were used in the projection methodology. For this study, regression analysis was performed to find the best capital stock series to use in projecting the implied practical capacity estimates. A linear model of the following form was estimated for each of the 446 manufacturing sectors:

$$Q^{pc} = a + b\,K \tag{3.3}$$

where Q^{pc} = implied practical capacity

K = capital stock

Equation (3.3) was estimated over the period 1974 through 1986. The implied practical capacity estimates were based upon the work in Steps 2 and 3; thus, they incorporate the imputation and annualization procedures.

The various capital stock measures were evaluated using several criteria. The first is simply goodness-of-fit, as measured by the simple average R^2. The second is the number of industries for which coefficient b is negative. The overall results are shown in Table 3.2.

The first two lines in Table 3.2 indicate that net and gross equipment stocks perform about equally well in tracking with the implied capacity measures over the historical period. The net equipment stocks show a slightly higher average fit. Including the OBA estimates of plant with equipment results in significantly lower correlations, using the concept of gross measures. Other tests, not reported in the table, found that the contemporaneous level of the capital stock yielded better correlations than did the lagged value.

Based upon the regression analysis, a decision was made to use net equipment stocks. In addition to being consistent with the 1984 study, the use of equipment alone simplifies the forecasting methodology described in the following step.

The revised capital stock series from OBA overcomes two major drawbacks that were discussed in the previous 1984 study. Because stock estimates at the 4-digit SIC level were not available for that study, it was necessary to base the analysis on combined plant and equipment stock. The previous study recognized that separate plant and equipment estimates might yield more satisfactory measures of the effective capital stock.

More important, as cited in the previous report, were the limitations of the stock measures based upon perpetual inventory procedures. Although no formal regression summary statistics were compiled in the previous study, our judgment is that a much higher percentage of industries had divergent trends in capital stock and implied capacity, as reflected in negative coefficients on b in Equation (3.3).

TABLE 3.2. Evaluation Measures for Capacity-Capital Stock Screening Regressions

Capital Stock Measure	Average R^2	Number: $b < 0$
Net Equipment	0.470	81
Gross Equipment	0.466	79
Gross Plant and Equipment	0.397	111

Note: 446 four-digit industries included in the analysis.

The relatively high number of inconsistent trends in the 1984 study led to the development of alternative capital stock series for each industry. This capital stock series was estimated as part of a smoothing procedure within a nonlinear regression. Estimated parameters in the nonlinear specification attempted to measure three concepts: 1) the initial (1974) capacity, 2) incremental capacity output-capital ratio, and 3) depreciation rate.

Although the nonlinear fitting procedure in the 1984 study generally produced satisfactory results, it had several drawbacks. First, the data series is generally not long enough to infer the independent influences of both the incremental output-capital ratio and the depreciation rates. As a result, constraints needed to be applied to these parameter estimates. Second, the nonlinear estimation is time-consuming, in that in many cases alternative starting values needed to be used to achieve a convergent solution.

Given the much larger number of sectors to analyze and the revised OBA capital stock series, this study used the simple linear model in Equation (3.3) to project practical capacity. To project capacity output, forecasts of the (equipment) capital stock were required. Equipment investment forecasts from the INFORUM interindustry model of the U.S., for 37 manufacturing sectors, were used to extrapolate the OBA-Faucett investment series from 1986. The investment data were used in a perpetual inventory framework to project the capital stock measures. The projected stock measures in Equation (3.3) were used to project values of (practical) capacity through 1992.

3.2.6 Step 6: Forecast of Emergency Capacity: Using Shift Factors

Capacity output, as developed to this point, is a measure of the annual production rate that can be achieved if the facilities are fully utilized, but at normal rates of use. In other words, capacity output is a measure of the achievable output, under normal operating conditions, if the plant and equipment are fully used, if no material shortages exist, and there is adequate labor. When the plant moves from capacity to emergency output, the plant and equipment are operated under emergency conditions rather than normal conditions. The extent to which there is a difference between these two will depend on what "normal" conditions are. In a continuous process industry, such as basic steel production, the plant and equipment are used 7 days a week, 24 hours a day, with plant shutdowns for maintenance or equipment failures. But for many industries, a single 40-hour shift per week is normal.

In a 168-hour week, a 40-hour shift is only 23.8 percent of the total time. In an emergency, such an industry might be able to expand output by a factor of four (1/0.238 = 4.2), leaving 8 hours for maintenance on the equipment. A continuous process industry, on the other hand, cannot expand output very much, since it already operates at near the physical limitations of the facilities.

For each 4-digit SIC manufacturing industry, a measure of the capability of the industry to expand under emergency conditions, called a shift factor, is calculated. The development of this measure is detailed in Chapter 4. For the purpose at hand, this measure is interpreted as a multiplier that converts practical capacity to emergency capacity.[a] Over the set of manufacturing industries this factor ranged from a low of 1.04 to a maximum of 3.2.

3.2.7 Time-Phased Measures of Emergency Capacity

A movement to emergency capacity cannot be completed immediately; any industry operating at less than continuous rates will require time to expand production to emergency levels. This time to expand production to emergency capacity levels can be explained by a number of factors. Delays in hiring workers, contracting for additional materials, and other factors make it impossible for a firm to increase production to maximum capacity instantaneously.

The time-phased measures of emergency capacity are based upon responses to a question in the SPC that asks respondents to indicate how long a period of time would be required to "expand actual operations to practical capacity providing that there was sufficient demand for the output." The SPC reports this information in terms of the percentage of firms (weighted by production levels) that could reach practical capacity within a given time period. For example, 10 percent of the firms may indicate that output could be expanded to practical capacity within a week, 30 percent within three months, 50 percent with six months, and the remaining 10 percent more than six months.

The cumulative distribution constructed from these responses would then indicate that 10 percent of the firms achieved capacity output within one week, 40 percent within three months, 90 percent within six months, and 100 percent within a year. But these responses might be different at different times during the business cycle--it may take longer to expand to capacity during cyclical peak than during slack capacity utilization.

(a) The shift factor in this study is interpreted in the same manner as in the development of FEMA's REGRIP and ROCS models. In the 1984 capacity study, the shift factors were the reciprocals of these measures. In that study, capacity output was divided by the shift factor to obtain an estimate of emergency capacity.

In the 1984 estimation of emergency capacity, the time-phasing was based upon an average response over the period 1977-1979. At that time, this period represented the only cyclical peak since the inception of the SPC. For the current study, the time-phasing is based on responses for 1988 (fourth quarter). For many industries, 1988 represents a peak during the 1980s expansion.

The data provided by the Bureau of Census included a percentage of firms that did not respond to the question regarding the length of time to expand to practical capacity. In the calculating the expansion factors, these non-responses were ignored.

The census data were also provided only at the 2-digit SIC level. The distributions at the 2-digit level were applied uniformly to all of the appropriate 4-digit SIC industries. Since this procedure does not require that current output be forecast, the last historical level of output was used as the point of departure to advance to emergency capacity.

4.0 SHIFT FACTORS

Shift factors are used to estimate the additional production, beyond practical capacity, that could be achieved if manufacturing plants worked the remaining available hours during a week. Given the estimate of the shift factor, emergency capacity is expressed as

Emergency capacity = practical capacity * shift factor

For continuous process industries, such as steel or petroleum refining, the shift factor is 1.0. For other industries, which may operate only one 8-hour shift, five days a week, the shift factor would likely exceed 3.

The derivation of shift factors in this study differs considerably from the 1984 study. In the earlier study, 4-digit SIC data were obtained only for the number of shifts at current production and at practical capacity. Unfortunately, the number of days per week that the plant operates and the hours per shift differ by industry and over time. Thus, with data on the number of shifts alone, it is difficult to estimate a concept of maximum production. In the current study, data on the actual number of days per week and the number of hours per day were used as a basis for the shift factor. The use of weekly hours provides a more accurate assessment of the additional time the plant could be operated.[a]

The previous study used data on the actual number of shifts to estimate an econometric equation for the shift factor. A major deficiency of this procedure is that it led to some unrealistically large changes in the shift factor from one year to the next.[b] The current study takes a more pragmatic approach. The number of weekly hours at practical capacity, as supplied by survey respondents to the SPC, is used as the basis for the estimates.

Two key issues must be addressed in developing shift factor estimates. The first concerns necessary downtime and maintenance. This issue has been addressed in the previous efforts to estimate shift factors, but only in a cursory manner. Section 4.1 discusses the results of an informal manufacturing survey to try to obtain primary data to answer this question.

The second issue, new in this study, concerns the productivity of night shift workers. One would expect that moving from one shift to three shifts would not necessarily triple output because of the added physiological demands

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(a) Although weekly hours are used as the basis for a multiplier to estimate emergency capacity from practical capacity, the term shift factor is still used in this study. For most industries, extra production would be achieved by going to additional shifts.

(b) In some sectors the shift factor changed by more than 50 percent in 1982.

of night work upon employees. Section 4.2 reviews the available literature to try to develop a quantitative judgment for this potential effect.

Following the discussion of these two issues, Section 4.3 brings together the pieces to yield the final estimates of shift factors. The section also discusses some consistency testing with the SPC data on weekly hours and utilization rates.

4.1 PLANT AND EQUIPMENT CONSTRAINTS TO CONTINUOUS 24-HOUR PRODUCTION

The current stock of plant and equipment in the U.S. is operated at something less than full capacity on an around-the-clock basis. The focus of this section is to estimate the maximum productive capacity of U.S. plants and equipment under national emergency conditions. A part of the approach used here to obtain such estimates was to attempt to determine the binding constraints to continuous (24 hours per day) and extended (6 months to a year) U.S. manufacturing production.

4.1.1 Informal Manufacturing Survey

During early May of 1990, a limited telephone survey was conducted to answer questions pertaining to the productive capacity of U.S. industries for an extended period of time (6 months to a year) under national emergency conditions. The survey was directed toward production engineers or plant operators in manufacturing plants identified to the 4-digit SIC level in Washington State. Washington State was targeted for the survey because it has been experiencing robust economic conditions and has the second largest (behind California) industrial sector of the mountain and west coast states. The economic conditions in Washington State during the first quarter of 1990 were so good that the Seattle housing market was identified as the fastest growing housing market in the country over the previous year. The Seattle metropolitan area unemployment rate was 3.8 percent in April 1990. Statewide, the Washington unemployment rate was 5.2 percent during the same period.

The survey respondents answered two questions after having been instructed to base their responses on a situation described by three assumptions. First, the respondent was asked to assume the continued use of the factory's existing plant and equipment. Second, the respondent was asked to assume the continued production of the factory's current mix of products. Finally, the respondent was asked to assume that additional skilled labor and/or materials and supplies could be easily obtained and should not be considered a constraint to increasing existing production at the factory to continuous and extended full-time production. It was then explained to the respondent that these assumptions were necessary in order to draw the focus of the questions entirely on the continuous and extended full-time production capacity of the factory's existing plant and equipment. These assumptions are generally consistent with those used by the Census Bureau in administering the SPC.

Given the described conditions, those surveyed responded to the following two questions: 1) What would be the effective constraints to continuous full-time (24 hours per day, 7 days a week) and extended (6 months to a year) productive use of your factory's current plant and equipment? and 2) How many hours of productivity (e.g., hours per day, per week, or per month) would be lost to those constraints to continuous production? If the respondent faltered in responding to the first question, the following queries were presented as prompts: 1) routine maintenance of equipment? or 2) change-overs between shifts and/or processes? or 3) cleanup operations between shifts? or, d) other constraints? If the respondent had difficulty in responding to the second question regarding production hours lost to unavoidable constraints, several ranges of possibilities were offered until the respondent felt comfortable with a particular range.

4.1.2 Survey Results

Table 4.1 summarizes the thirty-five responses that were obtained in the survey with the firms identified only by their 4-digit SIC industry identification number. The five food and kindred products industries surveyed (e.g., those with a 20 SIC prefix) reported an average of about 15 hours per week of unavoidable downtime during all-out around-the-clock production efforts. The unavoidable required downtime was reported to be needed for routine maintenance, breakdown repair, and cleanup with an emphasis on sanitation. Many of the firms surveyed were either currently experiencing or have had occasion to experience the operation of their existing plant and equipment on an all-out around-the-clock basis, so the constraints to all-out production were well known.

The lumber and wood products industries (e.g., those with a 24 SIC prefix) required an average minimum of about 7 hours per week and an average maximum of about 15 hours per week of unavoidable downtime during all-out around-the-clock production conditions.[a] The unavoidable required downtime was reported to be needed for routine maintenance, breakdown repair, and cleanup. Cleanup operations were said to be continuous and to overlap with other operations because dealing with wood products was described as a messy process.

The stone, clay and glass products industries (e.g., those with a 32 SIC prefix) reported an average minimum of about 10 hours per week required downtime and an average maximum of about 18 hours per week of unavoidable downtime during all-out around-the-clock production conditions. The unavoidable required downtime was reported to be needed for routine maintenance, breakdown repairs, and cleanup. In one instance, the respondent noted that onsite space for storing forms (e.g., molds) and finished products was the limiting

(a) Many respondents provided a range of hours per day or per week that the plant could not operate. The average minimum (maximum) is the average of the low (high) ends of these ranges. The maximum and minimum hours were set equal when the respondent provided only a point estimate.

TABLE 4.1. Emergency Capacity Survey Responses

SIC	Industry Group	Constraint to Continuous Production	Hours
2033	Canned fruits & vegetables	Clean-up & sanitation	4/d
2034	Dehydrated fruits, vegetables	Maintenance	6/w
2051	Bread & cake products	Clean-up & Maintenance	16/w
2065	Confectionery products	Repair breakdowns	8/m
2086	Bottled & canned soft drinks	"Backwash" water systems	3/d
2320	Men's & boy's furnishings	Maintenance & repair	24/w
2421	Sawmills & planing mills	Maintenance	8-10/w
2426	Hardwood dimension & flooring	Maintenance	5-6/w
2439	Structural wood members	Clean-up, maintenance & repair	2-4/d
2511	Wood household furniture	None indicated	0
2643	Bags, except textile bags	None indicated	0
2650	Paperboard containers & boxes	Repair breakdowns	8/w
2891	Adhesives & sealants	Catalyst change	8/3m
3079	Miscellaneous plastics goods	Breakdowns & changeovers	16-18/w
3231	Products of purchased glass	Maintenance	1/d
3271	Concrete block & brick	Breakdowns & cleanup	2-4/d
3273	Ready-mixed concrete	Maintenance	8/w
3443	Fabricated plate work	Maintenance	8/w
3443	Fabricated plate work	Maintenance	2-4/w
3444	Sheet metal work	Breakdowns	10-15/w
3448	Prefab metal buildings	Maintenance	8/w
3471	Plating & polishing	Clean equipment	24-32/w
3479	Metal coating services	Maintenance & repair	16/m
3498	Fabricated pipe & fittings	Maintenance	8/w
3536	Hoists, cranes, & monorails	Maintenance & repair	50/m
3537	Industrial trucks & tractors	Maintenance	4-6/w
3551	Food products machinery	None indicated	0
3551	Food products machinery	Maintenance & repair	16/m
3622	Industrial controls	Maintenance	1-2/d
3679	Electronic components	Breakdowns	8/w
3714	Motor vehicle parts	None indicated	0
3715	Truck trailers	Other	2-3/w
3728	Aircraft equipment	None indicated	0
3732	Boat building & repairing	Maintenance & cleanup	4/d
3823	Process control instruments	None indicated	0

factor to all-out production at their operation. One respondent said that all-out around-the-clock operations was the present norm at his plant and that only 1 hour downtime per day was needed to perform routine maintenance of the plant's equipment.

The eighteen respondents of the metal and machine industries (e.g., SIC prefixes 34, 35, 36, 37, and 38) reported an average minimum of about 7 hours per week for downtime and an average maximum of about 9 hours per week downtime during all-out around-the-clock production efforts. Interestingly, four of the eighteen (22%) respondents indicated that there were no constraints to operating their plant and equipment on an all-out basis, while 10 of the eighteen (55%) responded that routine maintenance would keep them from operating on an around-the-clock basis. Five respondents mentioned breakdowns and time for repairs as important factors in determining their production continuity.

The age of their present equipment led some respondents to question the reliability of their plant and equipment under the described stressful national emergency operating conditions. Cleanup of equipment was also mentioned as a likely binding constraint to continuous production.

4.2 LABOR PRODUCTIVITY AND SHIFT WORK

Increasing national production in a time of crisis would require increased utilization of capital equipment as new work shifts are added to the production schedule. A pertinent issue to estimating how much present national production could be increased by adding new work shifts to existing capital is whether night shift workers perform on a productive par with their daytime counterparts. Even though more than 25% of U.S. workers now have hours that differ from the traditional day shift, there is little agreement on the extent, if any, of the productivity loss associated with work during night hours.

Although there is a large literature devoted to the effects of shiftwork, most of the studies have been of an experimental nature. Various tests of perceptual-motor performance or cognitive performance have been developed to determine differentials between night and day schedules. It is often not clear how the results of these tests would translate into impacts on industrial productivity.

Section 4.2.1 below presents some of the key findings regarding shift work and individual performance. Following that, some of the scattered evidence concerning shift work and industrial productivity is discussed.

4.2.1 Shift Work and Individual Performance

The issue of shift work and performance has been studied extensively. In general, studies indicate that working in shifts can force body rhythms out of phase by altering sleep patterns. Out-of-phase body rhythms can, in turn, result in a deterioration of individual attitudes, health, and on-the-job performance. Of most importance is the established fact that night shift work reduces sleep length.

Psychologically, working in shifts has been found to affect key mental processes such as motivation, alertness, and judgment, and may cause depression or social problems with family or at work. Physiological or health related problems reportedly associated with rotating shifts include ulcers, increased incidence of heart attacks, and stress and fatigue resulting from sleep loss. Psychologically and physically based deterioration of performance is manifested at the work place in many ways. For example, cost increases from shift premiums, higher staff turnover, absenteeism, necessary changes in secondary service activities, and the potential for loss in productive efficiency (as measured by output per unit input) are all potential manifestations of shift work.

Indications are that, for many tasks, the night shift has the lowest performance, while the afternoon shift has the highest. Figure 4.1 provides a graphical description of on-the-job variations in perceptual-motor performance over a 24-hour period in six field studies.

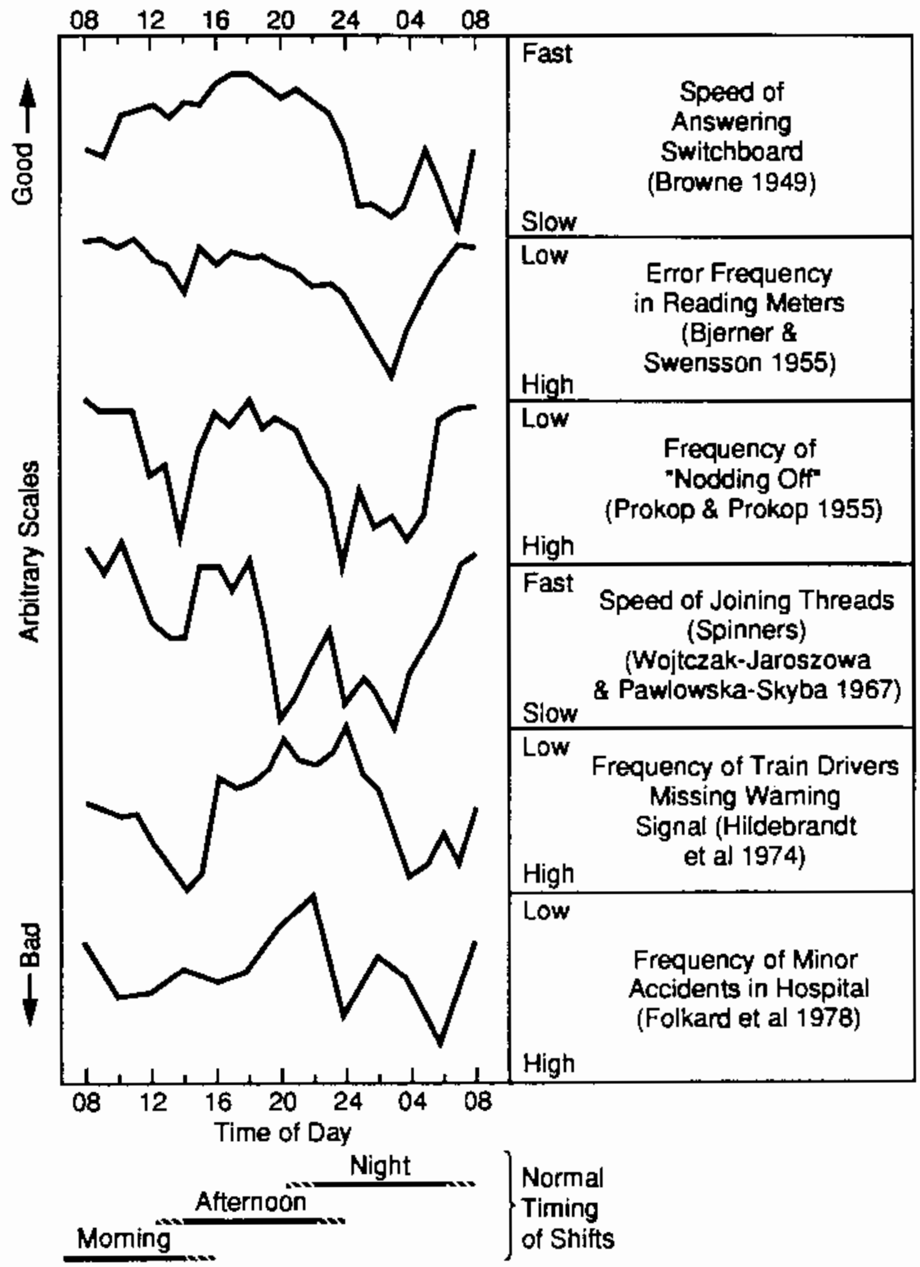

FIGURE 4.1. Variations in Job Performance Over the 24-Hour Period in Six Field Studies (Scheving and Halberg 1980, p. 295; from Folkard and Monk 1979)

As an example for discussion, the first study shown in Figure 4.1 assessed the response time and workload for teleprinter switchboard operators on a continuous shift system (Browne 1949). In that study, the average response time between day and night shifts was 25 to 30 percent longer on the night shift. However, the delays did not result in any serious production deficiency since they were not sufficient to result in missed calls or to affect the total production rate for the shift. The study concludes that in operations where timing is critical, as in externally paced operations such as assembly lines, the time of day would be more likely to produce a productivity effect.

As in Figure 4.1, most experimental studies of shift work have been primarily concerned with the performance of relatively simple perceptual-motor tasks which typically show a similar 24-hour performance pattern. However, the unfortunate fact is that studies of the performance of night shift workers are rare, and studies of industrial performance at night are unclear as to situational factors which probably obscure the results (Colquhoun and Rutenfranz 1980).

Much shift work performance research depends solely upon physiological variables to identify shift work hazards; the results of such research could be quite misleading (Webb 1982). Research which depends upon a single performance measure to identify shift work effects can also be misleading. Some factors might be sources of stress for some individuals but not for others; for example, because of differences in capacities to adjust to different external conditions (McCormick and Sanders 1980). Thus, shift worker performance is now recognized as, at a minimum, dependent on the type of task, the type of shift system, and the type of person. These three factors, and potentially several others, interact via the worker's various circadian rhythms and ability to sleep effectively during the day. Indeed, the increased use of multivariate techniques in studies of shift work illustrates the highly complex nature of individual responses to shift work (Salvendy 1987). More research under actual shift working conditions using performance measures, as well as productivity measures, is needed to fill the gap.

4.2.2 Quantifying Productivity Effects of Shift Work

Published studies of the effect of shift work on actual industrial output and productivity have been few and generally inconclusive. Reasons for this include that many shift work jobs do not lend themselves to common productivity measurements such as units per time, time per unit, or total units per shift. That is, although many studies address the physiologically and psychologically based "performance" differences between day and night shifts, such performance measures rarely translates literally into "productivity" (see, for example, the above discussion of Browne's 1949 study and McCormick and Sanders 1980). Even shift work jobs where common productivity measurements are possible may be in industries where productivity information is considered proprietary and therefore is not made available for public review and analysis. These complexities all contribute to the difficulties associated with making general statements regarding quantifiable effects of shift work on productivity. Thus, little real quantitative and well documented productivity data for comparisons among shifts[a], especially on an industry-specific basis, are available. Below, we present several of the key studies that were deemed relevant to the current study.

Some of the available evidence dates back to studies conducted in England during and after the First World War (Bjerner, Holm and Swennson as cited in Colquhoun and Rutenfranz, 1980). The Health and Munitions Workers Committee attempted to analyze whether there was any difference in working efficiency during day and night. One of the studies observed that when women had monotonous night work, requiring little physical effort, production was within 10 percent of the daytime production schedule. Unaccountably, the results for men were about the same for day and night shifts.[b]

Some extensive investigations were also conducted with workers in steel mills during the same period. No significant difference between day and night work was detected, regardless of whether the work involved great physical effort or light supervisory duties (Bjerner, Holm and Swennson as cited in Colquhoun and Rutenfranz, 1980).

A more recent quantitative study assessed the productivity of Yugoslavian women workers in a company manufacturing electronic equipment (Vidacek 1981). The women worked in three weekly rotated shifts, covering a 24-hour period: the morning shift (06:00 - 14:00), the afternoon shift (14:00 - 22:00) and the night shift (22:00 - 06:00). The afternoon shift's productivity was relatively highest (102.1%) and that of the night shift lowest (97.2%).

A post-war survey of manufacturing establishments in England asked plant managers to compare productivity during the day and night shifts. Unfortunately, as shown is Table 4.2, the quantitative assessment was made in terms of subjectively defined categories. To quote the authors' description of those results,

> "It would be reasonable to conclude from this evidence that although the majority believed productivity to be the same on the nightshift, an important minority believed it to be slightly less and a smaller minority thought it greater."

Framework for Additional Study

In his 1979 review of shift work and its effects on performance, Folkard (1980) remarks that the type of task in which the shift worker is typically

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(a) Among workers who rotate shifts weekly, as many as 60% fall asleep on the job (Siwolop 1986). The Wall Street Journal reported that reduced alertness because of shift work schedules causes $70 billion a year loss in productivity and safety.
(b) The source for this information does not indicate the extent of differences in production process and worker skills that might cause this difference.

TABLE 4.2. Comparison of Productivity as between Day and Nightshifts (for similar work)

Productivity on nightshift as compared to dayshift for firms making quantitative assessment	Establishments which had:	
	made comparative measurements	not made comparative measurements
	%	%
Much less	3	2
Slightly less	26	20
The same	58	71
More	13	7

Source: From Reading 37 of Colquhoun and Rutenfranz 1980.

engaged has changed over time. In the past, most shift work involved primarily perceptual or motor skills, with little reliance on cognitive skills. With the advent of continuous industrial processes and computer-controlled equipment, most shift workers today are required to perform more mentally-demanding tasks.

As a result of these technological changes in the work place, a promising approach to measuring the effects of shift work on productivity would be to quantify performance differentials by occupation and by the type of task to be performed during the shift. Table 4.3 is presented with hypothetical assignments of high, medium, and low classifications to indicate the type of qualitative information that, were it available, would be a useful starting point for quantifying industrial output potential from adding new shifts of labor to existing capital stock. To quantify effects by industry sector (SIC) would involve a further mapping of occupational categories in each industry.

Early studies, as shown by Figure 4.1, have indicated that it is primarily the perceptual-motor type tasks that are most seriously affected by moderate sleep deprivation that occurs with night shift work. More recently, in view of the increasingly cognitive nature of the shift worker's job, the general conclusions drawn from the studies presented in Figure 4.1 are now being considered suspect for their relevance to present conditions (Folkard - Reading 23- in Colquhoun, 1980). These findings are partially reflected in the assignment of potential qualitative impacts of shift work on productivity in Table 4.3.

TABLE 4.3. Hypothetical Qualitative Impact of Shift Work on Productivity (H = High, M = Medium, L = Low)

Industrial Occupations	Task Classification: Perceptual	Cognitive	Motor	Communication
White-collar				
Professional specialty technical	H	L	M	M
Executive administrative managerial	M	L	L	M
Sales				
Administrative support clerical	M	L	M	M
Blue-collar				
Precision production craft repair	H	M	H	M
Machine operators assemblers inspectors	H	L	H	L
Transportation	H	L	H	L
Material moving	H	L	H	L
Handlers equipment cleaners helpers laborers	L	L	H	L
Service	M	M	M	H

4.3 DERIVATION OF SHIFT FACTORS FROM CENSUS DATA

This section discusses the development of shift factors from the Bureau of Census information and the results of the research described in the previous two sections. As Section 3.2 indicated, shift factors are used to extrapolate the practical capacity estimates to maximum emergency capacity.

4.3.1 Census Bureau Data

The source of information on the number of shifts and weekly hours by 4-digit SIC is from the Bureau of the Census' SPC. From its inception, the SPC has requested information about plant schedules within the following framework:

	Actual operations	Preferred level of operations	Practical capacity
Shifts per day			
Days per week			
Hours per day			

This information has never been published by the Bureau of the Census at any level of aggregation. In previous work by Pacific Northwest Laboratory for FEMA regarding emergency capacity only selected portions of this information were available. In 1978, as part of the REGRIP model development, information on weekly hours for a single year (1976) was used to develop shift factors. In the 1984 study, time series analysis of data on the number of shifts, over the period 1977 through 1982, was performed.

As in the 1984 study, a special tabulation of these data was requested from the Bureau of the Census. In contrast to that study, all three data items--shifts per day, days per week, and hours per day--were collected. This information was provided on diskette for the years 1977 through 1988. The industry averages for each of these series were developed by using the number of production workers as weights.

Unfortunately, the small sample sizes in the SPC for many of the 4-digit SIC industries forced the Census Bureau to withhold many of the estimates because of insufficient statistical reliability or the need to maintain confidentiality. For the last year in the time series, 1988, there was no information on days per week for roughly 15 percent of the 4-digit SIC industries. A similar percentage was the case for the hours per day information.[a]

(a) As with the capacity utilization measures reported by the SPC, the day/hour/shift information is also subject to both sampling errors and nonsampling errors. Nonsampling errors include various response and operational errors: errors of collection, reporting, transcription, and bias due to nonresponse. With regard to sampling errors, the published results of the SPC provide standard errors for the capacity utilization estimates. No standard errors were provided by the Bureau of the Census for the days, hour, and shifts data. At the end of the next section, we develop "high" and "low" estimates of the shift factors to partially account for these types of errors.

4.3.2 Shift Factor Estimation

As in the previous studies, the concept of a shift factor is straightforward. Ignoring maintenance requirements, it is the maximum available hours per week (168) divided by the hours worked at practical capacity. Implicitly, it is assumed that plant output could increase proportionately to the additional hours operated. Thus, for example, if the SPC indicated that plants in an industry would operate, on average, 80 hours per week at practical capacity, the shift factor would be 2.0.

Shift factors vary considerably by industry. In continuous process industries such as steel, chemicals, paper, and petroleum refining, these factors are generally near 1.0. In other sectors that normally work forty-hour weeks and where plant managers have indicated that this schedule would be similar even at practical capacity, the shift factor might exceed 3.0.

Three separate issues were addressed in the derivation of shift factors in this study: 1) maintenance and downtime, 2) differential productivity due to shift work, and 3) statistical variation from sample data. We discuss each of these in turn below.

Maintenance and Downtime

Although non-continuous process industries must suspend operations for maintenance, our limited telephone survey indicates that the number of hours for this activity is not high. Few of the firms contacted said that they shut down more than 16 hours a week, with the majority falling into a range of 4 to 10 hours. Food processing firms appeared to have slighter higher requirements than most other manufacturing firms.

Although this limited survey provides valuable information, the number of firms contacted and the sample design is not sufficiently rigorous to make any strong statements about various sub-sectors within manufacturing. Accordingly, we have chosen a few reference points to be applied to several broad divisions within manufacturing. Specifically, we define the maximum number of weekly hours as follows:

for food processing, SIC 21:	153 hours or highest reported number of hours at practical capacity, 1977-1988
for the rest of manufacturing: SIC 22 - SIC 39	160 hours or highest reported number of hours at practical capacity, 1977-1988

Based upon the survey results, we have chosen 15 hours per week for maintenance and cleanup as an average for food processing and 8 hours per week as an average for other manufacturing. However, the data from the SPC may imply that even fewer hours would find the plant out of operation. In this case, we define the maximum number of weekly hours as the maximum survey response, based on days per week and hours per day, over the 1977-1988 time period. A number of 4-digit SICs indicated weekly hours at practical capacity exceeding 160 hours, denoting continuous process sectors.

Allowance for Shift Work

As discussed in Section 4.2.2, published studies of the effect of shift work on actual industrial output and productivity have been few and generally inconclusive. The two studies we located that did present some quantitative evidence pertain to quite different circumstances (the study of World War I munitions workers and Yugoslavian electronics assembly workers). After reviewing this literature, we believe there is likely some differential productivity impact due to shift work, but that it is not large. Seeking to take some account of this effect, we have assumed the following:

1. Plant hours in excess of 110 hours per week experience lower productivity

2. The productivity decrement between 110 and the maximum available hours is 5 percent.

The productivity decrement is adjusted if the average plant indicates that it would work more than 110 hours per week at practical capacity. Thus, for example, if the plant indicated 130 weekly hours at practical capacity, the 5 percent adjustment would be applied only on the additional hours up to the weekly maximum (in most cases, 30 hours = 160 hours - 130 hours). Thus, the productivity adjustment is zero or negligible for continuous process sectors.

Operationally, the productivity adjustment is converted into hours. Again, consider the example in the previous paragraph. If 30 hours are estimated to be worked during a night shift, we multiply 30 by 0.05 to obtain 1.5 hours.[a] The total number of available weekly hours is then reduced from 160 to 158.5. The figure 158.5 becomes the numerator in the expression to calculate the shift factor:

$$\text{Shift factor} = \frac{\text{Adjusted maximum weekly hours}}{\text{Weekly hours at practical capacity}} \qquad (4.1)$$

Sample variability

With the assumptions and procedures laid out in the previous two sections, a single estimate for the (productivity adjusted) maximum weekly hours is generated for each 4-digit SIC. From Equation (4.1), we need to settle

(a) The logic here is that if productivity is 95 percent during the night shift, then 30 hours worked during this period are equivalent to 28.5 "normal" hours.

upon an empirical definition of weekly hours at practical capacity in order to define the shift factor. The issue is that weekly hours at practical capacity, as calculated from the days per week and hours per day tabulations from the Census Bureau, show considerable year-to-year variation.

In the current study, we take the approach of developing a shift factor that can be used to estimate emergency capacity based on the most recent production levels of the industry. For the purposes of estimation, the three most recent SPC years are used: 1986, 1987 and 1988. To avoid letting the choice of a single year distort a more realistic estimate, we use an averaging technique to generate a "high" and "low" estimate of the shift factor.

To generate the "high" estimate, we simply average the two years with the lowest reported number of weekly hours at practical capacity. From Equation (4.1) the lower the number of reported hours at practical capacity, the higher is the shift factor. Of course, the opposite holds true to generate the "low" estimate of the shift factor.

For nearly a quarter of the 4-digit SIC industries, the Census Bureau withheld hours and days information for one or more of the latest three years. If only two years of data were available, no averaging was undertaken. The high estimate of shift factor was based on the smaller of the weekly hours estimates and vice versa for the low estimate of the shift factor. If only one year of data was available, the high and low estimates coincided.[a]

On balance, there is not a large difference between the high and low estimates of the shift factors. A simple average across the 446 four-digit SIC industries for the high estimates of the shift factor was 1.69. Averaging the low estimates yielded 1.59.

For the purposes of calculating the manufacturing emergency capacity estimates shown in Volume 2, the low estimates of the shift factor were used. This choice reflects a conservative approach; if an application study should determine that the level of emergency capacity may be a constraint, the high estimate of the shift factor can be substituted as a sensitivity test. The report format described in the next chapter includes both estimates of the shift factor and the (averaged) number of weekly hours at practical capacity as tabulated by the Census Bureau.

4.3.3 Output and Hours Worked

The estimation of shift factors is based on the assumption that plant output, beyond practical capacity, could increase proportionately to the hours of plant operation. The information provided by the Census Bureau permits some crude empirical support for this assumption.

(a) For 35 industries, no data were available for the years 1986-1988. In 21 of these industries, the shift factor was assigned to be the same as a similar industry. In 14 cases, weekly hours information was taken from the period 1983-1985.

At low utilization levels, a typical manufacturing plant may be operated for a minimal number of hours (e.g., five 8-hours shifts per week), but with some reduction in labor inputs. Initial increases in output may be achieved by calling back workers who have been laid off, but maintaining a similar work schedule. Further increases in output would require longer or additional shifts. To generalize, we can expect that the closer an industry is operating to practical capacity, the more likely it is that gains in output would be achieved primarily by increasing operating hours.

Figure 4.2 shows this hypothesized relationship in graphical fashion. Weekly operating hours along the x-axis are shown at three levels: H_1 at a "low" utilization rate, H_2 at a "high" utilization rate, and H_{pc} to represent the number of weekly hours at practical capacity. Output levels along the y axis are shown for the corresponding three points. Without knowledge of the shape of the functional relationship, the elasticities computed by moving to point C (practical capacity) from either A or B are arc elasticities. The elasticity evaluated from point A should be higher than that from B. Moreover, we would expect that the closer point B is to point C, the more the arc elasticity would approach unity. Beyond point C, we expect increases in output to be achieved by proportional increases in operating hours.

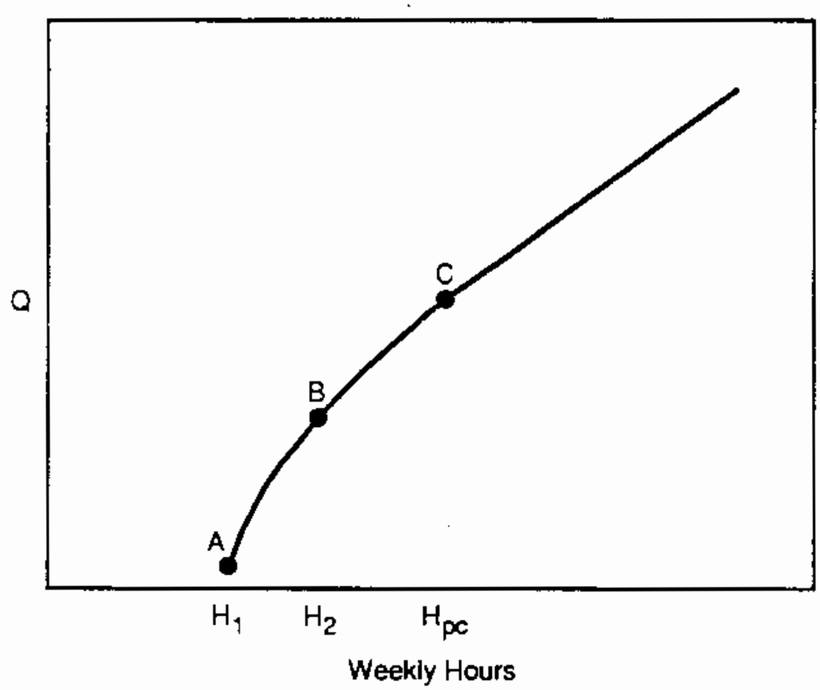

FIGURE 4.2. Hypothesized Relationship between Output (Q) and Weekly Hours

Data from the SPC can be used to compute an elasticity of output with respect to operating hours. The elasticity is defined as

$$E = \frac{\text{Percent change in output--current to practical capacity}}{\text{Percent change in operating hours (from actual to practical capacity)}} \quad (4.2)$$

The output/operating hours elasticities in Equation (4.2) were computed for each 4-digit SIC sector at both the lowest observed practical utilization rate and at the highest observed practical utilization rate over the 1977-1988 time period. To be included in the statistical analysis, the change in hours from actual operations to practical capacity was constrained to be more than 10 percent. This filter leads to the exclusion of the continuous process industries as well as industries displaying data inconsistencies. In some years, the SPC data imply that hours at practical capacity are lower than actual hours for a few industries.

The overall results in Table 4.4 conform to our earlier expectations. We show the unweighted average of the elasticities for the 400 four-digit sectors which met the 10 percent (increase in hours) criterion. At the minimum utilization rates, the mean elasticity is 2.82. At the maximum utilization rate, the mean elasticity approached was 1.25. Since the elasticity is computed as an arc elasticity, Figure 4.2 suggests that this finding is still consistent with unitary elasticity at or beyond practical capacity.

The standard deviations indicate considerable dispersion in the elasticities among the individual 4-digit industries. At the maximum utilization rate, 159 sectors out of 400 indicated elasticities less than 1.0.[a] Since sample sizes are very small for many of the 4-digit sectors, we suspect this may be due to random errors. Individual establishment data would be required to determine how extensive this apparent inconsistency is at the micro level. For some industries, however, there may be technical reasons for this relationship. Any process that requires both time and space, such as a drying process, may be a constraining factor. In the case of fixed times for drying, the firm may add a shift to increase production, but output would not increase in proportion to the additional plant hours.

The approach for this study is to ignore the sector-to-sector variation in the elasticities because the small sample sizes and resource constraints make it difficult to perform individual industry engineering analyses. From the analysis of the mean elasticity, the assumption of proportional increases in output to operating hours appears to be a reasonable approximation. Accordingly, the multiplicative shift factor formulation is used to generate estimates of emergency capacity.

(a) 61 sectors showed elasticities greater than 2.0 at the maximum observed utilization rate

TABLE 4.4. Mean Output Elasticities with Respect to Weekly Operating Hours

Computed at:	Mean	Std. Dev.
Minimum Utilization Rate	2.82	1.45
Maximum Utilization Rate	1.25	1.30

Note: Means calculated from 400 industries where ratio of weekly hours at practical capacity to actual hours exceeded 10 percent.

4.4 REFERENCES

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5.0 EMERGENCY OPERATING CAPACITY ESTIMATES: MANUFACTURING

The industry data and forecasts developed in this study may be valuable in a wide range of future analytical studies related to industrial mobilization issues. To aid potential users in understanding and exploiting interrelationships among the various data and forecast elements, a one-page format of tabular results and graphics was developed for each 4-digit SIC industry. Although these one-page summary reports provide the sole hard copy for the manufacturing EOC estimates, computer files were also developed that include only the estimates of emergency capacity and other selected data items.

This chapter describes the presentation format used for the manufacturing EOC; the results for one industry serve as an example.

5.1 HISTORICAL AND FORECAST VALUES

As an example of this reporting format, Table 5.1 shows the one-page summary results for SIC 3452, Bolts, Nuts, Rivets, and Washers. Although many of the items in the table are self-explanatory, it may be useful to summarize the data sources and methodology of the previous section as the various components of the table are discussed.

The first four columns relate only to the historical period covering 1974-1988. The output measure through 1986, as discussed in Chapter 3, is from the Office of Business Analysis (OBA) industry database. Federal Reserve Board (FRB) indexes of production were used to extrapolate 1987 and 1988 estimates. The quality of this extrapolation varies from sector to sector, depending upon the match between the FRB measure and the 4-digit SIC.

The Q4 CU Rate is the fourth quarter utilization rate as published by the Bureau of Census in the *Survey of Plant Capacity* (SPC). Values of the utilization rate that have been imputed are denoted with an asterisk. In the case of Bolts and Nuts, no imputations were required.

The Ann. CU Rate is the practical utilization rate converted to an annual basis. The annualization relied upon a regression interpolation procedure using FRB capacity utilization rates.

The fourth column, Implied Prac. Capac., is the implied industry capacity based on the annualized practical capacity estimate. It is simply the output in Column 1 divided by the utilization rate in Column 3.

The last five columns relate to the forecast of future practical and emergency capacity. Column 5, Gross Invest., shows gross investment in equipment in 1982 constant dollars from the OBA capital stocks database.

TABLE 5.1. Sample of Format - Bolts, Nuts, Rivets, and Washers

MILLIONS OF 1982 DOLLARS (EXCL. CU RATES)

	Gross Output	Q4 CU Rate	Ann. CU Rate	Implied Prac. Capac.	Gross In-vest.	Net Cap. Stk.	Pred. Prac. Capac.	Emergency Capacity 3 mon.	6 mon.	>6 mon.
1974	4,752	72	74.8	6,353	262.3	1,696	7,013			
1975	3,499	45	50.7	6,903	125.5	1,689	6,983			
1976	4,029	58	53.3	7,554	149.4	1,700	7,028			
1977	4,525	58	58.0	7,798	286.5	1,832	7,577			
1978	4,925	67	63.0	7,813	159.3	1,837	7,595			
1979	5,120	72	70.8	7,233	54.8	1,745	7,213			
1980	4,715	64	65.4	7,204	195.0	1,787	7,391			
1981	4,605	61	63.4	7,260	169.9	1,798	7,436			
1982	3,672	50	53.1	6,922	42.9	1,687	6,976			
1983	3,953	64	58.0	6,820	103.8	1,635	6,760			
1984	4,478	75	71.8	6,234	105.9	1,588	6,562			
1985	4,625	70	72.2	6,408	142.5	1,575	6,511			
1986	4,610	64	65.9	6,992	137.4	1,560	6,448			
1987	4,692	73	68.7	6,833	155.7	1,563	6,460			
1988	4,800	75	74.8	6,419	198.3	1,608	6,646	8,444	9,102	9,272
1989					205.0	1,655	6,843	8,694	9,370	9,545
1990					209.3	1,702	7,037	8,941	9,637	9,817
1991					218.7	1,754	7,252	9,214	9,931	10,116
1992					213.5	1,796	7,424	9,432	10,167	10,357

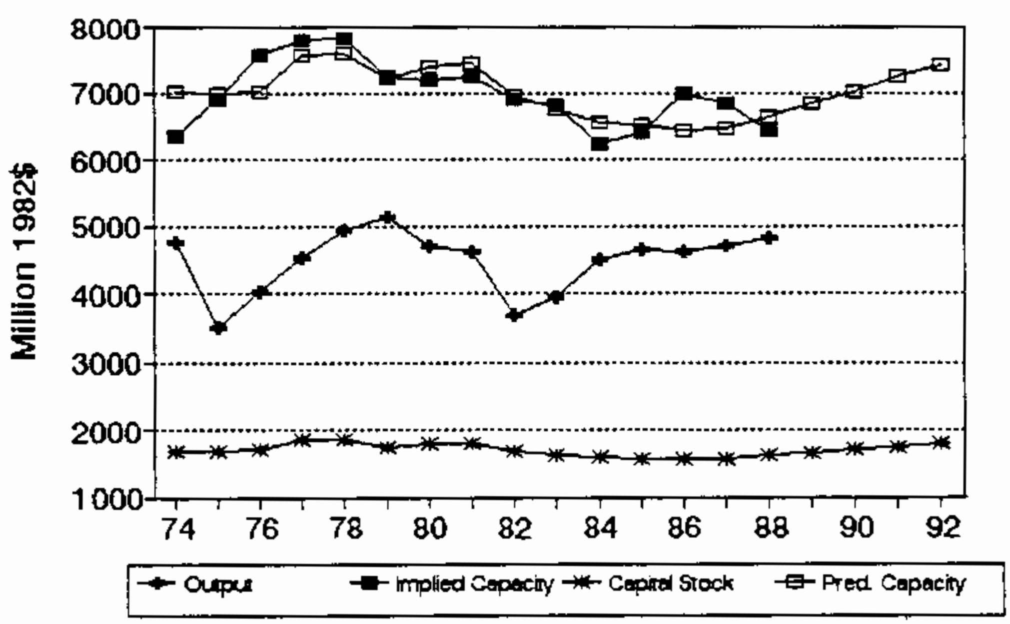
Capacity-Capital Stock Regression: Code 0 RSQ 0.590

Coefficients: Const -16.6 Stock 4.1 Ave. Capacity/Stock (74-86): 4.1

Ave. Weekly Hours (High) 113.0 Shift Factor 1.39 Ave Weekly Hours (Low) 103.6 Shift Factor 1.52

Note: Output, Investment, and Capital Stock extrapolated for 1987 and 1988.

3452 Bolts, nuts, rivets, and washers



Historical data were available only through 1986. Investment was extrapolated through 1992 based upon the INFORUM Outlook for June 1990.[a]

Column 6, Net. Cap. Stk., presents the net equipment stock from the OBA capital stocks database. As for investment, these values are expressed in 1982 constant dollars. Values from the OBA database itself run only through 1986. The capital stock estimates for 1987-1992 are based on a perpetual inventory method starting with the 1986 capital stock and the forecasts of gross investment. The depreciation rate used to generate the stock series was derived from analysis of the implied rates in the OBA database.

The predicted capacity in Column 7 results from the smoothing regression, using net capital stock as the explanatory variable, described in Chapter 3. The regression was over the period 1974-1986. The coefficients of this regression were used to forecast practical capacity over the period 1987 through 1992.

The last three columns show the emergency capacity estimates for three different time frames: 1) after 3 months, 2) after 6 months, and 3) greater than 6 months. The longest time frame, "greater than 6 months," is derived by multiplying the projected practical capacity by the shift factor. For Bolts, Nuts, Rivets and Washers, the shift factor used was 1.42. The intermediate time frame estimates, for 3 and 6 months, were developed from the Census Bureau information at the 2-digit SIC level described in Section 4.2.7.

5.2 AUXILIARY INFORMATION

Below the tabular portion of the tables is auxiliary information that may be valuable to the user. The first two lines, starting with "Capacity-Capacity Stock Regression," provides some information relating to the smoothing regression. The first value is a code that indicates the quality and type of smoothing regression that was performed. The codes can be interpreted as follows:[b]

(a) INFORUM--Interindustry Forecasting Model--University of Maryland. The INFORUM Model provides annual equipment investment forecasts for 57 sectors in the U.S. economy.

(b) A distribution of these codes across the 446 manufacturing industries is as follows: code 0, 229 industries; code 1, 95 industries; code 2, 10 industries; code -1, 56 industries; and code -2, 56 industries. As the results indicate, using capital stock alone achieved a close fit for one of the most two recent years in more than half of the manufacturing industries.

Code	Regression Quality
0	Good fit, predicted value for either 1985 or 1986 was within approximately 5 percent of implied practical capacity
1	Satisfactory fit, predicted value for 1985 and 1986 was more than 5 percent from implied practical capacity, but regression was judged satisfactory on inspection
2	Satisfactory fit, small negative coefficient on capital stock.
-1	Apparent break in series, perhaps from change in SPC sample. Capital stock is used in smoothing regression but constant adjustment is added to better fit last several years of data
-2	Negative coefficient on capital stock observed in initial regression. Time trend replaces capital stock for smoothing regression

The quality of fit in the final regression equation is measured by the R^2 (RSQ) shown after the code value. On the next line the regression coefficients are shown. In the case of Bolts, Nuts, Rivets, and Washers, the smoothing regression results are:

$$Q^{pc} = -16.6 + 4.1 * \text{Stock}, \qquad 1974\text{-}1986 \qquad R^2 = 0.590$$

If a constant adjustment or dummy variable is added to the regression, an additional term would be shown on this line. For example, a regression that added a dummy variable for 1983 through 1986 would show a term: D(83-86). A time trend regression, corresponding to a code of -2 above, would substitute the word "Time" for "Stock."

At the end of line two is the average capacity-capital stock ratio over the period 1974-1986. This number can be compared with the marginal capacity-capital stock as represented by the regression coefficient on the net stock. In this instance, the values are the same (to two significant digits), indicating that over the historical period, implied capacity has been roughly proportional to net stock.

The third line under the tabular data relates to the estimation of shift factors. As discussed in Section 4.3 of Volume 1, two estimates of the shift factor were computed to account for year-to-year variation. The "high" estimate of recent average weekly hours is shown first, followed by the shift factor based on this estimate. The "low" estimate of weekly hours is shown next, followed by the shift factor based on this number of hours.

5.3 GRAPHICS

Four key data series are plotted over the period 1974-1992: equipment stock (*), output (+), implied practical capacity from the SPC (solid rectangle), and the predicted value of practical capacity from the smoothing regression of Equation (3.1) in Volume 1 (outlined rectangle). All series are plotted in terms of millions of 1982 constant dollars. The outputs and implied capacity are plotted through 1988, although the regression in Equation (3.1) was estimated only through 1986. The outputs for 1987 and 1988 are estimated with an unknown level of error, because they have been extrapolated from 1986 levels through the use of FRB production indexes.[a]

The fitted values of capacity provide a clear picture of how well the regression formulation of Equation (3.1) has provided a smoothed or averaged series of practical capacity over the 1974-1986 period. In the case of Bolts, Nuts, Rivets, and Washers, the pattern suggests a definite decline in capacity over the first half of the 1980s. The investment forecast suggests some increase in capacity output into the early 1990s, although still not exceeding levels of the late 1970s.

(a) Again, the correspondence between the 4-digit SIC sectors and the FRB indexes is shown in Appendix A of Volume 1.

6.0 ESTIMATING CAPACITY IN NONMANUFACTURING INDUSTRIES: CONCEPTS AND METHODS

This section provides an overview of EOC in nonmanufacturing industries. We first define the set of nonmanufacturing industries used in this analysis and examine their role in the U.S. economy. Then we describe various methods for estimating EOC in these industries.

6.1 GENERAL CONCEPTS

The demand for output from nonmanufacturing industries will increase during a military build-up. Aside from demand caused by the increase in aggregate economic activity, many nonmanufacturing industries will be directly and indirectly supporting the increase in output from industries supplying military equipment. For example, the wholesale trade and transportation sectors will be involved in moving raw materials, semi-finished goods, and tools from suppliers to manufacturers producing military equipment. The hotel and retail food sectors would supply services to workers building new manufacturing facilities and working late night and grave-yard shifts. The finance, insurance, and real estate industry would provide services required to buy or construct new factories.

At the same time, the increasing share of the national economy provided by nonmanufacturing industries raises questions about the ability of the U.S. to respond to a military build-up, especially because of the perception that nonmanufacturing industries are characterized by low levels of technology and low productivity. This section will investigate the emergency operating capacity of nonmanufacturing industries by first examining the role of these industries in the U.S. economy and their characteristics. The section will then examine the measurement of output, inputs, and productivity in the nonmanufacturing sectors, followed by a discussion of methods that can be used to define and assess emergency operating capacity.

6.1.1 Defining Nonmanufacturing Industries

The following industrial categories from the SIC define the set of nonmanufacturing industries for the purposes of this analysis:

- transportation, communications, electric, gas, and sanitary services
- wholesale trade
- retail trade
- finance, insurance, and real estate
- services.

Appendix A shows a more detailed breakdown of industries (to the 2-digit SIC level). This set excludes manufacturing, extractive industries, construction, and public administration. This set of industries is commonly termed "the service sector." However, narrowly defined, the service sector refers only to one of the categories listed here. For the purposes of this analysis, the service sector will refer to those industries included in SIC Division I "Services," and the terms nonmanufacturing or non-goods producing industry will refer to the set of categories listed here.

The above categories represent a number of diverse industries with very different characteristics. The service sector (narrowly defined) includes such diverse industries as personal services (laundry, clothes repair, barbers, shoe repair, funeral services, etc.); business services (advertising, building maintenance, computer programming and data processing, etc.); medical services; engineering and research, etc.

In some cases, specific industries may be affected minimally by a military build-up (except through an increase in aggregate demand). In other cases, specific industries would be called upon to support a mobilization, directly or indirectly. For example, within the laundry, drycleaning, and garment industry sector is the industrial laundry industry, which provides cleaning services for working clothing such as clean room apparel, protective clothing, mats and rugs, etc. Computer services, engineering services, research and development services could all support a military build-up.

Because of the diversity of the services sector and nonmanufacturing industries in general, it is necessary to examine these industries in some detail and to avoid meaningless generalizations, such as equating services to "fast food restaurants and taking in each others' laundry."

6.1.2 Recent Trends in Nonmanufacturing Industries

During the period 1959-1984, employment in the nonmanufacturing sector (as defined in the preceding subsection) grew at an annual average rate of 2.6%, while employment in the manufacturing sector (including extractive industries and construction) grew at a rate of 0.4% (Kutscher and Personick 1986).[a] Over the same period, output in the nonmanufacturing sector grew at a rate of 4.1%, while output in the manufacturing sector grew at a rate of 2.4% (Kutscher and Personick 1986, Table 2). Clearly, the nonmanufacturing sector has provided the largest share of new jobs in the U.S. economy, and a large share of increased output.

This trend has resulted in a relative increase in the importance of the nonmanufacturing sector to the economy. As of 1986, the nonmanufacturing sector accounted for 56.4% of total employment and 56.5% of real gross domestic product, as compared to 48.0% of employment and 50.9% of output in 1974. Employment in the goods-producing sector went from a 34.2% share in

(a) The article uses the term "private service-producing" to define the same set of industries we call nonmanufacturing.

1973 to a 27.4% share in 1986, while output went from a 36.5% share in 1973 to a 32.5% share in 1986 (Kendrick 1988). However, because output continued to grow in the manufacturing (or broadly defined goods-producing) sector, the faster growth of the nonmanufacturing sector is not evidence of "deindustrialization."

Nonetheless, the relative growth of the nonmanufacturing sector has raised a number of questions about the implications of this growth for the health of the economy, some of which may affect the ability of the U.S. to respond to a national security emergency. Much of the concern over the growth of the nonmanufacturing sector is focused on income and the quality of employment opportunities.[a]

For the purposes of this study, however, the implications of the relative shift toward nonmanufacturing for productivity and technology utilization are more important. One reason given for arguing that wages in the nonmanufacturing sector are lower than in the manufacturing sector is that the industries in the sector tend to be labor-intensive, requiring low skill levels, and, therefore have low productivity (e.g., stereotyped as "hamburger flipping").[b] Supporting evidence for this argument comes from studies of labor productivity and total factor productivity for various industries. These studies tend to show that the nonmanufacturing sector exhibits slow productivity growth and therefore, may be a key factor in the slowdown in productivity growth for the U.S. economy as a whole. For example, data from the American Productivity Center report that total factor productivity for the nonmanufacturing sector fell by 0.3% per year during the period 1979-1986.[c] If true, this result would suggest that the nonmanufacturing sector could weaken the ability of the economy to respond to a national emergency, both because the sector is taking an increasing share of resources and because the sector would not be able to increase output in response to increased demand.

(a) See for example, Bluestone and Harrison (1982a) and Bluestone and Harrison (1988). This issue has led to considerable debate. Urquhart (1984) argues that most of the increased employment in the nonmanufacturing sector came from new job entrants, especially women, and not from displaced manufacturing workers. Rosenthal (1985) presents data suggesting that much of the decline in middle-income jobs has been matched by increases in high-paying jobs and that lower-paying jobs in both the manufacturing and nonmanufacturing have declined. Bluestone and Harrison (1988) argue that employment in all sectors is becoming increasingly polarized, with middle-income jobs decreasing and both high-paying and low-paying jobs increasing.

(b) These arguments are part of the basis of the "deindustrialization" hypothesis offered by Bluestone and Harrison in their various publications, cited previously. Waite (1988) provides a brief summary of the position, although he tends to reject the hypothesis for nonmanufacturing industries as a group.

(c) Cited in Kendrick (1988).

There is evidence, however, to suggest that this result is not entirely valid for the nonmanufacturing sector as a whole and is not valid at all for some sectors. This evidence falls into three areas:

- Individual industries within the nonmanufacturing sector show different rates of productivity growth and some industries show above average productivity growth.

- There are serious flaws in the current measurement of total factor productivity in nonmanufacturing industries, which result in underestimating productivity and productivity growth in these industries.

- A number of nonmanufacturing industries are among the most capital-intensive and most technologically innovative industries in the economy.

We will address these issues in the next section.

6.1.3 Technology, Productivity, and Measurement Problems in the Nonmanufacturing Sector

At the risk of redundancy, it is important to stress that nonmanufacturing industries are very diverse. They range from simple handicrafts, such as shoe repair and dressmaking, to such technologically advanced industries as medicine, computer programming, and electric utilities. The electric utility industry, for example, is the most capital-intensive industry in the U.S. Recent studies note the extensive use of sophisticated technologies in such industries as banking, insurance, telephone communications, investment brokerage, engineering and consulting services, and retail trade (Quinn, Baruch, and Paquette 1987; Roach 1988; and Quinn 1988). A collection of case studies sponsored by the National Academy of Engineering on technological innovation in the nonmanufacturing sector describes the development of automated teller machines for banks, an automated catalogue for automobile repair parts, tracking equipment for packages transported by Federal Express, and automation at the New York Stock exchange, among other examples (Guiles and Quinn 1988). These examples suggest that there is considerable scope for using new technologies, especially computers and other information processing equipment, to improve productivity in nonmanufacturing industries.

At the same time, the data on productivity in nonmanufacturing industries do seem to suggest that these technologies have not, in fact, led to increased productivity. Productivity growth in nonmanufacturing industries ranges from negative (implying decreasing productivity) to above that in manufacturing (Kendrick 1988; Mark 1988a; and Mark 1988b). Stephen Roach suggests that the investment in information technology in such industries as communications and finance has failed to produce commensurate improvements in productivity (Roach 1988). BLS estimates of productivity growth by industrial sector neither confirms, nor rejects Roach's suggestion. Between 1973 and 1985, productivity in the telephone communications industry increased at an annual rate of 6.2%.

Between 1981 and 1985, however, productivity growth was only 5.1%. Productivity growth in commercial banking was 0.6% per year between 1973 and 1985, but increased to 5.4% between 1981 and 1985.[a]

The financial sector [Finance, Insurance, Real Estate or (FIRE)], which includes commercial banking, can be used to illustrate the problems that exist in trying to measure productivity in nonmanufacturing industries. A recent study by Baily and Gordon (1988) points out that the measure of output in the FIRE sector used to measure productivity is based on labor input. BLS measures productivity as output divided by labor hours; thus measuring the growth in output by the growth in hours will result in no productivity growth, by definition. Baily and Gordon report that the number of shares traded in financial markets per employee in the financial industry grew by 9.7% per year between 1973 and 1979 and by 12.3% between 1979 and 1986. Similarly, labor productivity in processing checks by commercial banks increased at an annual rate of 7.6% between 1971 and 1986. Paul Glaser described how Citicorp (a New York-based bank holding company that controls Citibank) developed automated teller machines and how Citibank's branch system served three times as many customers in 1988 as it did in 1977, while increasing staff from 7,100 in 1977 to only 8,400 in 1988 (Glaser 1988). Keith and Grody (1988) described how the New York Stock Exchange automated its system for processing sales and purchases of stocks, with the result that the Exchange was able to handle a vast increase in transactions during the October 1987 "crash" without the "back-office crises" that occurred in the 1960s when the volume of transactions overwhelmed the largely manual processing of transactions.

This information suggests that the current measures of productivity may in fact be biased downward because of inappropriate measures of output for nonmanufacturing industries, at least for the FIRE sector. Baily and Gordon also discussed two other sources of downward bias in the measure of productivity in nonmanufacturing industries. The first is the price deflators used to convert current dollar output to constant dollars. Price deflators typically do not take into account quality changes. Thus, if a new model computer, for example, is faster and has greater storage capacity, it can do more than an older model. If the new model computer provides 50% more capability and costs 50% more, then there is effectively no change in output when a new model computer is sold. If, however, the price deflator does not take quality into account, output is reduced by 1/3 (i.e., 100/150) when the deflator is applied. This problem applies to manufacturing industries as well, but the ambiguities in defining nonmanufacturing output exacerbate the problem.

(a) Data for 1973-1985 from Mark (1988a) and data for 1981-1985 from Mark (1988b). BLS has developed productivity estimates for a number of nonmanufacturing industries, in addition to the two reported here. Details are in the two articles by Jerome Mark cited here. However, no BLS estimates are currently available for such industries as medicine, business services, and repair services. Roach (1988) and Kendrick (1988) report productivity estimates for different sets of industries as estimated by the American Productivity Center.

Hedonic price indices can be used to correct for quality changes for well-defined manufactured goods, as is being done with respect to computers, but may not be applicable to the nonmanufacturing sector (Faulhaber 1989; Baily and Gordon 1988).

The second measurement problem discussed by Baily and Gordon is labor quality. The standard approach to measuring productivity makes no adjustment for labor quality. An hour of labor is treated as an hour of labor whether it is an hour of work by a skilled machinist or an hour of work by teenager working in a fast-food establishment. Since the nonmanufacturing sector provides the largest share of job opportunities for workers who are entering the job market with few job skills, unadjusted hours-worked data may overstate the amount of effective labor in a given nonmanufacturing industry. This would tend to understate productivity as conventionally measured. However, the problem of lower quality labor in some nonmanufacturing industries may still adversely affect the ability of those industries to respond to increased demand during a defense build-up. In this case, the conventional measurements may accurately reflect a constraint on emergency operating capacity.

Based on the foregoing discussion, we must conclude that the evidence concerning productivity in the nonmanufacturing sector remains inconclusive. The conventional approach to measuring productivity growth suffers from serious measurement problems and does not appear to be useful for estimating EOC in the nonmanufacturing sector. As an alternative approach that avoids the measurement problems, Faulhaber, Allen and Mackinlay proposed using a service sector stock market index. The basis for this approach is that improvements in productivity will be reflected in increasing profits, and increasing profits lead to better stock market performance. Preliminary results suggest that the service sector index outperforms the Standard and Poor's 500 index, which would imply that the service sector is performing at least as well as the manufacturing sector.[a] Unfortunately, this approach provides no useful information about EOC in the nonmanufacturing sector.

6.2 METHODS FOR MEASURING EMERGENCY OPERATING CAPACITY IN NONMANUFACTURING INDUSTRIES

Given the measurement problems noted in the preceding section, it was necessary to address each of the nonmanufacturing industries by defining an appropriate concept for measuring output and the corresponding measure of capacity, and determining the availability of data to implement these measures. We developed a measure of EOC for each industry. Industry-specific EOC measures fell into two types: measures of physical capacity and measures of efficient production.

(a) Unpublished study, G. Faulhaber, F. Allen, and A. C. MacKinlay, 1989.

6.2.1 Measures of Physical Capacity

In some industries, there is a specific measure of physical capacity that constrains potential output in the short run. This constraint is particularly true in transportation and public utility industries. For example, the maximum amount of cargo that the railroads can carry is constrained by the number of available freight cars; the distance the cargo is to travel; and the time required to load, unload, and haul the freight cars. For these industries, it is possible to estimate this maximum capacity from available data.

At the same time, this maximum capacity represents an upper bound on capacity, which might not be attainable because of constraints on other factors of production such as labor and fuel, or because of limits imposed by scheduling requirements. As an example of the latter constraint, approximately 50% of freight car traffic involves empty cars. Thus, half of the carrying capacity of the railroad industry is used simply to move empty freight cars to points where they can be loaded. If all freight cars could be fully loaded for each trip, operating capacity could be doubled. The same sort of scheduling problem exists in electric utilities, where daily and seasonal variations in electricity use mean that much of the industry's generating capacity is idle much of the time.

These limitations do not mean that current industry practice is inefficient. They do mean that under normal conditions, maximum utilization of physical capacity is not a useful criteria for evaluating industry performance. The ability to meet customer demand at minimum cost and the long-run viability of firms are the criteria most likely to be used for evaluating industry performance. On the one hand, firms maintain some optimal level of idle capacity under normal operating conditions. On the other, this capacity could be available under emergency conditions, and maximum physical capacity is a useful indicator of emergency operating capacity.

There are, however, other industries for which physical capacity is not a useful concept or which cannot be directly measured by counting the industry equivalent of freight cars.

6.2.2 Production Frontiers and Emergency Operating Capacity

The alternative to measuring maximum physical capacity is to measure the output of an industry under the most efficient use of fixed inputs (such as capital stock) and variable inputs (such as labor, materials, or fuel). Then, the maximum output obtainable from the currently available capital stock is estimated, assuming that variable inputs are unconstrained. Production frontier analysis is used to estimate efficient output. In addition, production frontiers can simultaneously determine capacity utilization of the fixed inputs.

Production frontiers measure the potential output of an industry, company, or plant operated at maximum observed efficiency. Conceptually, production frontiers are equivalent to production functions. In practice, however, production functions are estimated as the best fit for the data, which typically means finding the average function, while production frontiers are estimated as envelopes bounding the observed maximum output. There are two methods for estimating production frontiers, parametric (econometric estimation) and nonparametric (linear programming). The nonparametric approach has direct application to the problem of estimating EOC and is the approach we have used in this study.

The method we used is based on the work of Färe, Grosskopf, and Kokkelenberg (hereafter abbreviated FGK) (1989). Appendix D describes the technical details of the methodology. The FGK method uses linear programming to determine maximum output given available inputs of factors of production. The basic result of the FGK methodology is an equation for capacity utilization,

$$CU = Output1/Output2$$

where CU is capacity utilization

Output1 is maximum output when all inputs (capital, labor, materials, etc.) are included as constraints in the linear programming problem

Output2 is maximum output when only capital is included as a constraint.

Output2 defines what output would be, based on existing capital stock, if labor and other variable factors are assumed to be available in an unlimited quantity. Output1 defines what output would be, given the actual amounts of labor and other factors, if the industry was operating along its production frontier. Capacity utilization is then defined as the current utilization of the potential output of the industry given capital input.

We calculate capacity utilization rather than simply using Output2 as our measure of EOC in order to use capacity utilization as an adjustment factor to estimate EOC using Bureau of Labor Statistics data on industry output. This two-step procedure allows us to estimate EOC using data that are consistent with the input/output model used by FEMA.

The linear programming problems used to solve for Output1 and Output2 can provide additional information about the various industries, such as which factors of production are constraints on output. This information will be noted in the discussion of industry-specific EOC, when relevant.

Production frontier analysis is the preferred method for measuring EOC. However, there are three types of industries where production frontier analysis cannot or need not be used. These are

1. Industries for which we cannot obtain sufficient data, especially for inputs. For example, to avoid violating confidentiality, government data-collecting agencies often withhold data on labor force, capital stock, etc., for industries with a very small number of producers.

2. Industries for which the most recent year's data reflect maximum efficiency and capacity utilization. Included are industries that are experiencing both growth and technological change and industries that are shrinking, but improving their efficiency. An example of the latter group is the railroad industry, which is reducing inputs, including freight cars, but increasing output because of efficiency improvements.

3. Industries that have a well-defined physical capacity. In this case, a simple estimate of maximum physical capacity is easier and more efficient to obtain than running a production frontier analysis.

These three types are not mutually exclusive and some industries will fall into two or all three types.

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7.0 EMERGENCY OPERATING CAPACITY ESTIMATES: NONMANUFACTURING

Because the nonmanufacturing industries are so diverse, no consistent set of data covers all of the industries. Indeed, it was necessary to develop individual data sources for almost all industries and to base our methodologies on the available data. In some cases, consistent and reliable data were available, even if the data forced us to use a different methodology than we might otherwise have used. In other cases, we made use of the best available data, even if those data were incomplete and of less than total reliability.

In the case of non-fuel minerals, the U.S. Bureau of Mines (BOM) provided specific estimates of mining capacity, which we either used directly or aggregated into larger sectors. In the case of banking, we were able to use the results of an industry study of productivity, although we did not have the data used in the study itself. At the other end of the spectrum, data on auto repair services, postal services, air transport, and trucking were a combination of published data from several sources and telephone conversations with trade associations and industry groups, and we estimated capacity.

In most other cases, data on a specific industry were assembled from one or more published sources and used to obtain capacity estimates using the best methodology, given the data. In some of these cases, the data were from a single source and appeared to be consistent. In others, several sources were used and the data may not have been fully consistent.

In a few cases, the data were frankly of poor quality. The data on water transportation showed inconsistencies between the number of vessels, average length of haul, ton-miles of cargo carried, and the number of hauls per year. As a result, we were forced to disregard much of the data and use very simple assumptions about vessel operations. Data on telecommunications and computer devices were very skimpy. The results we obtained represent our best estimate of EOC, given the available data.

7.1 SUMMARY OF INDUSTRY SPECIFIC METHODOLOGIES

The following summaries briefly describe the specific methodologies used to estimate EOC for nonmanufacturing industries. Detailed information on each industry-specific methodology is given in Appendix C. The common thread in all of the industry-specific methods was that we first obtained data on actual industry output for the latest available year (which varied from 1986 to 1988), then estimated maximum potential capacity for that year using the industry-specific methods we developed. The ratio of actual output to maximum potential output is the capacity utilization rate. This rate was then divided into the BLS estimate of actual output in that year, which is reported in 1982 constant dollars. This yields an estimate of EOC in 1982 dollars. The estimates of EOC are presented in tabular format in Section 7.2.

7.1.1 Mining

EOC for four mining sectors, which exclude fuels (except for uranium), is based on the concept of rated capacity as defined and estimated by the BOM. BOM defines rated capacity as "... the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operation rate, based on physical equipment of the plant and given acceptable operating procedures involving labor, energy, materials, and maintenance." Capacity is defined to include both operating plants and "... plants temporarily closed that, in the opinion of the author [i.e., the responsible BOM analyst], can be brought into production within a short period of time with minimum capital expenditures." (BOM, "Iron Ore, 1988," p. 14). BOM introduced estimates of rated capacity in its Minerals Yearbook, 1988, which was published in early 1990. EOC for a fifth mining sector, Stone and Clay Mining, is estimated using a different method, described below.

In all sectors, the ratio of 1988 actual production to 1988 capacity is calculated, then applied to the 1988 BLS data on output to obtain an estimate of EOC in 1982 constant dollars. Since the BLS data are restricted to two sectors, Metals and Non-metal Mining, data from the Census of Mining were used to allocate the BLS data to the five sectors we are using. Census data were used because they were the only complete and consistent data available covering the entire non-fuels mining industry.

- Iron and Ferroalloy Ores. EOC estimates for the iron and ferroalloy ores sector are restricted to iron ore capacity. Molybdenum is the only ferroalloy mined in the U.S. in any significant quantity. Molybdenum output is measured in millions of pounds, while iron ore output is measured in millions of tons. We assume that sector output is largely determined by iron ore production. Our measure of iron ore capacity is rated capacity of iron pellet production, since pelletizing operations will be a binding constraint on ore production.

- Copper Ores. EOC for copper ore is estimated from BOM capacity and output data for copper mines and for copper produced as a by-product of gold, silver, lead, and zinc mining.

- Non-ferrous Metal Ores (excluding Copper). Our estimated EOC for this sector is based on BOM data on capacity and output in lead and zinc mining. We assume that EOC for lead and zinc mining applies to the entire sector. Except for gold, silver, and uranium, the other ores in this sector are not mined in the U.S.; are mined in small quantities; or are produced by one or two firms and data are not available. Gold and silver are mined in part as by-products of lead and zinc mining so that using lead and zinc as a proxy is not unreasonable. In the special case of uranium, data from the U.S. Department of Energy show that 1986 uranium production was 8.3 million pounds, while production in 1980 was 44 million pounds and available reserves were in excess of 300 million pounds. This means that uranium is readily available for emergencies.

Lead and zinc capacity and output are aggregated using 1988 unit price data to convert both output and capacity to values, which are then used to calculate capacity utilization.

- Chemical and Fertilizer Minerals. Our estimate of EOC for this sector uses BOM capacity and output data for potash, soda, phosphate rock, and sulfur. Except for boron, the remaining minerals in this sector are not produced in large quantities in the U.S. or are of less interest (such as rock salt). Boron is produced by a small number of firms and key data are not available. The separate capacity and output data for each of the minerals we are using are aggregated by price to estimate total capacity and output, which are then used to calculate an estimate of capacity utilization for the sector.

- Stone and Rock Mining and Quarrying. Because stone and rock are readily available and because the sector currently operates on a one-shift/five-day-per-week schedule, we estimated EOC for this sector based on a three-shift/five-day-per-week schedule, or three times current output. This schedule readily converts to a utilization rate of 0.3333.

Coal Mining

Coal mining is an industry in which output has increased, while such inputs as the number of active mines and miners has decreased. However, inactive coal mines remain in existence and can be reopened if the demand for coal is sufficiently high. Therefore, we used the FGK method to estimate maximum potential output in the coal mining industry, using the number of mines that were actually in operation in 1978 (the peak year of number of mines) and the number of miner-hours employed in that year as our constraints. Because of improved productivity, output per miner-hour was higher in 1986 (the latest year for which we have data) than in 1978; and potential output in 1986 is higher than actual output in 1978, even with the same number of miner-hours and operating mines.

Solving the FGK linear programming problem with both mines and miner-hours as constraints provided one estimate of potential output. Solving the linear programming problem with only the number of mines as the constraint provided a somewhat higher estimate of potential output. For the purpose of estimating EOC, we selected the first, more conservative estimate, which nonetheless was substantially higher than actual output in 1986. We then estimated capacity utilization in 1986, based on our estimate of potential output, and then used the capacity utilization rate and the BLS data to estimate EOC in constant 1982 dollars.

Oil and Natural Gas Extraction

The FGK method was applied to the oil and gas extraction industry to obtain an estimate of potential maximum output. The industry was treated as a joint-product case, with a single estimate of maximum potential output for both oil and natural gas. Capacity utilization was estimated based on the solution of the two-stage FGK linear programming problem (with oil and natural gas reserves as the fixed factors), and this estimate was applied to the BLS data to obtain EOC in constant 1982 dollars.

7.1.2 Transportation Industries

The transportation sectors cover railroads, trucks, shipping, airlines, and oil pipelines.

- Railroad Transportation. EOC in railroad transportation was estimated from data on the number of freight cars, average capacity per freight car, and average length of haul per ton of cargo. We then assumed that under emergency conditions the average freight car would make 25 full-load hauls per year, allowing for an empty return trip. This estimate of ton-miles per year was compared with actual ton-miles for 1988 to obtain a measure of capacity utilization. That measure of capacity utilization was then applied to 1988 output (as estimated by BLS in 1982 dollars) to obtain EOC as measured by output in constant 1982 dollars.

- Highway Transportation. Our analysis of EOC in highway transportation concentrated on cargo transportation by the heavy trucking industry. Using data on the number of truck tractors and trailers, average capacity per trailer, average length of haul, and number of hauls per year, we estimated potential capacity assuming that all hauls carry full trailer loads.

  Our estimates are based on approximately three trailers per truck-tractor (allowing each truck tractor to haul one trailer, while the other two are loading or unloading). Information from the trucking industry suggests that the current number of hauls (187 per truck-tractor per year) is close to the maximum potential number and that any unused capacity comes from hauls of less than full load. Once we estimated 1988 potential capacity (in ton-miles), we calculated a capacity utilization rate based on 1988 actual ton-miles. The capacity utilization rate was then applied to the BLS estimate of 1988 output (in 1982 dollars) to obtain EOC in 1982 dollars.

- Water Transportation. Unlike most industries, water transportation has a specific reserve capacity, largely maintained by the U.S. government for emergencies. This capacity was added to unused or available surplus capacity in the private water transportation industry as part of the estimate of EOC.

  The water transportation industry is complicated by the fact that there are three distinct parts to the industry: overseas transportation, coastal transportation, and inland waterways (including the Great Lakes). Because the length of haul is very different in each part of the industry, ton-miles is not a useful measure. Instead, we used total tonnage and estimated capacity for the water transportation industry as a whole. Specific reasons for this are discussed in detail in Appendix C.

We estimated potential capacity by taking the total capacity of active and reserve vessels (including ships and barges) and assuming twenty hauls per year per ton of capacity, as an average for all classes of vessels. This capacity was compared with actual output for 1986 and capacity utilization calculated. The estimate of capacity utilization was then applied to the BLS estimate of 1986 output to obtain EOC in constant 1982 dollars.

- Air Transportation. Data from the Air Transport Association of America showed that in 1988 the airline industry had a load factor (or capacity utilization rate) of 55.4% for combined passenger and cargo traffic. This capacity utilization rate was applied directly to the BLS estimate of output for 1988 to obtain an estimate of EOC in constant 1982 dollars.

- Oil Pipeline Industry. For the oil pipeline industry, the FGK method was applied. Solution to the linear programming problem for 1988 showed that 1988 was on the best practice production frontier when all factors of production were included. When the linear programming problem was solved with only pipeline mileage as a constraint, potential output was estimated to be approximately 1.1% higher than observed output. The resulting capacity utilization rate was applied to the BLS data for 1988 to obtain an estimate of EOC in constant 1982 dollars.

7.1.3 Public Utilities

Estimates of EOC were developed for electric and natural gas utilities.

- Electric Utilities. Our estimate of EOC for the electric utility industry is based on available generating capacity. The electric utility industry maintains sufficient generating and transmission capacity to meet annual peak loads. One measure of EOC would be maximum output at peak load, which is simply existing capacity for all generators.

  A better measure for our purposes, however, would be annual maximum potential generation, which is existing capacity times the number of hours in a year, adjusted for availability and maintenance requirements. The reason for this is that generation can be increased without adding capacity if increased demand occurs during non-peak periods so that utilization of existing capacity increases.

  This concept fits into the analysis of emergency capacity, since under emergency conditions, industries will be operating around the clock, not just during normal business hours. A simple adjustment to incorporate availability and maintenance requirements is to use 1988 peak load (which was 80% of total capacity) to define the amount of generating capacity that would be available under emergency conditions, allowing a margin for maintenance or outages. Then actual 1988 generation was used to calculate a capacity utilization estimate, which was then applied to the BLS data to obtain our estimate of EOC in constant 1982 dollars.

- Natural Gas Utilities. The key factor that determines maximum operating capacity for the natural gas utilities (other than the availability of natural gas) is the capacity of the transmission and distribution system. There is, however, no direct measure of the total system capacity. We can use instead historical peak sales as a proxy for system capacity. During the period 1965 to 1987, 1972 had the highest annual sales, substantially above sales in 1987. During the same period, January 1972 had the highest monthly sales, which on an annual basis were more than twice 1987 annual sales. These data mean that the transmission and distribution system is able to deliver these quantities of natural gas to consumers and, therefore, provide reliable measures of EOC. We use the 1972 annual sales as our primary measure of EOC because they represent a known, sustainable level of output, rather than January 1972 monthly sales, which might not be sustainable for an entire year. The 1972 annual sales were used to estimate capacity utilization in 1987, and capacity utilization was applied to the BLS data to obtain EOC in 1982 constant dollars.

7.1.4 Communications

The FGK method was used to estimate EOC for the telecommunications services industry. An alternative method would be to assume that peak load on the telecommunications sector could be extended throughout the year. This alternative would imply a very large EOC, but requires the assumption that business (as opposed to personal) calls, data transmission, fax transmission, etc., could be made outside of normal business hours (even assuming longer hours during an emergency), without disrupting business activities and reducing the utility of telecommunications. Nonetheless, this alternative approach does suggest that our estimate of EOC using the FGK method may be conservative and actual EOC may be higher.

Data on output (measured as revenue in constant dollars) and labor were obtained from the 1989 U.S. Industrial Outlook. Data on capital stock came from the Department of Commerce's Capital Stock Data Base. Using the FGK method, we obtained a capacity utilization rate of 98%, which implies an EOC of 2% more than actual output. This utilization rate was applied to the BLS data to give an EOC in constant 1982 dollars.

7.1.5 Banking

For the banking industry, we focus on the checking and electronic fund transfer functions of the banking system, rather than on teller services or lending. Automatic teller machines effectively mean that there is no practical limit on expanding teller services. Capacity for lending activities is not really definable and loans can be made by others, such as credit agencies. On the other hand, check clearing and fund transfers can be a serious bottleneck for the industry. Data from the Bank Administration Institute (BAI) showed the average number of items processed per hour by all financial institutions. These BAI data show that the most efficient institutions (16% of the institutions) processed at least 52% more items per hour than did the less efficient institutions. We assume that under emergency conditions all institutions would adopt the most efficient procedures, and this assumption implies a current utilization rate of emergency capacity of 66%. This utilization rate is then applied to the BLS data to give an estimate of EOC in constant 1982 dollars.

7.1.6 Hotels and Lodging Places

The capacity of the hotel and lodging industry is simply the number of beds available. We assume that under emergency conditions, each hotel room will have two beds and the double occupancy would be the rule if needed to meet demand. The American Hotel and Motel Association provided data on 1988 room occupancy rates, percentage of rooms occupied by two people, and number of rooms. These data were used to estimate the 1988 bed occupancy rate and the total number of beds, assuming two per room. EOC is defined as 100% bed occupancy. The emergency capacity utilization rate is then calculated and applied to the BLS data to yield an estimate of EOC in constant 1982 dollars.

7.1.7 Computer and Data Processing Services

Our review of the computer and data processing services industry leads us to conclude that this industry is currently operating at full capacity. The industry is expanding output annually, uses the latest available technology, and has had difficulties finding enough qualified personnel. It is possible that during an emergency, existing resources within the industry could be redirected, but total output would not increase.

7.1.8 Automotive Repair Shops and Services

According to the Duffy-Vinet Institute (a management consulting and training firm), capacity utilization in the automotive repair industry is 60%. We applied this number directly to an estimate of 1988 output in the industry. Our estimate of 1988 output is based on the BLS data. The BLS data for this industry cover not only repair services but also parking and carwashes. Using data from the 1987 Census of Services, we calculated that repair services accounted for 59.39% of the output of the BLS sector. This percentage was applied to the BLS data to obtain estimated output for repair services. We then calculated EOC using the 60% capacity utilization rate to estimate EOC in constant 1982 dollars.

This estimate excludes automotive repair services provided by department stores, auto supply and parts stores, and service stations that receive 50% or more of their revenue from gasoline sales. Data on auto repair services from these businesses are included in retail trade statistics and are not separately available.

7.1.9 U.S. Postal Service

Our estimate of EOC for the postal service is based on the volume of mail carried during the postal service's peak load period, between Thanksgiving and Christmas. We assume that EOC for the postal service is equal to the annual volume of mail that would be carried if the service operated at peak level for the entire year. The postal service provided data showing 161.1 billion pieces of mail handled in 1988. Of this total, one-eleventh (1/11) was handled during the four-week period between Thanksgiving and Christmas. Since there are 13 four-week periods in a year, we take one-eleventh of the total, then multiply by 13 to give us the annual volume of mail at peak capacity. We then calculate the capacity utilization rate and apply this to the BLS data to estimate EOC in constant 1982 dollars.

7.1.10 Doctors and Dentists

Our estimate of EOC for doctors and dentists is based on American Medical Association (AMA) data on the number of patients seen per hour by doctors in 1988. The AMA data suggest that there is little available capacity by increasing the number of hours doctors work, so that the only way to increase output is to see more patients per hour. The AMA provides regional data on patients seen per hour, as well as a national average. We took the number of patients seen per hour by doctors in the East South Central census division as our measure of potential capacity, since this region had the highest average number of patients per hour. Dividing this number by the average number of patients per hour for the U.S. as a whole gives us an estimate of capacity utilization, which is then applied to the BLS data to give us an EOC estimate in constant 1982 dollars. We also assume that the same potential increase applies to dentists.

7.1.11 Hospitals

The FGK method was used to estimate EOC for the hospital industry. This method was chosen over the alternative of using a simple occupancy rate for hospital beds because hospitals provide other services to in-patients than simply a place to sleep. Outpatient care was excluded from the estimate of EOC because outpatient care can be provided by other industries (such as doctors' offices and clinics). Data on patient days and various inputs (beds, doctors, nurses, and support staff) were obtained for 1988 on a regional basis. Using beds as the fixed input, we solved the FGK linear programming problems for each region, obtaining an estimate of capacity for each region. With the number of beds as weights, the regional estimates were aggregated to a national estimate. The estimate of national capacity utilization was then applied to the BLS data to obtain an estimate of EOC in constant 1982 dollars.

7.2 ESTIMATES OF NONMANUFACTURING EMERGENCY OPERATING CAPACITY

Table 7.1 presents PNL's estimate of EOC for nonmanufacturing industries. For each industry, Table 7.1 lists the BLS output estimate for the years 1986, 1987, and 1988 and the PNL estimate of capacity utilization for the year for which we have the latest data. The estimate of EOC is the BLS industry output estimate for that year divided by the PNL estimate of capacity utilization. The Bureau of Economic Analysis' input-output (I/O) classification number, also used BLS in its industry sectoring scheme, is provided for reference.

TABLE 7.1. Nonmanufacturing Emergency Operating Capacity Estimates

SIC Codes	Classification	Industry Title	1986	1987	1988
101 106	5.00	Iron & Ferralloy Ores			
		BLS Data			
		Output (millions of 1982 $)	2,120.3	2,217.3	2,623.1
		PNL Analysis			
		EOC Utilization (%)			84.0
		EOC in millions of 1982 $			3,117.3
102	6.01	Copper Ores			
		BLS Data			
		Output (millions of 1982 $)	2,029.8	2,122.6	2,511.0
		PNL Analysis			
		EOC Utilization (%)			84.0
		EOC in millions of 1982 $			2,988.4
103	6.02	Non-Ferrous Ores, Excl. Copper			
		BLS Data			
		Output (millions of 1982 $)	2,607.0	2,726.1	3,224.9
		PNL Analysis			
		EOC Utilization (%)			58.0
		EOC in millions of 1982 $			5,551.6
11 12	7.00	Coal Mining			
		BLS Data			
		Output (millions of 1982 $)	30,722	31,697	32,771
		PNL Analysis			
		EOC Utilization (%)	78.0		
		EOC in millions of 1982 $	39,250		
131	8.00	Oil and Gas Extraction			
		BLS Data			
		Output (millions of 1982 $)	173,267	168,125	166,280
		PNL Analysis			
		EOC Utilization (%)	75.0		
		EOC in millions of 1982 $	231,138.2		

TABLE 7.1. (contd)

SIC Codes	I/O Classification	Industry Title	1986	1987	1988
14	9.00	Stone, Clay, & Quarry Mine			
		BLS Data			
		Output (millions of 1982 $)	7,132.9	7,428.1	8,077.2
		PNL Analysis			
		EOC Utilization (%)			33.0
		EOC in millions of 1982 $			24,234.0
147	10.00	Chemical and Fertilizer Materials			
		BLS Data			
		Output (millions of 1982 $)	4,779.1	4,976.9	5,412.5
		PNL Analysis			
		EOC Utilization (%)			78.0
		EOC in millions of 1982 $			6,902.8
40 474	65.01	Railroads			
		BLS Data			
		Output (millions of 1982 $)	31,990	35,263	35,388
		PNL Analysis			
		EOC Utilization (%)			58.0
		EOC in millions of 1982 $			61,184.8
42	65.03	Trucking			
		BLS Data			
		Output (millions of 1982 $)	83,017	87,702	91,004
		PNL Analysis			
		EOC Utilization (%)			43.0
		EOC in millions of 1982 $			210,524.3
4311	78.01	U.S. Postal Service			
		BLS Data			
		Output (millions of 1982 $)	29,068	30,535	31,092
		PNL Analysis			
		EOC Utilization (%)			85.0
		EOC in millions of 1982 $			36,743.1

TABLE 7.1. (contd)

SIC Codes	I/O Classification	Industry Title	1986	1987	1988
44	65.05	Water Transportation			
		BLS Data			
		Output (millions of 1982 $)	27,467	27,104	28,328
		PNL Analysis			
		EOC Utilization (%)	79.0		
		EOC in millions of 1982 $	34,853.1		
45	65.05	Air Transport			
		BLS Data			
		Output (millions of 1982 $)	56,938	61,459	64,288
		PNL Analysis			
		EOC Utilization (%)			55.0
		EOC in millions of 1982 $			116,043.3
46	65.06	Oil Pipelines			
		BLS Data			
		Output (millions of 1982 $)	8,755	8,931	8,888
		PNL Analysis			
		EOC Utilization (%)			99.0
		EOC in millions of 1982 $			8,981.4
491	68.01	Electric Utilities			
493	78.02				
	79.08	BLS Data			
		Output (millions of 1982 $)	120,297	124,045	129,883
		PNL Analysis			
		EOC Utilization (%)			60.0
		EOC in millions of 1982 $			517,559.5
492	68.02	Natural Gas Utilities			
		BLS Data			
		Output (millions of 1982 $)	89,504	85,264	87,059.00
		PNL Analysis			
		EOC Utilization (%)		62.0	
		EOC in millions of 1982 $		138,144.8	

TABLE 7.1. (contd)

SIC Codes	I/O Classifi-cation	Industry Title	1986	1987	1988
60	70.01	Banking			
		BLS Data			
		Output (millions of 1982 $)	103,870	106,242	109,839
		PNL Analysis			
		EOC Utilization (%)			66.0
		EOC in millions of 1982 $			157,378
70	72.01	Hotel & Lodging Places			
		BLS Data			
		Output (millions of 1982 $)	44,110	46,126	48,714
		PNL Analysis			
		EOC Utilization (%)			56.0
		EOC in millions of 1982 $			87,316
737	73.01	Computer & Data Process			
		BLS Data			
		Output (millions of 1982 $)	56,214	59,849	62,451
		PNL Analysis			
		EOC Utilization (%)			100.0
		EOC in millions of 1982 $			62,451
753 7549	75.00	Auto Repair			
		BLS Data			
		Output (millions of 1982 $)	42,167	43,848	44,939
		PNL Analysis			
		EOC Utilization (%)			60.0
		EOC in millions of 1982 $			74,732
801	77.01	Doctors & Dentists			
		BLS Data			
		Output (millions of 1982 $)	93,242	94,220	100,203
		PNL Analysis			
		EOC Utilization (%)			83.0
		EOC in millions of 1982 $			120,147.5

TABLE 7.1. (contd)

SIC Codes	I/O Classification	Industry Title	1986	1987	1988
806	77.02	Hospitals			
		BLS Data			
		Output (millions of 1982 $)	104,806	110,968	114,943
		PNL Analysis			
		EOC Utilization (%)			88.0
		EOC in millions of 1982 $			130,322.4

8.0 PRODUCTION FUNCTION ANALYSIS

As part of this project, PNL also investigated the use of both the FGK methodology in estimating EOC and parametric cost frontiers to estimate EOC for manufacturing industries. This section reports the results of that investigation.

8.1 APPLICATION OF THE FARE-GROSSKOPF-KOKKELLENBERG METHODOLOGY TO ESTIMATING EMERGENCY OPERATING CAPACITY FOR MANUFACTURING INDUSTRIES

Our use of the FGK method to estimate EOC for certain nonmanufacturing industries leads to the obvious extension of applying this method to estimating EOC for manufacturing industries. Because this is an investigation into the methodology, we did not develop a separate data base for the manufacturing sector, using instead the same data on output, capital stock, and labor input used in the estimation of EOC reported in Chapter 3. The data set covers the years 1971 to 1986, and capacity utilization is estimated for 1986.

The FGK method is outlined in Chapter 6, and described in detail in Appendix D. The FGK method estimates capacity utilization as output in 1986. This estimate is adjusted to reflect the most efficient use of both inputs based on observed practice in each industry, divided by estimated output constrained only by the available capital stock, also adjusted to reflect the most efficient use of capital stock based on observed practice. The results of the method as applied to 446 four-digit SIC manufacturing industries are reported in Column 1 of Table 8.1.[a] Capacity utilization estimates for 1986 based on the Census survey of manufacturers (see Chapter 6) are reported in Column 2 of Table 8.1 for comparison.

Even a cursory comparison of the two capacity utilization measures shows significant differences. In some cases, the differences are very great. In most cases, the Census estimates of capacity utilization are lower than those obtained using the FGK methodology. The lack of a close relationship between the two estimates of EOC is indicated by the correlation and Spearman rank order correlation coefficients between the two estimates. The simple correlation was 0.305, while the rank order correlation was 0.285.

There are several possible explanations for these differences:

- Because the FGK method with one fixed input keys off of the highest observed output/capital ratio, errors in estimating capital stock will produce erroneous estimates of potential capacity and capacity utilization.

(a) To maintain readability, all tables have been placed at the end of the chapter.

- There are substantial differences in the reported capacity utilization and the utilization of labor services in the Census survey. This suggests that survey respondents may be unrealistic in their estimate of maximum practical capacity.

- The data used to implement the FGK method are based on estimates of output, capital stock, and labor input for each 4-digit SIC industry. The Census survey of capacity utilization is based on a sample of establishments in each industry. Therefore, it is possible that the survey estimates of capacity utilization may be accurate for the survey sample, but may not capture changes in the aggregate output and capacity of the industry because of changes in the number or operations of establishments not included in the survey.

- It is possible that an industry may consistently operate at some level of capacity utilization (say 75%) during the period covered by the data used in the FGK procedure. If so, then the FGK method would be likely to estimate capacity utilization in the most recent observation at or close to 100%.

- A variant of this hypothesis is that an industry may operate at the same level of capacity utilization during both the basis and the last years, without regard to other years.

- If the basis year is the last year in the period, then the FGK estimate of capacity utilization will be 100%, by definition. If the last year has the highest rate of capacity utilization (even if this is less than 100%), then it is likely that the basis year will be the last year, giving an FGK estimate of 100% capacity utilization.

- Given that the FGK method estimates potential output based on the observed best practice year, it is reasonable to assume that the FGK estimate of capacity utilization will be greater than or equal to the survey estimate because it is unlikely that any observed level of output will exceed the survey definition of "practical output." Therefore, cases in which the FGK estimate is less than the survey estimate warrant special consideration.

No doubt there are other possible explanations for the differences in the two estimates of EOC. However, in the absence of more detailed data on the establishments responding to the Census survey and on each industry, we cannot indicate which estimate is more accurate.

At the same time, we did examine several ways to combine the FGK and Census estimates of capacity utilization to see if there was a consistent relationship between them that might not be captured by the correlation coefficients. The following adjustment factors were examined:

- A modified FGK measure of capacity utilization that uses actual 1986 output, rather than the efficiency-adjusted 1986 output, as the measure of current usage. This measure includes potential capacity from unused capital and inefficient use of existing capacity.

- The capacity utilization rate from the Census survey for the basis year of the solution of the linear programming problem used to estimate maximum potential output using only capital stock as the constraint (i.e., the denominator of the FGK capacity utilization measure). The basis year, in this case, is the year in which the output/capital ratio was the highest.

- The ratio of actual labor use in the fourth quarter, as reported by the Census survey, to labor use under maximum practical output, also as reported by the Census survey. This ratio was calculated for both 1986 and the basis year.

- The modified FGK capacity utilization rate times the survey capacity utilization for the basis year. This measure attempts to capture the effect of available unused capacity in the year in which the output/capital ratio was the highest.

- The preceding measure times the labor utilization rate from the Census survey for the basis year. This method adjusts for any additional information from the reported labor utilization rate.

Because the Census survey did not include 1971 (the first year of data used in the FGK method) and because data for actual and maximum labor use were missing, the number of industries for which the adjusted measures of EOC could be calculated was reduced to 167. Table 8.2 shows the simple and rank order correlations between several of the alternative measures of capacity utilization and the Census survey for 1986.

There is little correlation between the 1986 survey estimates of capacity utilization and the alternative measures listed in Table 8.2. The highest correlation involves adjusting the modified FGK2 measure using the capacity utilization rate for the basis year from the Census survey. However, this was only about 0.64. Using the basis year labor utilization rate from the Census survey as a further adjustment actually reduced the correlation coefficient. This result suggests that there may be some inconsistencies in the way the establishments in the Census survey responded to the survey. This possibility is supported by the fact that the correlation between the 1986 survey capacity utilization rate and the 1986 labor utilization rate was 0.43.

This preliminary investigation of production frontier analysis (the FGK methodology) as a method of estimating capacity utilization suggests that there may be limits to the usefulness of the approach because of data limitations. This fact was reflected in our estimation of EOC for nonmanufacturing industries where the FGK method was supplemented by other methodologies, based on the individual characteristics of the specific nonmanufacturing industries and data availability.

At the same time, our investigation raises some questions about the consistency of the Census survey of capacity utilization. Recent papers by Champion and Thorpe (1987) and O'Neill and Thorpe (1988) discuss the issue of consistency in the Census survey, without reaching a definitive conclusion. In addition to the problem of inconsistencies between capacity utilization and labor utilization, these papers note that many establishments responding to the survey reported that current, "preferred" (i.e., profit maximizing), and "practical" (i.e., maximum sustainable with locally available labor supplies) output are all equal. This result tends to violate the usual assumption of a U-shaped average cost curve. This issue is discussed at length in O'Neill and Thorpe.

There are several possible explanations for these results. One is that the survey respondents failed to understand the survey question or were careless in their responses. O'Neill and Thorpe and Champion and Thorpe both note the relationship between what the Census survey terms the "preferred" level of output and production at the point where price equals short-run marginal cost; survey respondents could be confused between this point and minimum short-run average cost. Another possibility is that many establishments are indeed operating at their practical level of output and that level of output represents their preferred level because they are constrained by their available capital stock, rather than by labor supplies or demand for their product.

One way to resolve these issues is to examine a sample of the responding establishments in detail to determine if their responses accurately reflected their situation, and if not, why not. This would be a difficult and expensive task and might be hampered by firms' resistance to revealing such information. Another approach is to analyze data on inputs, outputs, prices, etc., to determine what preferred and practical output would be, given the available capital stock and input prices. This determination could be made with cost or production frontier analyses, which are based on the same concepts as the FGK methodology but which apply different analytical tools to the question.

8.2 A COST FRONTIER METHOOOLOGY FOR ESTIMATING EMERGENCY OPERATING CAPACITY

The FGK methodology uses a non-parametric linear programming approach to estimate EOC based on observed best practice performance by an industry. The use of observed best practice performance can limit the estimate of EOC, especially in the case where the observed best practice does not involve the full employment of available quasi-fixed factors of production (i.e., those factors that are fixed in the short run, such as capital stock). An alternative approach is to develop a parametric model of the production process that can be used to estimate what output would be if quasi-fixed factors were fully utilized.

A cost frontier is one such model that is appropriate for use in estimating EOC. A cost frontier is defined as the minimum cost of producing a given quantity of output. This definition conforms to the textbook definition of a cost function; however, it differs from the usual econometric estimate of a cost function, which measures the average cost (across the observations) of producing that output. Although there are a number of methods for estimating a cost frontier, we will use a parametric linear programming method. Appendix D describes cost frontiers in more detail and discusses the various estimation methods. Appendix D also presents the details of the methodology we are using to estimate EOC from the cost frontier.

The basic concept behind our approach is that most industries typically do not operate in long-run competitive equilibrium. This is especially true in terms of the utilization of capital stock. Firms will often acquire capital stock in excess of current requirements in anticipation of future growth in demand and to allow for increased flexibility to respond to unanticipated changes in market conditions. Similarly, firms retain their current capital stock during temporary declines in demand. The result of these and other factors is that capital stock utilization is either less than or greater than the optimum and only rarely, if ever, at the optimum. By estimating a cost frontier, we can estimate what the optimal level of output would be if the industry were in fact in long-run competitive equilibrium with the given level of its capital stock.

Briefly, our methodology is as follows:

- We assume that the cost frontier can be approximated by a transcendental logarithmic (translog) equation. Translog cost and production functions and frontiers are extensively used in economic analysis and their properties are well known.

- We estimate the parameters of the translog cost frontier for a given industry, using time series data on output, total cost, and factor prices and assuming three factors of production: capital, labor, and intermediate inputs (materials, energy, parts, etc.).

- The estimated parameters are then used to calculate the optimal share equations for each factor of production.

- Using the share equations, the existing capital stock, and the factor prices, we calculate the optimal amount of labor and intermediate inputs for that amount of capital at those prices.

- We then calculate the level of output corresponding to the estimated optimal factor inputs.

Suitable data on inputs and outputs for the establishments responding to the Census survey are not available to us at this time. Therefore, to test the methodology, we used data for seven industries for the years 1970-1979 from Jorgenson et al. (1988). This data set was used because it represents the current state of the art in measuring capital and labor inputs and because the data are structured in the form of a Divisia index, which was specifically designed to be consistent with a translog function. The seven industries are

- transportation equipment (except motor vehicles) and ordnance
- motor vehicles
- non-electrical machinery
- fabricated metal
- chemicals
- primary metals
- rubber and miscellaneous plastics.

Table 8.3 shows our estimate of output per sector and actual output (both in the form of a Divisia index). For each observation, our estimate was at least equal to actual output and was higher in all but a few cases. This implies that there is considerable capacity within most industries that could be utilized in an emergency.

Once we obtained the equilibrium adjusted estimates of inputs and output for these seven industries, the next stage is to apply the FGK method to the adjusted data to estimate capacity utilization. This way, the observed best practices at least reflect the optimal use of inputs during each observation. Table 8.4 summarizes the results of the FGK method estimates of capacity utilization for 1979.

In Table 8.4, the equilibrium adjusted output in Column 2 is equivalent to the "preferred" output concept in the Census survey; that is, it represents profit maximizing output given capital stock and input prices and assuming that there is enough demand for the product. Column 3 gives maximum output, given the capital stock, and is conceptually equivalent to "practical" output in the Census survey. For all seven industries, the equilibrium adjusted output exceeds actual output, while maximum output exceeds equilibrium adjusted output in four cases. In three cases, maximum output equals the equilibrium adjusted output, which implies that output is constrained by the available capital stock. Two of these industries, chemicals and rubber, involve at least some continuous process operations, which is consistent with capital stock being the constraining factor of production. The third industry, machinery, is not a continuous process industry, and this result may reflect a combination of high growth in output and high utilization.

The results summarized in Tables 8.3 and 8.4 represent only a test of the methodology. These test results do suggest that cost frontiers can be a very useful method for estimating EOC. Further research into the use of cost frontiers would involve updating the data series from 1979, while retaining the detailed analyses of capital stock vintage and labor force characteristics that Jorgenson et al. conducted in developing their data.

The analysis should extend to other industries. Jorgenson et al. developed data for over forty industries (not all of them manufacturing). At the same time, the analysis should look at a more disaggregated set of industries. The seven industries analyzed here represent a very high degree of aggregation, which tends to reduce the amount of information contained in the data. The methodology we have developed can be used at any degree of aggregation, down to individual plants.

TABLE 8.1. Comparison of FGK and Census Survey Utilization Rates for 1986

No.	SIC	Title	FGK	SPC
1	2011	Meatpacking plants	1.000	.817
2	2013	Sausages and other prepared meats	1.000	.705
3	2016	Poultry dressing plants	1.000	.781
4	2017	Poultry and egg processing	.944	.802
5	2021	Creamery butter	.908	.720
6	2022	Cheese, natural and processed	.919	.819
7	2023	Condensed and evaporated milk	.893	.746
8	2024	Ice cream and frozen desserts	.997	.589
9	2026	Fluid milk	1.000	.761
10	2032	Canned specialties	.921	.783
11	2033	Canned fruits and vegetables	1.000	.596
12	2034	Dehydrated fruits, vegetables, soups	.804	.842
13	2035	Pickles, sauces, and salad dressing	.868	.623
14	2037	Frozen fruits and vegetables	.767	.689
15	2038	Frozen specialties	.715	.783
16	2041	Flour, other grain mill products	1.000	.841
17	2043	Cereal breakfast foods	.608	.789
18	2044	Rice milling	.752	.746
19	2045	Blended and prepared flour	.619	.518
20	2046	Wet corn milling	.900	.892
21	2047	Dog, cat, and other pet food	1.000	.720
22	2048	Prepared feeds, n.e.c.	.965	.655
23	2051	Bread, cake, and related products	.958	.765
24	2052	Cookies and crackers	.662	.775
25	2061	Raw cane sugar	.945	.803
26	2062	Cane sugar refining	.814	.880
27	2063	Beet sugar	.916	.954
28	2065	Confectionery products	.837	.665
29	2066	Chocolate and cocoa products	.807	.768
30	2067	Chewing gum	.950	.623
31	2074	Cottonseed oil mills	.779	.715
32	2075	Soybean oil mills	1.000	.841
33	2076	Vegetable oil mills, n.e.c.	.484	.793
34	2077	Animal and marine fats and oils	1.000	.749
35	2079	Shortening and cooking oils	.933	.786
36	2082	Malt beverages	1.000	.786
37	2083	Malt	.482	.902
38	2084	Wines, brandy, and brandy spirits	.813	.639
39	2085	Distilled liquor, except brandy	.783	.700
40	2086	Bottled and canned soft drinks	.902	.639
41	2087	Flavoring extracts and syrups, n.e.c.	.993	.595
42	2091	Canned and cured seafoods	.611	.730
43	2092	Fresh or frozen packaged fish	.741	.721
44	2095	Roasted coffee	.846	.734
45	2097	Manufactured ice	.863	.645
46	2098	Macaroni and spaghetti	.757	.855
47	2099	Food preparations, n.e.c.	.897	.610
48	2111	Cigarettes	.356	.848
49	2121	Cigars	.853	.694
50	2131	Chewing and smoking tobacco	1.000	.699
51	2141	Tobacco stemming and redrying	.610	.694
52	2211	Weaving mills, cotton	.937	.911

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
53	2221	Weaving mills, synthetic	.921	.806
54	2231	Weaving and finishing mills, wool	.956	.804
55	2241	Narrow fabric mills	.986	.585
56	2251	Women's hosiery, except socks	1.000	.724
57	2252	Hosiery, n.e.c.	.824	.777
58	2253	Knit outerwear mills	.826	.925
59	2254	Knit underwear mills	.879	.814
60	2257	Circular knit fabric mills	1.000	.836
61	2258	Warp knit fabric mills	.835	.560
62	2259	Knitting mills, n.e.c.	1.000	.703
63	2261	Finishing plants, cotton	1.000	.873
64	2262	Finishing plants, synthetics	1.000	.877
65	2269	Finishing plants, n.e.c.	1.000	.671
66	2271	Woven carpet and rugs	1.000	.744
67	2272	Tufted carpet and rugs	1.000	.744
68	2279	Carpet and rugs, n.e.c.	1.000	.824
69	2281	Yarn mills, except wool	1.000	.859
70	2282	Throwing and winding mills	.966	.823
71	2283	Wool yarn mills	.567	.669
72	2284	Thread mills	.985	.721
73	2291	Felt goods, except woven felts and hats	1.000	.801
74	2292	Lace goods	.906	.852
75	2293	Paddings and upholstery filling	1.000	.857
76	2294	Processed textile waste	.904	.762
77	2295	Coated fabrics, not rubberized	.955	.508
78	2296	Tire cord and fabric	1.000	.900
79	2297	Non woven fabrics	.794	.663
80	2298	Cordage and twine	.833	.638
81	2299	Textile goods, n.e.c.	.966	.838
82	2311	Men's and boys' suits and coats	.930	.823
83	2321	Men's and boys' shirts and nightwear	.852	.872
84	2322	Men's and boys' underwear	1.000	.819
85	2323	Men's and boys' neckwear	1.000	.969
86	2327	Men's and boys' separate trousers	.960	.800
87	2328	Men's and boys' work clothing	.869	.791
88	2329	Men's and boys' clothing, n.e.c.	.975	.814
89	2331	Women's and misses' blouses and waists	.808	.929
90	2335	Women's and misses' dresses	1.000	.463
91	2337	Women's and misses' suits and coats	1.000	.604
92	2339	Women's and misses' outerwear, n.e.c.	.875	.708
93	2341	Women's and children's underwear	.919	.878
94	2342	Brassieres and allied garments	1.000	.690
95	2351	Millinery	.750	.770
96	2352	Hats and caps except millinery	.717	.403
97	2361	Children's dresses and blouses	.956	.606
98	2363	Children's coats and suits	.735	.673
99	2369	Children's outerwear, n.e.c.	.814	.997
100	2371	Fur goods	.850	.710
101	2381	Fabric dress and work gloves	.813	.790
102	2384	Robes and dressing gowns	1.000	.602
103	2385	Waterproof outergarments	.996	.613
104	2386	Leather and sheep lined clothing	.419	.682
105	2387	Apparel belts	.775	.539

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
106	2389	Apparel and accessories, n.e.c.	.983	.768
107	2391	Curtains and draperies	1.000	.648
108	2392	House furnishings, n.e.c.	1.000	.812
109	2393	Textile gabs	.964	.691
110	2394	Canvas and related products	.940	.754
111	2395	Pleating and stitching	.969	.738
112	2396	Automotive and apparel trimmings	.816	.753
113	2397	Schiffli machine embroideries	.600	.708
114	2399	Fabricated textile products, n.e.c.	.957	.546
115	2411	Logging camps and logging contractors	1.000	.707
116	2421	Sawmills and planing mills, general	1.000	.844
117	2426	Hardwood dimension and flooring	1.000	.871
118	2429	Special product sawmills, n.e.c.	.809	.778
119	2431	Millwork	.996	.775
120	2434	Wood kitchen cabinets	.993	.672
121	2435	Hardwood veneer and plywood	1.000	.584
122	2436	Softwood veneer and plywood	1.000	.923
123	2439	Structural wood members, n.e.c.	.911	.525
124	2441	Nailed wood boxes and shook	1.000	.622
125	2448	Wood pallets and skids	1.000	.753
126	2449	Wood containers, n.e.c.	.860	.748
127	2451	Mobile homes	.813	.648
128	2452	Prefabricated wood buildings	.991	.607
129	2491	Wood preserving	1.000	.567
130	2492	Particleboard	.953	.933
131	2499	Wood products, n.e.c.	1.000	.664
132	2511	Wood household furniture	.929	.776
133	2512	Upholstered household furniture	1.000	.861
134	2514	Metal household furniture	1.000	.657
135	2515	Mattresses and bedsprings	1.000	.722
136	2517	Wood TV and radio cabinets	.702	.710
137	2519	Household furniture, n.e.c.	.937	.543
138	2521	Wood office furniture	.904	.748
139	2522	Metal office furniture	.727	.664
140	2531	Public building and related furniture	1.000	.696
141	2541	Wood partitions and fixtures	.769	.584
142	2542	Metal partitions and fixtures	.910	.612
143	2591	Drapery hardware and blinds and shades	1.000	.783
144	2599	Furniture and fixtures, n.e.c.	.686	.655
145	2611	Pulp mills	.701	.946
146	2621	Paper mills, except building paper	.819	.943
147	2631	Paperboard mills	.835	.938
148	2641	Paper coating and glazing	.985	.777
149	2642	Envelopes	1.000	.860
150	2643	Bags, except textile bags	.848	.736
151	2645	Die-cut paper and board	1.000	.799
152	2646	Pressed and molded pulp goods	1.000	.721
153	2647	Sanitary paper products	.722	.861
154	2648	Stationery products	.894	.739
155	2649	Converted paper products, n.e.c.	.812	.560
156	2651	Folding paperboard boxes	1.000	.782
157	2652	Set-up paperboard boxes	.825	.859
158	2653	Corrugated and solid fiber boxes	1.000	.695
159	2654	Sanitary food containers	1.000	.709

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
160	2655	Fiber cans, drums, and similar products	.816	.566
161	2661	Building paper and board mills	.511	.786
162	2711	Newspapers	.800	.860
163	2721	Periodicals	.720	.890
164	2731	Book publishing	.950	.886
165	2732	Book printing	.917	.699
166	2741	Miscellaneous	1.000	.863
167	2751	Commercial printing, letterpress	1.000	.731
168	2752	Commercial printing, lithographic	.936	.777
169	2753	Engraving and plate printing	1.000	.840
170	2754	Commercial printing, gravure	.882	.851
171	2761	Manifold business forms	.998	.782
172	2771	Greeting card publishing	.965	.822
173	2782	Blankbooks and looseleaf binders	.918	.604
174	2789	Bookbinding and related work	.989	.707
175	2791	Typesetting	1.000	.867
176	2793	Photoengraving, electro-, stereo-typing	.870	.847
177	2795	Lithographic platemaking services	.743	.695
178	2812	Alkalies and chlorine	.876	.838
179	2813	Industrial gases	.876	.768
180	2816	Inorganic chemicals	.741	.804
181	2819	Industrial inorganic chemicals, n.e.c	.776	.604
182	2821	Plastics materials and resins	.782	.810
183	2822	Synthetic rubber	.869	.762
184	2823	Cellulosic manmade fibers	.994	.932
185	2824	Organic fibers, noncellulosic	1.000	.871
186	2831	Biological products	.820	.676
187	2833	Medicinals and botanicals	.950	.714
188	2834	Pharmaceutical preparations	.712	.604
189	2841	Soap and other detergents	.712	.631
190	2842	Polishes and sanitation goods	.971	.624
191	2843	Surface active agents	.893	.525
192	2844	Toilet preparations	.675	.656
193	2851	Paints and allied products	.934	.596
194	2861	Gum and wood chemicals	.886	.591
195	2865	Cyclic crudes and intermediates	.645	.753
196	2869	Industrial organic chemicals, n.e.c.	.676	.759
197	2873	Nitrogenous fertilizers	.838	.573
198	2874	Phosphatic fertilizers	.476	.684
199	2875	Fertilizers, mixing only	1.000	.304
200	2879	Agricultural chemicals, n.e.c.	.450	.649
201	2891	Adhesives and sealants	.899	.609
202	2892	Explosives	.826	.366
203	2893	Printing ink	.886	.550
204	2895	Carbon black	.983	.855
205	2899	Chemical preparation, n.e.c.	.950	.446
206	2911	Petroleum refining	.703	.855
207	2951	Paving mixtures and blocks	.804	.628
208	2952	Asphalt felts and coating	.621	.742
209	2992	Lubricating oils and greases	.506	.549
210	2999	Petroleum and coal products, n.e.c.	.717	.559
211	3011	Tires and inner tubes	.947	.813
212	3021	Rubber and plastics footwear	.797	.896

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
213	3031	Reclaimed rubber	.220	.674
214	3041	Rubber and plastics hose and belting	.823	.560
215	3069	Fabricated rubber products, n.e.c.	.967	.670
216	3079	Miscellaneous plastics products	.991	.711
217	3111	Leather tanning and finishing	.793	.690
218	3131	Boot and shoe cut stock and findings	.853	.644
219	3142	House slippers	.529	.699
220	3143	Men's footwear, except athletic	.793	.795
221	3144	Women's footwear, except athletic	.908	.679
222	3149	Footwear, except rubber, n.e.c.	.787	.568
223	3151	Leather gloves and mittens	.618	.761
224	3161	Luggage	.695	.516
225	3171	Women's handbags and purses	.673	.728
226	3172	Personal leather goods	.760	.694
227	3199	Leather goods, n.e.c.	.992	.601
228	3211	Flat glass	1.000	.810
229	3221	Glass containers	.796	.912
230	3229	Pressed and blown glass, n.e.c.	.644	.714
231	3231	Products of purchased glass	.895	.829
232	3241	Cement, hydraulic	.937	.878
233	3251	Brick and structural clay tile	.819	.568
234	3253	Ceramic wall and floor tile	.799	.818
235	3255	Clay refractories	.887	.345
236	3259	Structural clay products, n.e.c.	.966	.734
237	3261	Vitreous plumbing fixtures	.956	.858
238	3262	Vitreous china food utensils	.599	.826
239	3263	Fine earthenware food utensils	.376	.640
240	3264	Porcelain electrical supplies	.730	.675
241	3269	Pottery products, n.e.c.	.616	.628
242	3271	Concrete block and brick	1.000	.749
243	3272	Concrete products, n.e.c.	1.000	.576
244	3273	Ready-mixed concrete	1.000	.591
245	3274	Lime	.864	.765
246	3275	Gypsum products	.992	.929
247	3281	Cut stone and stone products	.970	.837
248	3291	Abrasive products	.965	.682
249	3292	Asbestos products	.614	.595
250	3293	Gaskets, packing and sealing devices	.651	.683
251	3295	Minerals, ground or treated	.773	.753
252	3296	Mineral wool	1.000	.839
253	3297	Nonclay refractories	1.000	.639
254	3299	Nonmetallic mineral products, n.e.c.	.693	.687
255	3312	Blast furnaces and steel mills	.611	.623
256	3313	Electrometallurgical products	.921	.531
257	3315	Steel wire and related products	.747	.741
258	3316	Cold finishing of steel shapes	.870	.655
259	3317	Steel pipe and tubes	.549	.398
260	3321	Gray iron foundries	.532	.651
261	3322	Malleable iron foundries	.635	.602
262	3324	Steel investment foundries	.772	.770
263	3325	Steel foundries, n.e.c.	.354	.605
264	3331	Primary copper	.716	.606
265	3333	Primary zinc	.651	.533

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
266	3334	Primary aluminum	.732	.743
267	3339	Primary nonferrous metals, n.e.c.	.692	.557
268	3341	Secondary nonferrous metals	.567	.471
269	3351	Copper rolling and drawing	.988	.687
270	3353	Aluminum sheet plate, and foil	.770	.781
271	3354	Aluminum extruded products	.793	.711
272	3355	Aluminum rolling and drawing, n.e.c.	.892	.534
273	3356	Nonferrous rolling and drawing, n.e.c.	.866	.534
274	3357	Nonferrous wire drawing and insulating	.988	.663
275	3361	Aluminum foundries	.672	.666
276	3362	Brass, bronze, and copper foundries	.843	.607
277	3369	Nonferrous foundries, n.e.c.	.794	.670
278	3398	Metal heat treating	.942	.753
279	3399	Primary metal products, n.e.c.	1.000	.478
280	3411	Metal cans	.942	.574
281	3412	Metal barrels, drums, and pails	.859	.613
282	3421	Cutlery	.668	.848
283	3423	Hand and edge tools, n.e.c.	.575	.753
284	3425	Handsaws and saw blades	.973	.735
285	3429	Hardware, n.e.c.	.897	.808
286	3431	Metal sanitary ware	.827	.716
287	3432	Plumbing fittings and brass goods	.848	.735
288	3433	Heating equipment except electric	.761	.714
289	3441	Fabricated structural metal	.785	.680
290	3442	Metal doors, sash, and trim	.961	.641
291	3443	Fabricated plate work (boiler shops)	.573	.577
292	3444	Sheet metal work	.691	.653
293	3446	Architectural metal work	.991	.618
294	3448	Prefabricated metal buildings	.635	.504
295	3449	Miscellaneous metal work	.818	.622
296	3451	Screw machine products	.870	.766
297	3452	Bolts, nuts, rivets, and washers	.972	.659
298	3462	Iron and steel forgings	.336	.504
299	3463	Nonferrous forgings	.482	.579
300	3465	Automotive stampings	.842	.796
301	3466	Crowns and closures	1.000	.649
302	3469	Metal stampings, n.e.c.	.731	.654
303	3471	Plating and polishing	.875	.590
304	3479	Metal coating and allied services	.860	.403
305	3482	Small arms ammunition	.881	.519
306	3483	Ammunition, except for small arms, n.e.c.	.875	.507
307	3484	Small arms	.706	.577
308	3489	Ordnance and accessories, n.e.c.	.802	.549
309	3493	Steel springs, except wire	.530	.569
310	3494	Valves and pipe fittings	.631	.544
311	3495	Wire springs	.624	.571
312	3496	Miscellaneous fabricated wire products	.933	.701
313	3497	Metal foil and leaf	.812	.684
314	3498	Fabricated pipe and fittings	.411	.510
315	3499	Fabricated metal products, n.e.c.	.758	.657
316	3511	Turbines and turbine generator sets	.736	.616
317	3519	Internal combustion engines, n.e.c.	.492	.517
318	3523	Farm machinery and equipment	.411	.286

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
319	3524	Lawn and garden equipment	.842	.726
320	3531	Construction machinery	.437	.466
321	3532	Mining machinery	.372	.533
322	3533	Oil field machinery	.255	.279
323	3534	Elevators and moving stairways	.951	.728
324	3535	Conveyors and conveying equipment	.752	.575
325	3536	Hoist, cranes, and monorails	.835	.274
326	3537	Industrial trucks and tractors	.697	.752
327	3541	Machine tools, metal cutting types	.571	.434
328	3542	Machine tools, metal forming types	.618	.638
329	3544	Special dies, tools, jigs and fixtures	.826	.798
330	3545	Machine tool accessories	.636	.642
331	3546	Power driven hand tools	.643	.602
332	3547	Rolling mill machinery	.625	.670
333	3549	Metal working machinery, n.e.c.	.762	.607
334	3551	Food products machinery	.529	.635
335	3552	Textile machinery	.765	.748
336	3553	Woodworking machinery	.821	.694
337	3554	Paper industries machinery	.720	.555
338	3555	Printing trades machinery	.849	.751
339	3559	Special industry machinery, n.e.c.	.594	.431
340	3561	Pumps and pumping equipment	.553	.545
341	3562	Ball and roller bearings	.651	.587
342	3563	Air and gas compressors	.539	.489
343	3564	Blowers and fans	.681	.609
344	3565	Industrial patterns	.898	.819
345	3566	Speed changers, drives, and gears	.463	.619
346	3567	Industrial furnaces and ovens	.719	.634
347	3568	Power transmission equipment, n.e.c.	.574	.526
348	3569	General industrial machinery, n.e.c.	.700	.560
349	3573	Electronic computing equipment	1.000	.618
350	3574	Calculating and accounting machines	.914	.641
351	3576	Scales and balances, except laboratory	.678	.779
352	3579	Office machines, nec, and typewriters	.820	.846
353	3581	Automatic merchandising machines	.858	.611
354	3582	Commercial laundry equipment	.757	.715
355	3585	Refrigeration and heating equipment	.784	.711
356	3586	Measuring and dispensing pumps	.745	.517
357	3589	Service industry machinery, n.e.c.	.775	.534
358	3592	Carburetors, pistons, rings, valves	.485	.701
359	3599	Machinery, except electrical n.e.c.	.746	.642
360	3612	Transformers	.710	.692
361	3613	Switchgear and switchboard apparatus	.566	.674
362	3621	Motors and generators	.559	.541
363	3622	Industrial controls	.669	.571
364	3623	Welding apparatus, electric	.599	.513
365	3624	Carbon and graphite products	.515	.503
366	3629	Electrical industrial apparatus, n.e.c.	.587	.649
367	3631	Household cooking appliances	.906	.593
368	3632	Household refrigerators and freezers	.700	.672
369	3633	Household laundry equipment	1.000	.884
370	3634	Electric housewares and fans	.983	.577
371	3635	Household vacuum cleaners	.942	.631

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
372	3636	Sewing machines	.664	.688
373	3639	Household appliances, n.e.c.	.866	.874
374	3641	Electric lamps	.753	.701
375	3643	Current-carrying wiring devices	.729	.549
376	3644	Noncurrent-carrying wiring devices	.660	.720
377	3645	Residential lighting fixtures	.804	.520
378	3646	Commercial lighting fixtures	1.000	.715
379	3647	Vehicular lighting equipment	.702	.815
380	3648	Lighting equipment, n.e.c.	.887	.610
381	3651	Radio and TV receiving sets	.973	.648
382	3652	Phonograph records	.944	.708
383	3661	Telephone and telegraph apparatus	.826	.649
384	3662	Radio and TV communication equipment	.696	.738
385	3671	Electron tubes, all types	.737	.806
386	3674	Semiconductors and related devices	.726	.632
387	3675	Electronic capacitors	.489	.621
388	3676	Electronic resistors	.702	.687
389	3677	Electronic coils and transformers	.693	.680
390	3678	Electronic connectors	.636	.534
391	3679	Electronic components, n.e.c.	.672	.596
392	3691	Storage batteries	.753	.830
393	3692	Primary batteries, dry and wet	.914	.634
394	3693	X-ray apparatus and tubes	.534	.582
395	3694	Engine electrical equipment	.793	.760
396	3699	Electrical equipment and supplies, n.e.c.	1.000	.678
397	3711	Motor vehicles and car bodies	.601	.775
398	3713	Truck and bus bodies	.739	.763
399	3714	Motor vehicle parts and accessories	.570	.754
400	3715	Truck trailers	.681	.555
401	3721	Aircraft	.646	.622
402	3724	Aircraft engines and engine parts	.695	.714
403	3728	Aircraft equipment, n.e.c.	.899	.738
404	3731	Ship building and repairing	.696	.517
405	3732	Boat building and repairing	.711	.711
406	3743	Railroad equipment	.337	.398
407	3751	Motorcycles, bicycles, and parts	.616	.502
408	3761	Guided missiles and space vehicles	.620	.608
409	3764	Space propulsion units and parts	.573	.694
410	3769	Space vehicle equipment, n.e.c.	.638	.696
411	3792	Travel trailers and campers	.814	.399
412	3795	Tanks and tank components	.573	.703
413	3799	Transportation equipment, n.e.c.	.723	.478
414	3811	Engineering and scientific instruments	.747	.647
415	3822	Environmental controls	.701	.727
416	3823	Process control instruments	.545	.492
417	3824	Fluid meters and counting devices	.674	.899
418	3825	Instruments to measure electricity	.528	.741
419	3829	Measuring and controlling devices, n.e.c.	.940	.433
420	3832	Optical instruments and lenses	.882	.587
421	3841	Surgical and medical instruments	.689	.688
422	3842	Surgical appliances and supplies	.702	.758
423	3843	Dental equipment and supplies	.754	.766
424	3851	Ophthalmic goods	.775	.722

TABLE 8.1. (contd)

No.	SIC	Title	FGK	SPC
425	3861	Photographic equipment and supplies	.754	.713
426	3873	Watches, clocks, and watchcases	.862	.637
427	3911	Jewelry, precious metal	.933	.491
428	3914	Silverware and plated ware	.791	.540
429	3915	Jewelers' materials and lapidary work	.934	.737
430	3931	Musical instruments	.546	.408
431	3942	Dolls	.436	.532
432	3944	Games, toys, and childrens vehicles	.948	.710
433	3949	Sporting and athletic goods, n.e.c.	1.000	.504
434	3951	Pens and mechanical pencils	.870	.772
435	3952	Lead pencils and art goods	.831	.782
436	3953	Marking devices	.899	.767
437	3955	Carbon paper and inked ribbons	.892	.675
438	3961	Costume jewelry	.792	.707
439	3962	Artificial flowers	.685	.832
440	3963	Buttons	.961	.586
441	3964	Needles, pins, and fasteners	.574	.498
442	3991	Brooms and brushes	.956	.629
443	3993	Signs and advertising displays	.961	.688
444	3995	Burial caskets	.775	.635
445	3996	Hard surface floor coverings	.961	.790
446	3999	Manufacturing industries, n.e.c.	.906	.593

TABLE 8.2. Simple and Rank Order Correlation Coefficients for Alternative Measures of Capacity Utilization

Simple correlations:

FGK2: Survey1	0.2386
Labor ratio final: Survey1	0.4309
FGK2*Survey2: Survey1	0.6416
FGK2*Survey2*Labor ratio basis: Survey1	0.6141

Rank order correlations:

FGK2: Survey1	0.2382
Labor ratio final: Survey1	0.3584
FGK2*Survey2: Survey1	0.5136
FGK2*Survey2*Labor ratio basis: Survey1	0.4637

Notes: Survey1 is capacity utilization for 1986 from the Census survey
Survey2 is capacity utilization for the basis year from the Census survey
FGK2 is capacity utilization based on 1986 actual output as the measure of current use

TABLE 8.3. Actual and Projected Output, 1970-1979

Year	Transportation Actual	Transportation Model	Motor Vehicles Actual	Motor Vehicles Model	Machinery Actual	Machinery Model	Fabricated Metals Actual	Fabricated Metals Model
1970	37.702	39.231	48.271	60.703	56.315	68.233	41.58	43.86
1971	35.18	52.784	61.696	73.352	53.559	72.389	40.524	45.135
1972	35.474	46.742	65.906	74.445	61.979	69.779	43.824	46.524
1973	39.88	69.197	76.391	77.076	72.52	72.520	48.157	48.157
1974	38.716	53.753	64.142	68.779	77.501	94.457	46.133	48.829
1975	37.166	56.85	57.56	74.558	66.567	99.338	39.706	54.273
1976	35.553	53.414	74.728	82.489	70.567	94.686	43.496	56.164
1977	36.491	52.772	85.176	91.238	77.55	91.981	46.742	58.59
1978	41.509	53.274	89.828	93.582	83.431	96.394	50.2	60.337
1979	47.958	50.975	84.594	104.80	88.204	109.54	52.167	60.876

Year	Chemicals Actual	Chemicals Model	Primary Metals Actual	Primary Metals Model	Rubber Actual	Rubber Model
1970	48.743	61.937	56.935	73.596	14.243	15.474
1971	50.229	62.791	53.266	72.490	14.94	17.5
1972	54.861	62.382	62.191	78.164	17.47	18.05
1973	60.141	65.067	75.134	77.954	18.884	19.25
1974	62.835	82.038	77.982	84.918	18.191	20.243
1975	55.557	76.981	57.914	77.448	15.534	22.6
1976	62.077	74.732	58.305	73.059	16.497	22.552
1977	66.572	86.628	63.267	76.219	19.223	23.352
1978	70.625	105.3	70.764	82.369	20.877	24.104
1979	73.151	128.07	72.108	84.922	22.118	28.068

Source: Actual - Jorgenson, et al. (1988)
Model - PNL projections using cost frontier model

TABLE 8.4. Capacity Utilization Estimates Applying the FGK Method to the Output from the Cost Frontier Analysis for 1979

Industry	(1)	(2)	(3)	(4)	(5)
Transportation	47.96	50.98	74.67	0.683	0.642
Motor Vehicles	84.59	104.8	118.2	0.769	0.769
Machinery	88.20	109.5	118.2	0.927	0.927
Fabricated Metals	52.17	60.88	63.92	0.952	0.816
Chemicals	73.15	128.1	128.1	1.000	0.571
Primary Metals	72.12	84.92	87.91	0.966	0.966
Rubber	22.18	28.07	28.07	1.000	0.788

Columns: (1) Index of Actual Output, 1979
(2) Index of Equilibrium Adjusted Output (all inputs constrained)
(3) Maximum Output (capital only constrained)
(4) FGK Capacity Utilization Rate (col. (2)/col. (3))
(5) Modified FGK Capacity Utilization Rate (col. (1)/col. (3))

8.3 REFERENCES

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APPENDIX A

INDUSTRY CONCORDANCES

APPENDIX A

INDUSTRY CONCORDANCES

TABLE A.1. Four-Digit SIC Industry and FRB Concordance

No.	SIC	EOC Industry	SIC	FRB Industry
1	2011	Meatpacking plants	NA	Beef
2	2013	Sausages and other prepared meats	NA	Pork
3	2016	Poultry dressing plants	NA	Poultry
4	2017	Poultry and egg processing	NA	Poultry
5	2021	Creamery butter	2021	Butter
6	2022	Cheese, natural and processed	2022	Cheese
7	2023	Condensed and evaporated milk	2023	Concentrated Milk
8	2024	Ice cream and frozen desserts	2024	Frozen Deserts
9	2026	Fluid milk	202	Dairy Prod
10	2032	Canned specialties	203	Canned and Frozen Food
11	2033	Canned fruits and vegetables	203	Canned and Frozen Food
12	2034	Dehydrated fruits, vegetables, soups	203	Canned and Frozen Food
13	2035	Pickles, sauces, and salad dressing	203	Canned and Frozen Food
14	2037	Frozen fruits and vegetables	203	Canned and Frozen Food
15	2038	Frozen specialties	203	Canned and Frozen Food
16	2041	Flour, other grain mill products	2041	Flour
17	2043	Cereal breakfast foods	204	Grain Mill Products
18	2044	Rice milling	204	Grain Mill Products
19	2045	Blended and prepared flour	2041	Flour
20	2046	Wet corn milling	204	Grain Mill Products
21	2047	Dog, cat, and other pet food	204	Grain Mill Products
22	2048	Prepared feeds, n.e.c.	204	Grain Mill Products
23	2051	Bread, cake, and related products	205	Bakery Products
24	2052	Cookies and crackers	205	Bakery Products
25	2061	Raw cane sugar	20	Food
26	2062	Cane sugar refining	20	Food
27	2063	Beet sugar	20	Food
28	2065	Confectionery products	20	Food
29	2066	Chocolate and cocoa products	20	Food
30	2067	Chewing gum	20	Food
31	2074	Cottonseed oil mills	207	Fats and Oils
32	2075	Soybean oil mills	207	Fats and Oils
33	2076	Vegetable oil mills, n.e.c.	207	Fats and Oils
34	2077	Animal and marine fats and oils	207	Fats and Oils
35	2079	Shortening and cooking oils	207	Fats and Oils
36	2082	Malt beverages	2082,3	Beer and Ale
37	2083	Malt	2082,3	Beer and Ale
38	2084	Wines, brandy, and brandy spirits	2084	Wine and Brandy
39	2085	Distilled liquor, except brandy	2085	Liquors
40	2086	Bottled and canned soft drinks	2086,7	Soft Drinks
41	2087	Flavoring extracts and sirups, n.e.c.	2086,7	Soft Drinks
42	2091	Canned and cured seafoods	209	Coffee & Misc. Foods
43	2092	Fresh or frozen packaged fish	209	Coffee & Misc. Foods

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FRB Industry
44	2095	Roasted coffee	209	Coffee & Misc. Foods
45	2097	Manufactured ice	209	Coffee & Misc. Foods
46	2098	Macaroni and spaghetti	209	Coffee & Misc. Foods
47	2099	Food preparations, n.e.c.	209	Coffee & Misc. Foods
48	2111	Cigarettes	211	Cigarettes
49	2121	Cigars	212	Cigars
50	2131	Chewing and smoking tobacco	21	Tobacco Products
51	2141	Tobacco stemming and redrying	21	Tobacco Products
52	2211	Weaving mills, cotton	221	Cotton Fabrics
53	2221	Weaving mills, synthetic	222	Synthetic Fabrics
54	2231	Weaving and finishing mills, wool	221-4	Fabrics
55	2241	Narrow fabric mills	221-4	Fabrics
56	2251	Women's hosiery, except socks	2251,2	Hosiery
57	2252	Hosiery, n.e.c.	2251,2	Hosiery
58	2253	Knit outerwear mills	2253,4,7-9	Knit Garments
59	2254	Knit underwear mills	2253,4,7-9	Knit Garments
60	2257	Circular knit fabric mills	2253,4,7-9	Knit Garments
61	2258	Warp knit fabric mills	2253,4,7-9	Knit Garments
62	2259	Knitting mills, n.e.c.	2253,4,7-9	Knit Garments
63	2261	Finishing plants, cotton	221	Cotton Fabrics
64	2262	Finishing plants, synthetics	222	Synthetic Fabrics
65	2269	Finishing plants, n.e.c.	222	Synthetic Fabrics
66	2271	Woven carpet and rugs	227	Carpeting
67	2272	Tufted carpet and rugs	227	Carpeting
68	2279	Carpet and rugs, n.e.c.	227	Carpeting
69	2281	Yarn mills, except wool	228,9	Yarns and Misc. Textiles
70	2282	Throwing and winding mills	228,9	Yarns and Misc. Textiles
71	2283	Wool yarn mills	228,9	Yarns and Misc. Textiles
72	2284	Thread mills	228,9	Yarns and Misc. Textiles
73	2291	Felt goods, except woven felts and hats	228,9	Yarns and Misc. Textiles
74	2292	Lace goods	228,9	Yarns and Misc. Textiles
75	2293	Paddings and upholstery filling	228,9	Yarns and Misc. Textiles
76	2294	Processed textile waste	228,9	Yarns and Misc. Textiles
77	2295	Coated fabrics, not rubberized	228,9	Yarns and Misc. Textiles
78	2296	Tire cord and fabric	228,9	Yarns and Misc. Textiles
79	2297	Non woven fabrics	228,9	Yarns and Misc. Textiles
80	2298	Cordage and twine	228,9	Yarns and Misc. Textiles
81	2299	Textile goods, n.e.c.	228,9	Yarns and Misc. Textiles
82	2311	Men's and boys' suits and coats	228,9	Yarns and Misc. Textiles
83	2321	Men's and boys' shirts and nightwear	23	Apparel Products
84	2322	Men's and boys' underwear	23	Apparel Products
85	2323	Men's and boys' neckwear	23	Apparel Products
86	2327	Men's and boys' separate trousers	23	Apparel Products
87	2328	Men's and boys' work clothing	23	Apparel Products
88	2329	Men's and boys' clothing, n.e.c.	23	Apparel Products
89	2331	Women's and misses' blouses and waists	23	Apparel Products
90	2335	Women's and misses' dresses	23	Apparel Products
91	2337	Women's and misses' suits and coats	23	Apparel Products
92	2339	Women's and misses' outerwear, n.e.c.	23	Apparel Products
93	2341	Women's and children's underwear	23	Apparel Products
94	2342	Brassieres and allied garments	23	Apparel Products
95	2351	Millinery	23	Apparel Products

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FRB Industry
96	2352	Hats and caps except millinery	23	Apparel Products
97	2361	Children's dresses and blouses	23	Apparel Products
98	2363	Children's coats and suits	23	Apparel Products
99	2369	Children's outerwear, n.e.c.	23	Apparel Products
100	2371	Fur goods	23	Apparel Products
101	2381	Fabric dress and work gloves	23	Apparel Products
102	2384	Robes and dressing gowns	23	Apparel Products
103	2385	Waterproof outergarments	23	Apparel Products
104	2386	Leather and sheep lined clothing	23	Apparel Products
105	2387	Apparel belts	23	Apparel Products
106	2389	Apparel and accessories, n.e.c.	23	Apparel Products
107	2391	Curtains and draperies	23	Apparel Products
108	2392	House furnishings, n.e.c.	23	Apparel Products
109	2393	Textile gabs	23	Apparel Products
110	2394	Canvas and related products	23	Apparel Products
111	2395	Pleating and stitching	23	Apparel Products
112	2396	Automotive and apparel trimmings	23	Apparel Products
113	2397	Schiffli machine embroideries	23	Apparel Products
114	2399	Fabricated textile products, n.e.c.	23	Apparel Products
115	2411	Logging camps and logging contractors	241,2	Logging and Lumber
116	2421	Sawmills and planing mills, general	241,2	Logging and Lumber
117	2426	Hardwood dimension and flooring	241,2	Lumber Products
118	2429	Special product sawmills, n.e.c.	241,2	Lumber Products
119	2431	Millwork	243	Millwork and Plywood
120	2434	Wood kitchen cabinets	243	Millwork
121	2435	Hardwood veneer and plywood	243	Millwork
122	2436	Softwood veneer and plywood	243	Millwork
123	2439	Structural wood members, n.e.c.	243	Millwork
124	2441	Nailed wood boxes and shook	241	Lumber Products
125	2448	Wood pallets and skids	241	Lumber Products
126	2449	Wood containers, n.e.c.	241	Lumber Products
127	2451	Mobile homes	245	Manufactured Homes
128	2452	Prefabricated wood buildings	245	Manufactured Homes
129	2491	Wood preserving	243	Lumber Products
130	2492	Particleboard	243	Lumber Products
131	2499	Wood products, n.e.c.	243	Lumber Products
132	2511	Wood household furniture	251	Household Furniture
133	2512	Upholstered household furniture	251	Household Furniture
134	2514	Metal household furniture	251	Household Furniture
135	2515	Mattresses and bedsprings	251	Household Furniture
136	2517	Wood TV and radio cabinets	251	Household Furniture
137	2519	Household furniture, n.e.c.	251	Household Furniture
138	2521	Wood office furniture	252,4,9	Fixt., Office Furn.
139	2522	Metal office furniture	252,4,9	Fixt., Office Furn.
140	2531	Public building and related furniture	252,4,9	Fixt., Office Furn.
141	2541	Wood partitions and fixtures	252,4,9	Furniture and Fixtures
142	2542	Metal partitions and fixtures	252,4,9	Furniture and Fixtures
143	2591	Drapery hardware and blinds and shades	252,4,9	Fixt., Office Furn.
144	2599	Furniture and fixtures, n.e.c.	252,4,9	Fixt., Office Furn.
145	2611	Pulp mills	261	Wood Pulp
146	2621	Paper mills, except building paper	261	Paper
147	2631	Paperboard mills	263	Paperboard

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FR8 Industry
148	2641	Paper coating and glazing	264	Converted Paper Products
149	2642	Envelopes	264	Converted Paper Products
150	2643	Bags, except textile bags	264	Converted Paper Products
151	2645	Die-cut paper and board	264	Converted Paper Products
152	2646	Pressed and molded pulp goods	264	Converted Paper Products
153	2647	Sanitary paper products	264	Converted Paper Products
154	2648	Stationery products	264	Converted Paper Products
155	2649	Converted paper products, n.e.c.	264	Converted Paper Products
156	2651	Folding paperboard boxes	265	Paperboard Containers
157	2652	Set-up paperboard boxes	265	Paperboard Containers
158	2653	Corrugated and solid fiber boxes	265	Paperboard Containers
159	2654	Sanitary food containers	265	Paperboard Containers
160	2655	Fiber cans, drums, and similar products	265	Paperboard Containers
161	2661	Building paper and board mills	263	Paperboard
162	2711	Newspapers	271	Newspapers
163	2721	Periodicals	272,3,7	Periodicals, Books, Cards
164	2731	Book publishing	272,3,7	Periodicals, Books, Cards
165	2732	Book printing	272,3,7	Periodicals, Books, Cards
166	2741	Miscellaneous	274-6,8,9	Job Printing
167	2751	Commercial printing, letterpress	274-6,8,9	Job Printing
168	2752	Commercial printing, lithographic	274-6,8,9	Job Printing
169	2753	Engraving and plate printing	274-6,8,9	Job Printing
170	2754	Commercial printing, gravure	274-6,8,9	Job Printing
171	2761	Manifold business forms	274-6,8,9	Job Printing
172	2771	Greeting card publishing	274-6,8,9	Job Printing
173	2782	Blankbooks and looseleaf binders	274-6,8,9	Job Printing
174	2789	Bookbinding and related work	274-6,8,9	Job Printing
175	2791	Typesetting	274-6,8,9	Job Printing
176	2793	Photoengraving, electro-, stereo-typing	274-6,8,9	Job Printing
177	2795	Lithographic platemaking services	274-6,8,9	Job Printing
178	2812	Alkalies and chlorine	2812	Alkalies and Chlorine
179	2813	Industrial gases	2813	Industrial Gases
180	2816	Inorganic chemicals	2816	Inorganic Pigments
181	2819	Industrial inorganic chemicals, n.e.c	2819	Inorganic Chem, nec
182	2821	Plastics materials and resins	2821	Plastics Materials
183	2822	Synthetic rubber	2822	Synthetic Rubber
184	2823	Cellulosic manmade fibers	2823,4	Synthetic Fibers
185	2824	Organic fibers, noncellulosic	2823,4	Synthetic Fibers
186	2831	Biological products	283	Chemical Products
187	2833	Medicinals and botanicals	283	Drugs and Medicine
188	2834	Pharmaceutical preparations	283	Drugs and Medicine
189	2841	Soap and other detergents	284	Soap and Toiletries
190	2842	Polishes and sanitation goods	284	Soap and Toiletries
191	2843	Surface active agents	284	Soap and Toiletries
192	2844	Toilet preparations	284	Soap and Toiletries
193	2851	Paints and allied products	285	Paints
194	2861	Gum and wood chemicals	286	Indust. Organic Chem.
195	2865	Cyclic crudes and intermediates	286	Indust. Organic Chem.
196	2869	Industrial organic chemicals, n.e.c.	286	Indust. Organic Chem.
197	2873	Nitrogenous fertilizers	287	Agricultural Chemicals
198	2874	Phosphatic fertilizers	287	Agricultural Chemicals
199	2875	Fertilizers, mixing only	287	Agricultural Chemicals

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FRB Industry
200	2879	Agricultural chemicals, n.e.c.	287	Agricultural Chemicals
201	2891	Adhesives and sealants	283-5,9	Chemical Products
202	2892	Explosives	283-5,9	Chemical Products
203	2893	Printing ink	283-5,9	Chemical Products
204	2895	Carbon black	283-5,9	Chemical Products
205	2899	Chemical preparation, n.e.c.	283-5,9	Chemical Products
206	2911	Petroleum refining	291,9	Petroleum Refining
207	2951	Paving mixtures and blocks	NA	Refinery Nonfuel Mat.
208	2952	Asphalt felts and coating	NA	Refinery Nonfuel Mat.
209	2992	Lubricating oils and greases	NA	Refinery Nonfuel Mat.
210	2999	Petroleum and coal products, n.e.c.	NA	Refinery Products, nec
211	3011	Tires and inner tubes	301	Tires
212	3021	Rubber and plastics footwear	302-4,6	Rub. Prod. Ex. Tires
213	3031	Reclaimed rubber	302-4,6	Rub. Prod. Ex. Tires
214	3041	Rubber and plastics hose and belting	302-4,6	Plastics products, nec
215	3069	Fabricated rubber products, n.e.c.	302-4,6	Rub. Prod. Ex. Tires
216	3079	Miscellaneous plastics products	307	Plastics products, nec
217	3111	Leather tanning and finishing	31	Leather and Products
218	3131	Boot and shoe cut stock and findings	314	Shoes
219	3142	House slippers	314	Shoes
220	3143	Men's footwear, except athletic	314	Shoes
221	3144	Women's footwear, except athletic	314	Shoes
222	3149	Footwear, except rubber, n.e.c.	314	Shoes
223	3151	Leather gloves and mittens	313,5-7,9	Pers. Leather Gds
224	3161	Luggage	313,5-7,9	Pers. Leather Gds
225	3171	Women's handbags and purses	313,5-7,9	Pers. Leather Gds
226	3172	Personal leather goods	313,5-7,9	Pers. Leather Gds
227	3199	Leather goods, n.e.c.	313,5-7,9	Pers. Leather Gds
228	3211	Flat glass	322	Pressed and Blown Glass
229	3221	Glass containers	3221	Glass Containers
230	3229	Pressed and blown glass, n.e.c.	322	Pressed and Blown Glass
231	3231	Products of purchased glass	322	Pressed and Blown Glass
232	3241	Cement, hydraulic	324	Cement
233	3251	Brick and structural clay tile	3251	Brick
234	3253	Ceramic wall and floor tile	3253,5	Clay Tile
235	3255	Clay refractories	3253,5	Clay Tile
236	3259	Structural clay products, n.e.c.	3259	Clay Sewer Pipe
237	3261	Vitreous plumbing fixtures	326-9	Concrete and Misc.
238	3262	Vitreous china food utensils	326-9	Concrete and Misc.
239	3263	Fine earthenware food utensils	326-9	Concrete and Misc.
240	3264	Porcelain electrical suppplies	326-9	Concrete and Misc.
241	3269	Pottery products, n.e.c.	326-9	Concrete and Misc.
242	3271	Concrete block and brick	326-9	Concrete and Misc.
243	3272	Concrete products, n.e.c.	326-9	Concrete and Misc.
244	3273	Ready-mixed concrete	326-9	Concrete and Misc.
245	3274	Lime	326-9	Concrete and Misc.
246	3275	Gypsum products	326-9	Concrete and Misc.
247	3281	Cut stone and stone products	326-9	Concrete and Misc.
248	3291	Abrasive products	326-9	Concrete and Misc.
249	3292	Asbestos products	326-9	Concrete and Misc.
250	3293	Gaskets, packing and sealing devices	326-9	Concrete and Misc.
251	3295	Minerals, ground or treated	326-9	Concrete and Misc.
252	3296	Mineral wool	326-9	Concrete and Misc.

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FRB Industry
253	3297	Nonclay refractories	326-9	Concrete and Misc.
254	3299	Nonmetallic mineral products, n.e.c.	326-9	Concrete and Misc.
255	3312	Blast furnaces and steel mills	331	Basic Steel and Mill Prod.
256	3313	Electrometallurgical products	331	Basic Steel and Mill Prod.
257	3315	Steel wire and related products	331	Basic Steel and Mill Prod.
258	3316	Cold finishing of steel shapes	331	Basic Steel and Mill Prod.
259	3317	Steel pipe and tubes	NA	Construction Steel
260	3321	Gray iron foundries	332	Iron and Steel Foundries
261	3322	Malleable iron foundries	332	Iron and Steel Foundries
262	3324	Steel investment foundries	332	Iron and Steel Foundries
263	3325	Steel foundries, n.e.c.	332	Iron and Steel Foundries
264	3331	Primary copper	3331	Copper
265	3333	Primary zinc	333	Primary Nonf. Metals
266	3334	Primary aluminum	3334	Aluminum
267	3339	Primary nonferrous metals, n.e.c.	333	Primary Nonf. Metals
268	3341	Secondary nonferrous metals	334	Secondary Nonf. Metals
269	3351	Coppper rolling and drawing	3351	Copper Mill Prod.
270	3353	Aluminum sheet plate, and foil	3353-5	Aluminum Mill Prod
271	3354	Aluminum extruded products	3353-5	Aluminum Mill Prod
272	3355	Aluminum rolling and drawing, n.e.c.	3353-5	Aluminum Mill Prod
273	3356	Nonferrous rolling and drawing, n.e.c.	335,6	Nonferrous Products
274	3357	Nonferrous wire drawing and insulating	335,6	Nonferrous Products
275	3361	Aluminum foundries	336	Nonferrous Foundries
276	3362	Brass, bronze, and copper foundries	336	Nonferrous Foundries
277	3369	Nonferrous foundries, n.e.c.	336	Nonferrous Foundries
278	3398	Metal heat treating	333-6,9	Nonferrous Metals
279	3399	Primary metal products, n.e.c	333-6,9	Nonferrous Metals
280	3411	Metal cans	341	Metal Containers
281	3412	Metal barrels, drums, and pails	341	Metal Containers
282	3421	Cutlery	342	Hardware, Tools, Cutlery
283	3423	Hand and edge tools, n.e.c.	342	Hardware, Tools, Cutlery
284	3425	Handsaws and saw blades	342	Hardware, Tools, Cutlery
285	3429	Hardware, n.e.c.	342	Hardware, Tools, Cutlery
286	3431	Metal sanitary ware	344	Structural Metal Prod.
287	3432	Plumbing fittings and brass goods	344	Structural Metal Prod.
288	3433	Heating equipment except electric	344	Structural Metal Prod.
289	3441	Fabricated structural metal	344	Structural Metal Prod.
290	3442	Metal doors, sash, and trim	344	Structural Metal Prod.
291	3443	Fabricated plate work (boiler shops)	344	Structural Metal Prod.
292	3444	Sheet metal work	344	Structural Metal Prod.
293	3446	Architectural metal work	344	Structural Metal Prod.
294	3448	Prefabricated metal buildings	344	Structural Metal Prod.
295	3449	Miscellaneous metal work	344	Structural Metal Prod.
296	3451	Screw machine products	345-7	Fasteners, Stampings, Etc.
297	3452	Bolts, nuts, rivets, and washers	345-7	Fasteners, Stampings, Etc.
298	3462	Iron and steel forgings	345-7	Fasteners, Stampings, Etc.
299	3463	Nonferrous forgings	345-7	Fasteners, Stampings, Etc.
300	3465	Automotive stampings	345-7	Fasteners, Stampings, Etc.
301	3466	Crowns and closures	345-7	Fasteners, Stampings, Etc.
302	3469	Metal stampings, n.e.c.	345-7	Fasteners, Stampings, Etc.
303	3471	Plating and polishing	345-7	Fasteners, Stampings, Etc.
304	3479	Metal coating and allied services	345-7	Fasteners, Stampings, Etc.

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FRB Industry
305	3482	Small arms ammunition	34	Fabricated Metal Products
306	3483	Ammunition, except for small arms, n.e.c.	34	Fabricated Metal Products
307	3484	Small arms	34	Fabricated Metal Products
308	3489	Ordnance and accessories, n.e.c.	34	Fabricated Metal Products
309	3493	Steel springs, except wire	34	Fabricated Metal Products
310	3494	Valves and pipe fittings	34	Fabricated Metal Products
311	3395	Wire springs	34	Fabricated Metal Products
312	3496	Miscellaneous fabricated wire products	34	Fabricated Metal Products
313	3497	Metal foil and leaf	34	Fabricated Metal Products
314	3498	Fabricated pipe and fittings	34	Fabricated Metal Products
315	3499	Fabricated metal products, n.e.c.	34	Fabricated Metal Products
316	3511	Turbines and turbine generator sets	351,2	Engine and Farm Equip
317	3519	Internal combustion engines, n.e.c.	351,2	Engine and Farm Equip
318	3523	Farm machinery and equipment	351,2	Engine and Farm Equip
319	3524	Lawn and garden equipment	351,2	Engine and Farm Equip
320	3531	Construction machinery	353	Construct. and Allied Eq.
321	3532	Mining machinery	353	Construct. and Allied Eq.
322	3533	Oil field machinery	353	Construct. and Allied Eq.
323	3534	Elevators and moving stairways	353	Construct. and Allied Eq.
324	3535	Conveyors and conveying equipment	353	Construct. and Allied Eq.
325	3536	Hoist, cranes, and monorails	353	Construct. and Allied Eq.
326	3537	Industrial trucks and tractors	353	Construct. and Allied Eq.
327	3541	Machine tools, metal cutting types	354	Metalworking Machinery
328	3542	Machine tools, metal forming types	354	Metalworking Machinery
329	3544	Special dies, tools, jigs and fixtures	355	Spec. and Genl. Ind. Eq
330	3545	Machine tool accessories	354	Metalworking Machinery
331	3546	Power driven hand tools	354	Metalworking Machinery
332	3547	Rolling mill machinery	355	Metalworking
333	3549	Metal working machinery, n.e.c.	354	Metalworking Machinery
334	3551	Food products machinery	355,6	Spec. and Genl. Ind. Eq
335	3552	Textile machinery	355,6	Spec. and Genl. Ind. Eq
336	3553	Woodworking machinery	355,6	Spec. and Genl. Ind. Eq
337	3554	Paper industries machinery	355,6	Spec. and Genl. Ind. Eq
338	3555	Printing trades machinery	355,6	Spec. and Genl. Ind. Eq
339	3559	Special industry machinery, n.e.c.	355,6	Spec. and Genl. Ind. Eq
340	3561	Pumps and pumping equipment	355,6	Spec. and Genl. Ind. Eq
341	3562	Ball and roller bearings	355,6	Spec. and Genl. Ind. Eq
342	3563	Air and gas compressors	355,6	Spec. and Genl. Ind. Eq
343	3564	Blowers and fans	355,6	Spec. and Genl. Ind. Eq
344	3565	Industrial patterns	355,6	Spec. and Genl. Ind. Eq
345	3566	Speed changers, drives, and gears	355,6	Spec. and Genl. Ind. Eq
346	3567	Industrial furnaces and ovens	355,6	Spec. and Genl. Ind. Eq
347	3568	Power transmission equipment, n.e.c.	355,6	Spec. and Genl. Ind. Eq
348	3569	General industrial machinery, n.e.c.	355,6	Spec. and Genl. Ind. Eq
349	3573	Electronic computing equipment	357-7	Office, Serv, and Misc.
350	3574	Calculating and accounting machines	357-7	Office, Serv, and Misc.
351	3576	Scales and balances, except laboratory	357-7	Office, Serv, and Misc.
352	3579	Office machines, nec, and typewriters	357-9	Office, Serv, and Misc.
353	3581	Automatic merchandising machines	357-9	Office, Serv, and Misc.
354	3582	Commercial laundry equipment	357-9	Office, Serv, and Misc.
355	3585	Refrigeration and heating equipment	357-9	Office, Serv, and Misc.
356	3586	Measuring and dispensing pumps	357-9	Office, Serv, and Misc.
357	3589	Service industry machinery, n.e.c.	357-9	Office, Serv, and Misc.

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FRB Industry
358	3592	Carburetors, pistons, rings, valves	357-9	Office, Serv, and Misc.
359	3599	Machinery, except electrical n.e.c.	357-9	Office, Serv, and Misc.
360	3612	Transformers	361,2	Major Elect. Eq. and Pts
361	3613	Switchgear and switchboard apparatus	361,2	Major Elect. Eq. and Pts
362	3621	Motors and generators	361,2	Major Elect. Eq. and Pts
363	3622	Industrial controls	361,2	Major Elect. Eq. and Pts
364	3623	Welding apparatus, electric	361,2	Major Elect. Eq. and Pts
365	3624	Carbon and graphite products	361,2	Major Elect. Eq. and Pts
366	3629	Electrical industrial apparatus, n.e.c.	361,2	Major Elect. Eq. and Pts
367	3631	Household cooking appliances	3631	Cooking Equipment
368	3632	Household refrigerators and freezers	3632	Refrigeration Appl.
369	3633	Household laundry equipment	3633	Laundry Appliances
370	3634	Electric housewares and fans	3634-6,9	Misc. Appliances
371	3635	Household vacuum cleaners	3634-6,9	Misc. Appliances
372	3636	Sewing machines	3634-6,9	Misc. Appliances
373	3639	Household appliances, n.e.c.	3634-6,9	Misc. Appliances
374	3641	Electric lamps	364-6,9	Misc. Appliances
375	3643	Current-carrying wiring devices	364-6,9	Misc. Appliances
376	3644	Noncurrent-carrying wiring devices	364-6,9	Misc. Appliances
377	3645	Residential lighting fixtures	364-6,9	Misc. Appliances
378	3646	Commercial lighting fixtures	364-6,9	Misc. Appliances
379	3647	Vehicular lighting equipment	364-6,9	Misc. Appliances
380	3648	Lighting equipment, n.e.c.	364-6,9	Misc. Appliances
381	3651	Radio and TV receiving sets	365	TV and Radio Sets
382	3652	Phonograph records	365	TV and Radio Sets
383	3661	Telephone and telegraph apparatus	366	Communication Equipment
384	3662	Radio and TV communication equipment	366	Communication Equipment
385	3671	Electron tubes, all types	3671	TV Tubes
386	3674	Semiconductors and related devices	367	TV Tubes
387	3675	Electronic capacitors	367	Misc. Electrical Supp.
388	3676	Electronic resistors	367	Misc. Electrical Supp.
389	3677	Electronic coils and transformers	367	Misc. Electrical Supp.
390	3678	Electronic connectors	367	Misc. Electrical Supp.
391	3679	Electronic components, n.e.c.	367	Misc. Electrical Supp.
392	3691	Storage batteries	367	Storage Batteries
393	3692	Primary batteries, dry and wet	369	Storage Batteries
394	3693	X-ray apparatus and tubes	369	Misc. Electrical Supp.
395	3694	Engine electrical equipment	369	Misc. Electrical Supp.
396	3699	Electrical equipment and supplies, n.e.c.	369	Misc. Electrical Supp.
397	3711	Motor vehicles and car bodies	NA	Autos, Total
398	3713	Truck and bus bodies	NA	Trucks and Buses
399	3714	Motor vehicle parts and accessories	3714	Motor Vehicle Parts
400	3715	Truck trailers	3715	Truck Trailers
401	3721	Aircraft	372	Aircraft and Parts
402	3724	Aircraft engines and engine parts	372	Aircraft and Parts
403	3728	Aircraft equipment, n.e.c.	372	Aircraft and Parts
404	3731	Ship building and repairing	373	Ships and Boats
405	3732	Boat building and repairing	373	Ships and Boats
406	3743	Railroad equipment	374	Railroad Equipment
407	3751	Motorcycles, bicycles, and parts	374-6,9	Rail and Misc Trans Eq.
408	3761	Guided missiles and space vehicles	374-6,9	Rail and Misc Trans Eq.
409	3764	Space propulsion units and parts	374-6,9	Rail and Misc Trans Eq.
410	3769	Space vehicle equipment, n.e.c.	374-6,9	Rail and Misc Trans Eq.

TABLE A.1. (contd)

No.	SIC	EOC Industry	SIC	FRB Industry
411	3792	Travel trailers and campers	374-6,9	Truck Trailers
412	3795	Tanks and tank components	374-6,9	Rail and Misc Trans Eq.
413	3799	Transportation equipment, n.e.c.	374-6,9	Rail and Misc Trans Eq.
414	3811	Engineering and scientific instruments	381-4	Equipment Instr. and Pts
415	3822	Environmental controls	381-4	Equipment Instr. and Pts
416	3823	Process control instruments	381-4	Equipment Instr. and Pts
417	3824	Fluid meters and counting devices	381-4	Equipment Instr. and Pts
418	3825	Instruments to measure electricity	381-4	Equipment Instr. and Pts
419	3829	Measuring and controlling devices, n.e.c.	381-4	Equipment Instr. and Pts
420	3832	Optical instruments and lenses	381-4	Equipment Instr. and Pts
421	3841	Surgical and medical instruments	381-4	Equipment Instr. and Pts
422	3842	Surgical appliances and supplies	381-4	Equipment Instr. and Pts
423	3843	Dental equipment and supplies	381-4	Equipment Instr. and Pts
424	3851	Opthalmic goods	38	Instruments
425	3861	Photographic equipment and supplies	38	Instruments
426	3873	Watches, clocks, and watchcases	38	Instruments
427	3911	Jewelry, precious metal	391,3,4,6	Misc. Consumer Goods
428	3914	Silverware and plated ware	391,3,4,6	Misc. Consumer Goods
429	3915	Jewelers' materials and lapidary work	391,3,4,6	Misc. Consumer Goods
430	3931	Musical instruments	391,3,4,6	Misc. Consumer Goods
431	3942	Dolls	391,3,4,6	Misc. Consumer Goods
432	3944	Games, toys, and childrens vehicles	391,3,4,6	Misc. Consumer Goods
433	3949	Sporting and athletic goods, n.e.c.	395,9	Misc. Consumer Goods
434	3951	Pens and mechanical pencils	395,9	Misc. Business Supplies
435	3952	Lead pencils and art goods	395,9	Misc. Business Supplies
436	3953	Marking devices	395,9	Misc. Business Supplies
437	3955	Carbon paper and inked ribbons	391,3,4,6	Misc. Business Supplies
438	3961	Costume jewelry	391,3,4,6	Misc. Consumer Goods
439	3962	Artificial flowers	391,3,4,6	Misc. Consumer Goods
440	3963	Buttons	391,3,4,6	Misc. Consumer Goods
441	3964	Needles, pins, and fasteners	395,9	Misc. Consumer Goods
442	3991	Brooms and brushes	395,9	Misc. Business Supplies
443	3993	Signs and advertising displays	395,9	Misc. Business Supplies
444	3995	Burial caskets	395,9	Misc. Business Supplies
445	3996	Hard surface floor coverings	395,9	Misc. Business Supplies
446	3999	Manufacturing industries, n.e.c.	395,9	Misc. Business Supplies

APPENDIX B

IMPUTATIONS FOR MISSING PRACTICAL CAPACITY UTILIZATION DATA

APPENDIX B

IMPUTATIONS FOR MISSING PRACTICAL CAPACITY UTILIZATION DATA

This appendix documents the imputations that were made to fill in missing practical capacity utilization rates as published by the Bureau of the Census in the Survey of Plant Capacity. The imputation methods were discussed in Section 3.2.1.

The appendix contains one table (B.1) that lists all of the 4-digit SIC industries for which imputations were made. The imputation method is listed by a code letter:

R Regression on similar industry (industries)

A Assignment of specific values--judgmentally determined

I Interpolation between earlier and later year

If the regression method was used, Column 4 of Table B.1 lists the SICs that were used in the linkage regression [Equation (3.1)]. The final column gives the years over which the linkage regression was estimated. In most cases the entire period, 1974-1986 (excluding the years for which there were missing values) was used; these cases are denoted with an "*". In some instances, visual inspection of the industry series suggested a subperiod would be more appropriate. Here, the specific time period for the regression is shown.

TABLE B.1. Imputation of Capacity Utilization by SIC.

SIC	Years Imputed	Method	SIC used	Time Period
2021	1974-76, 1983,1984	R	2023	1977-1982
2034	1984	R	2032, 2023	*
2041	1975	R	2045	1976-1983
2043	1974	R	2041 *	*
2044	1974,1975 1977	R	2040	*
2061	1974-1978	R	2060	*
2062	1984	R	2063	*
2067	1975	I	*	*
2074	1974	R	2070	*
2075	1974,1975	R	2070	*
2076	1974-1978 1983-1987	R	2070	*
2077	1983	I	*	*
2091	1984-1986	R	2092 *	*
2092	1984	I	*	*
2097	1983-1984	R	2090	1979-1982 1985-1987
2111	1983-1984	R	2100	*
2121	1979-1982	R	2100	*
2131	1974-1977 1985-1987	R (1975 SET TO 99.00)	2100	*
2231	1979	I	*	*
2257	1984	R	2250	*
2259	1976-1977 1984-1987	R	2257 *	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
2269	1984	R	*	*
2271	1979-1982	R	2270	*
2279	1974-1982 1985-1987	A	CU(2270)+8	*
2283	1974-1977 1979-1982	R	2282	*
2291	1975-1976 1977-1982	R	2290	*
2292	1974-1983	A	CU = 80	*
2293	1977-1978 1983	I	*	*
2294	1975-1978	R	2200	*
2299	1977, 1979-1987	R	2290	*
2311	1984	I	*	*
2321	1984,1985	I	2320	*
2322	1979-1986	R	2320	*
2323	1976,1979- 1983	I	2320	*
2327	1984-1985 1987	R	2320	*
2329	1983-1984 1987	R	2320	*
2331	1984-1987	A	CU(1984-87) =CU(1983)	*
2335	1982-1986	R	2330	*
2337	1974,1983- 1985	R	2330	*
2339	1984	I	2330	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
2340	1976, 1982	R	2300	*
2341	1976	R	2340	*
2342	1977, 1985	I	2340	*
2351	1974-1985 1987	A	CU=CU(1986) =77	*
2352	1985	R	2350	*
2360	1984-1987	R	2300	*
2361	1974-1975 1984-1987	R	2369 CU(1975)=50	 *
2363	1979-1982 1977	T	2360	1974-1978 1983
2369	1984-1987	A	CU(1987-1987) =CU(1983)	*
2371	1974-1982 1985-1987	A	CU(2371) =CU(2300) (Match in 1983 1984)	
2380	1985, 1987	R	2300	*
2384	1974-1976 1978 1984-1987	R	2380	*
2385	1976, 1984- 1982, 1985	R	2380	*
2386	1979-1983 1985	R	2380	*
2389	1975, 1978, 1984-1985 1987	R	2380	*
2391	1974, 1985- 1987	R	2390	1976-1984
2392	1985-1987	R	2390	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
2393	1983	I	*	*
2394	1974,1981	I(1984) A,1974=82	*	*
2395	1979,1982 1984-1987	R A	2390 CU(1987)=84	*
2397	ALL YEARS	A	CU(2397)= CU(2390)	*
2399	1974,1977	R	2390	*
2426	1980	I	*	*
2429	1974-1978 1983,1985	R	2420	*
2434	1984	I	*	*
2448	1983	R	2440,2441 2449	*
2451	1985	A	CU(1985)=54	*
2452	1983	R	2450 2451	*
2491	1974	R	2450	*
2492	1974,1977 1981	R	2490	*
2499	1985,1986	R	2490	*
2514	1979,1984 1986	R	2510	1974-1978 1980-1982 1986
2515	1983	I	*	*
2517	1979,1984 1986	R	2510	*
2519	1976,1979- 1982	I	*	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
2521	1981	A (Yields 2520 AVE)	CU(1981)=72	*
2531	1979-1982	R	2500	*
2541	1984	I	*	*
2542	1984	I	*	*
2646	1976-1982	R	2647	1974-1975 1983-1985
2648	1974,1984	R	2640	*
2649	1984-1987	R Essentially Constant (1983-1987)	2640	*
2652	1984	I	*	*
2721	1984-1987	A	CU(1984-1987) = CU(1983)	*
2731	1984-1987	A I	CU(1987)=90 TO ACHIEVE 2730 AVE INT 1983-1987	*
2732	1975,1984	R	2700	*
2741	1986	R	2700	*
2753	1974-1975 1979-1983	A I	CU(1974-75)=CU(1976) INTERP BETWEEN 1978 & 1984	*
2771	1985-1987	R	2700	*
2790	1977,1982-1984	R	2790	*
2791	1983,1986	R	2790	*
2793	1979-1987	R	2795	*
2795	1984,1986	I	*	*
2812	1974	R	2810	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
2840	1974	R	2800	*
2841	1983	R	2840	*
2861	1982	1982 CHANGED FROM 100 TO 55	*	*
2875	1984,1985 1987	R	2890	*
2890	CHECK			
2895	CHECK			
2951	1975	R	2952	*
2992	1978	R	2990	1974-1987 EXCL 2992
2999	1974-1978 1982	R	2990	*
3021	1984,1986	I	*	*
3031	1974-1983 1987	A	CU (1974-83)=CU(1984)=78 CU(1987)=CU(1986)=61	*
3111	1974-1977 1984-1987	R A	3000	*
3131	1974-1975 1979-1982	R	3000	*
3142	ALL	A	CU(3142)=CU(3140)	*
3149	1984,1987	R	3144	*
3151	1979-1983	R	3100	1974-1978
3161	1984	R	3000	*
3170	1974,1982	A I	CU(1974)=92	*
3171	1979-1982	R	3170	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
3172	1981,1983-1984	R	3170,3171	1974-1979 1982,1985 1987
3199	1979-1982	R	3000	*
3251	1987	R	3253	*
3259	1987	R	3253	*
3261	1981-1982	R	3260	*
3262	1977-1978	R	3260	*
3263	1974,1977 1979-1987	A	CU(1974)=87 CU(1977)=INTERPOLATION CU(1979-1987) = CU(1978)	*
3269	1979,1981 1982	R	3260	*
3274	1974,1976-1977,1982	R	3275	*
3281	1979-1984	A	CU(1979-1984)=90,80,70,60 65,70	*
3292 ASBESTOS	1984-1987	A	CU(1984-1987)=CU(1983)	*
3297	1986	R	3299	*
3322	1981	R	3320	*
3325	1983	R	3324	*
3330	1976	R	3300	*
3331	1987	R	3330	*
3333	1984	R	3332	*
3341	1984	I	*	*
3369	1984	R	336	*
3399	1983	R	339,3398	1974-1987 EXCL 1984

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
3412	1984-1987	R	341,3411	*
3441	1984	R	3443	*
3446	1986	R	3444	*
3448	1987	R	3440	*
3449	1975	R	344	*
3489	1985,1987	R	348	*
3496	1984	I	*	*
3531	1983	R	3535	*
3536	1985-1987	R	3535	*
3547	1983,1987	R	354	*
3552	1985-1986	R	355	*
3553	1984	I	*	*
3574	1985	I	3579	*
3581	1977,1979-1982	I	*	*
3582	1974-1975 1979-1983	A I	CU(1974-1976)=CU(1977)	*
3586	1980-1982, 1986	R	3589	*
3636	1979-1982, 1984-1987	R	3639	*
3645	1987	R	364	*
3648	1987	R	364	*
3652	1986-1987	R	365,3651	*
3692	1986	R	369	*
3716	1974-1976	R	3715	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
3732	1987	R	373,3731	*
3751	1984	R	37	*
3790	1978,1983-1985	I	*	*
3792	1988,1987	R	379	*
3795	1974,1984-1985,1987	R	379	*
3799	1983-1987	R	379	*
3841	1986	R	384,3842	*
3843	1985-1987	R	384,3842	*
3851	1984-1985, 1987	R	38	*
3914	1974,1979-1983	R CU(1982=30) A	3915 (AFTER IMPUTATIONS)	*
3915	1984,1985	I	*	*
3931	1986	R	39	*
3942	1979-1983, 1985	R	394,3944,3949	*
3950	1982	A (CU 1982 = 60)	*	*
3952	1979-1982, 1984	R	395,3951	*
3953	1979-1982, 1986	R	395	*
3955	1974-1979 1981	R	395	*
3960		R	39	*
3961	1983,1987	R	396	*

TABLE B.1. (contd)

SIC	Years Imputed	Method	SIC used	Time Period
3962	1974-1983 1986	R	396	*
3963	1974-1982 1985-1986	R	396	*
3964	1980-1982 1984-1986	R	396	*
3993	1978	R	399	*
3995	1987	R	399	*
3996	1974-1978	R	39	*
3999	1984	R	399	*

APPENDIX C

INDUSTRY SPECIFIC METHODOLOGIES FOR NONMANUFACTURING

APPENDIX C

INDUSTRY SPECIFIC METHODOLOGIES FOR NONMANUFACTURING

Industry: Iron and Ferroalloy Ores

General Discussion: The U.S. Bureau of Mines provides estimates of capacity for some, though not all, non-energy minerals. Capacity estimates are available for iron ore. We will not provide specific estimates of EOC for ferroalloy ores. The SIC includes the following metals as ferroalloys: chromium, cobalt, manganese, molybdenum, nickel, tantalum, and tungsten. The U.S. produces only molybdenum in any quantity, and output is very small relative to iron ore. We assume, therefore, that EOC for iron ore applies to the industry as a whole.

The Bureau of Mines (BOM) defines "rated capacity" as ". . . the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operation rate, based on the physical equipment of the plant, and given acceptable operating procedures involving labor, energy, materials, and maintenance." Capacity is defined to include both operating plants and ". . . plants temporarily closed that, in the opinion of the author [i.e., the responsible BOM analyst], can be brought into production within a short period of time with minimum capital expenditures." (Bureau of Mines, "Iron Ore, 1988" p. 14)

The same publication identifies "installed production capacity" for iron ore at 83 million metric tons per year and for pelletizing at 70 million metric tons. However, "effective production capacity" for pellets was at least 12 million metric tons less than installed capacity (p. 4). The context makes it clear that effective capacity conforms to the above definition of rated capacity. Most iron ore produced in the U.S. is processed into pellets before shipping, and pelletizing by mining firms is considered a mining activity within the SIC definition. Total U.S. iron ore production in 1988 was 57.5 million metric tons, of which 56 million metric tons were shipped as pellets.

Output Measure: Output is defined as metric tons per year of "usable" iron ore, as specified by BOM.

Input Measures: None used.

Emergency Operating Capacity Measure: There are several options for defining EOC for the iron ore industry:

- Nameplate capacity for usable ore mining

- Nameplate capacity for pellet production

- Effective or rated capacity for usable ore mining
- Effective or rated capacity for pellet production.

Since pellet production capacity is less than ore mining capacity (whether nameplate or effective), effective pellet capacity provides the minimum EOC. However, since effective capacity involves "acceptable" operating procedures, it is possible that under emergency conditions, the industry would adopt emergency operating procedures that would increase capacity utilization up to (or even beyond) nameplate capacity. Under this assumption, nameplate pellet capacity would be an appropriate EOC concept. At the same time, ore can be used in iron production without prior pelletization (known as direct reduction). Under emergency conditions, direct reduction iron may be increased to fully utilize iron ore production that exceeds pellet production capacity. If so, then nameplate ore mining capacity can be used for EOC. All three concepts will be reported. However, rated capacity for pellet production will be the primary definition of EOC.

Primary Data Sources: U.S. Department of the Interior, Bureau of Mines, "Iron Ore, 1988."

Secondary Data Sources: None

Preliminary Calculations:

Using BOM capacity data:

- Effective pellet production capacity - 66.55 million metric tons per year (Table 14 of "Iron Ore, 1988").
- Nameplate pellet production capacity - 79 million metric tons per year (p. 4 of "Iron Ore, 1988").
- Nameplate usable iron ore mining capacity - 83 million metric tons per year (p. 4 of "Iron Ore, 1988").

EOC: Iron and Ferroalloy Ores

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	2120.3	2217.3	2623.1
PNL Analysis			
Output (millions of metric tons of pellets)			56
Emergency Operating Capacity			66.55
EOC Utilization			.8415
EOC in millions of 1982 $			3117.3

Industry: Copper Ores

General Discussion: The U.S. Bureau of Mines provides estimates of capacity for some, though not all, non-energy minerals. Capacity estimates are available for copper ore.

The Bureau of Mines (BOM) defines "rated capacity" as ". . . the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operation rate, based on the physical equipment of the plant, and given acceptable operating procedures involving labor, energy, materials, and maintenance." Capacity is defined to include both operating plants and ". . . plants temporarily closed that, in the opinion of the author [i.e., the responsible BOM analyst], can be brought into production within a short period of time with minimum capital expenditures." (Bureau of Mines, "Iron Ore, 1988" p. 14)

The available estimates of copper mining capacity apply only to operating mines. This includes both copper mines and mines that produce copper as a byproduct of gold, lead, silver, or zinc mining. The Copper chapter of the Minerals Yearbook, 1988 reports 1.69 million metric tons per year of operating mine capacity (Table 6). Production of copper from mines in 1988 was 1.42 million metric tons (Table 1).

Output Measure: Output is defined as metric tons per year of copper (as recovered from ore after milling). This is effectively the copper content of the ore, rather than the ore itself.

Input Measures: None used.

Emergency Operating Capacity Measure: At present, we are using capacity of operating mines as the measure of EOC and actual output to calculate the utilization rate of EOC.

Primary Data Sources: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1988, "Copper"

Secondary Data Sources: None

Preliminary Calculations: None

EOC: Copper Mining

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	2029.8	2122.6	2511.0
PNL Analysis			
Output (millions of metric tons)			1.42
Emergency Operating Capacity			1.69
EOC Utilization			.8402
EOC in millions of 1982 $			2988.4

Industry: Non-Ferrous Metal Ores, except Copper

General Discussion: The non-ferrous metals (except copper) industry covers a large number of metal ores, all of which have different production characteristics in the U.S. Since lead, zinc, gold, and silver are frequently mined as joint products and because the U.S. is not a major producer of the other metals in this industry, our analysis will focus on lead and zinc mining. Although the U.S. is a leading producer of gold, the two major ores, in terms of volume of domestic production, are lead and zinc.

The U.S. Bureau of Mines provides estimates of capacity for some, though not all, non-energy minerals. The Bureau of Mines (BOM) defines "rated capacity" as ". . . the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operation rate, based on the physical equipment of the plant, and given acceptable operating procedures involving labor, energy, materials, and maintenance." Capacity is defined to include both operating plants and ". . . plants temporarily closed that, in the opinion of the author [i.e., the responsible BOM analyst], can be brought into production within a short period of time with minimum capital expenditures." (Bureau of Mines, "Iron Ore, 1988" p. 14)

The "Zinc" and "Lead" chapters of the Minerals Yearbook, 1988 provide specific estimates of 1988 lead and zinc mining capacity. Lead mining capacity is estimated at 655 thousand metric tons, while zinc capacity is estimated at 350 thousand metric tons. Lead production in 1988 was 385.0 thousand metric tons, while zinc production was 244.3 thousand metric tons.

Two new mines which have significant impacts on zinc capacity have recently begun production in Alaska. One mine, Greens Creek on Admiralty Island went into production in 1989, with an annual zinc production capacity of 23,000 tons (in addition to 8,000 tons of lead, 6.4 million ounces of silver and 36,000 ounces of gold). The second mine, Red Dog, began production in 1990. In 1991 it should reach its annual capacity of 314,000 tons of zinc and 64,000 tons of lead. In other words, by 1992, zinc mining capacity will be more than twice peak 1980s output. However, we do not include these mines in our 1988 capacity estimates because these mines were not yet operating. For future years, there is the issue of whether or not other mines will close as a result of the new capacity.

Output Measure: Output is defined as metric tons per year of lead and zinc.

Input Measures: None used.

Emergency Operating Capacity Measure: EOC for non-ferrous metals (except copper) is defined to be combined lead and zinc production capacity. To aggregate lead and zinc capacity, the value of capacity output was estimated using the price of each metal, in dollars per metric ton. EOC is then measured in terms of the value of output in 1988 dollars. The value of output was also calculated, using the same prices, and the combined value of output was used to compute the capacity utilization rate for the industry. The prices were calculated using the reported output and value from the "Lead" and "Zinc" chapters of the Minerals Yearbook, 1988.

Primary Data Sources: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1988.

Secondary Data Sources: None

Preliminary Calculations:

Mineral	1988 Output (thousands of metric tons)	1988 Capacity (thousands of metric tons)	1988 Price (dollars per ton)	1988 Value of Output (millions of dollars)	1988 Value of Capacity (millions of dollars)
Lead	385.0	655	818.76	315.2	636.3
Zinc	244.3	350	1327.26	324.3	464.5
Total				639.5	1,100.8

Capacity Utilization Rate = .5809

EOC: Non-Ferrous Metal Ores (Except Copper)

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	2,607.0	2,726.1	3,224.9
PNL Analysis			
Output (millions of 1988 $)			639.5
Emergency Operating Capacity (millions of 1988$)			1,100.8
EOC Utilization			.5809
EOC in millions of 1982 $			5,551.6

Industry: Chemical and Fertilizer Minerals

General Discussion: While chemical and fertilizer minerals include a large number of different minerals, we will focus on the four key fertilizer minerals: potash, soda, phosphate, and sulfur. The remaining minerals are too diverse to aggregate into a single number with any meaning for EOC.

The U.S. Bureau of Mines provides estimates of capacity for some, though not all, non-energy minerals. The Bureau of Mines (BOM) defines "rated capacity" as ". . . the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operation rate, based on the physical equipment of the plant, and given acceptable operating procedures involving labor, energy, materials, and maintenance." Capacity is defined to include both operating plants and ". . . plants temporarily closed that, in the opinion of the author [i.e., the responsible BOM analyst], can be brought into production within a short period of time with minimum capital expenditures." (Bureau of Mines, "Iron Ore, 1988" p. 14)

The individual chapters of the Minerals Yearbook, 1988 provide specific estimates of mining capacity for their respective minerals and we will use those estimates, except in the case of sulfur. The reported capacity for sulfur includes both mining and manufacturing sources so that another procedure is used to estimate sulfur mining capacity.

BOM estimates phosphate rock mining capacity in 1988 to be 59.9 million metric tons ("Phosphate Rock," Table 24). This is lower than the capacity reported in the Minerals Yearbook, 1987, which was 63.2 million metric tons per year. (p. 674.)

Soda is mined in two forms, soda ash (sodium carbonate) and sodium sulfate. In 1988, soda ash nameplate capacity was 10,200 thousand short tons per year ("Soda Ash and Sodium Sulfate," Table 10). BOM estimates that sodium sulfate mining in 1988 had an annual nameplate capacity of 510 thousand short tons ("Soda Ash and Sodium Sulfate," Table 11). (In addition, the U.S. had an estimated annual nameplate capacity of 539 thousand tons of synthetic sodium sulfate, which is classified under chemical manufacturing, not mining.)

In 1988, U.S. potash capacity (primarily potassium chloride and potassium sulfate) was 2,060 thousand metric tons (in K_2O equivalent) ("Potash," Table 12).

Frasch process mining (extracting sulfur by melting underground deposits with hot water then pumping out the solution) accounts for about 1/3 of U.S. sulfur production. Except for trivial amounts of sulfur extracted from pyrites and gaseous compounds, the remaining 2/3 of U.S. production comes from byproducts of petroleum refining, natural gas processing, coke production, and metal ore processing. These industries are all manufacturing industries. BOM reports that annual sulfur production capacity from all sources in 1988 amounted to 13,000 thousand metric tons ("Sulfur," Table 20). Unfortunately, BOM also notes that Frasch mining capacity is "... quite variable over time ... " and does not provide a separate capacity estimate for Frasch mining. In the absence of more specific data, we will assume that Frasch mining capacity equals 33 percent of total U.S. capacity or 4,290 thousand metric tons.

Output Measure: Output is defined as metric tons per year for each mineral. This involves conversion of the soda data from short tons to metric tons. Since one metric ton equals approximately 2,204.6 pounds, the conversion factor is 1.1023 short tons per metric ton.

Input Measures: None used.

Emergency Operating Capacity Measure: EOC for chemical and fertilizer minerals is defined as the weighted sum of potash, soda, phosphate rock, and sulfur capacity; prices are used as weights. The actual 1988 output of each mineral is also weighted by price to obtain total output for the sector, which is then used to estimate capacity utilization.

Primary Data Sources: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1988, individual mineral chapters for soda, potash, phosphate rock, and sulfur.

Secondary Data Sources: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1987.

Preliminary Calculations:

Mineral	1988 Estimated Capacity (thousands of metric tons)	1988 Output (thousands of metric tons)	1988 Price (dollars per metric ton)
Phosphate rock	59,900	45,389	19.56
Soda ash	9,253	8,738	73.81
Sodium sulfate	463	361	86.90
Potash	2,060	1,262	168.37
Sulfur	4,290	3,174	99.24

Mineral	1988 Value of Capacity (thousand dollars)	1988 Value of Output (thousand dollars)
Phosphate rock	1,171,644.0	887,808.8
Soda ash	682,963.9	644,951.8
Sodium sulfate	40,234.0	31,370.9
Potash	346,842.2	212,482.9
Sulfur	425,752.6	314,987.8
Total Value (thousand dollars)	2,667,435.7	2,091,602.2
Capacity Utilization Rate		.7841

EOC: Chemical and Fertilizer Minerals Mining

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	4779.09	4976.89	5412.45
PNL Analysis			
Output (millions of 1988 $)			2091.6
Emergency Operating Capacity			2667.4
EOC Utilization			.7841
EOC in millions of 1982 $			6902.75

Industry: Stone and Clay Mining and Quarrying

General Discussion: Because of the abundance of stone and clay for building material (the primary market for stone and clay products) and because the stone and clay mining industry currently operates on a one-shift, 5-day per week schedule, EOC for this industry can be simply defined as 3 times current production, based on moving to a three-shift per day operation (or going to two, 12-hour shifts). Output may be expanded even more by working seven days per week, but time must be made available for equipment maintenance to sustain output.

Output Measure: None used.

Input Measures: None used.

Emergency Operating Capacity Measure: Assumed to be 3 times current production

Primary Data Sources: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, 1987.

Secondary Data Sources: None

Preliminary Calculations:

EOC: Stone and Clay Mining and Quarrying

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	7,132.9	7,428.1	8,077.2
PNL Analysis			
Output			--
Emergency Operating Capacity			--
EOC Utilization			.3333
EOC in millions of 1982 $			24,234.0

Industry: Coal Mining

General Discussion: The coal mining industry has recently shown a significant increase in productivity: as output has increased, both labor input and the number of active mines has declined (see Table C.1). Our approach to defining and measuring EOC in coal mining uses the FGK procedure to identify the best practice in the industry during the period 1970-1986, which turns out to be the most recent observation (1986). We then estimate the potential output using 1986 productivity applied to the number of mines in operation during 1978 (the year with the highest number of mines in our sample period) under the assumption of no constraint on the hours of labor by miners. We also estimate potential output using both the number of mines and the hours worked by miners in 1978, assuming 1986 productivity.

The underlying rationale for this methodology is that the old mines (including coal deposits) remain; they were shut down because they were too expensive to operate compared with active mines in 1986. Improved productivity has led to increased output from the active mines to meet rising demand. Recent trends have been toward larger mines and more output from surface mining. However, because coal mines do not disappear (unlike machinery or other fixed factors of production), they can be reopened. Coal Production, 1986 notes that "... smaller mines, many of them underground operations, will remain important sources of coal because they can be more easily opened or closed to meet changes in the demand for coal." (p. 9)

Output Measure: Output is measured in tons of bituminous and lignite coal produced, per year. Anthracite production is declining, and accounts for less than one percent of total coal production.

Input Measures: Inputs are the number of mines and the annual number of hours worked by miners. The number of hours is calculated by dividing annual output by the tons per miner-hour reported in Coal Production, 1986 by the Energy Information Administration of the U.S. Department of Energy.

Emergency Operating Capacity Measure: EOC is measured in terms of tons of coal per year, and in terms of a percentage increase over 1986 production.

Primary Data Sources: U.S. Department of Energy, Energy Information Administration, Coal Production, 1986, DOE/EIA-0118(86), January 1988.

Secondary Data Sources: None

Preliminary Calculations:

A. As noted, published data on annual production and output per miner-hour were used to calculate annual hours worked by miners, for use as an input.

B. Application of the FGK methodology showed that, when both the number of mines and miner hours were included as constraints, only the number of mines was a binding constraint and that the 1986 observation represented best practice. Under these conditions, the FGK methodology shows no excess capacity.

C. To allow for increasing the number of mines by reopening mines closed because of economic factors, we reran the FGK procedure, using the number of mines and miners from 1978 (the peak year in terms of the number of mines). The output of this set of runs measures efficiency and capacity utilization in 1978, taking into account improvements in productivity between 1978 and 1986.

D. Table C.2 shows the results of the various numerical analyses. The analysis for 1978 shows capacity utilization of 86 percent, assuming 1986 technology. However, maximum output in 1978, as estimated with the FGK procedure using all inputs, exceeded actual output (1129.56 million tons versus 665.1 million tons, a 69.9 percent increase). This implies an underutilization of labor input. Details of the linear programming analysis suggest that this was indeed the case. In the linear program solution for 1978, with both labor and fixed (mines) inputs, labor was the binding constraint. In addition, comparing 1978 with 1986, the number of miner-hours fell relatively less than the number of mines. The number of mines in 1986 was 67.5 percent of the number of mines in 1978, while worker hours in 1986 were 78.4 percent of the hours in 1978.

For our purposes, the critical results are that using the number of mines and the number of miner-hours employed in 1978 with 1986 technology would produce an increase in coal production of 27.5 percent over 1986 production. Assuming no constraint on the number of miner-hours, production could increase by 48.2 percent over 1986 production.

E. It should be noted that these estimates depend on being able to reopen closed mines with current technology within the 6-month period defining the short-run for this analysis.

TABLE C.1. Coal Production and Inputs, 1970-1986

Bituminous and Lignite

Year	Total Production (millions of tons)	Number of Mines	Number of Workers Per Day (average)	Average Tons Per Miner Per Hour	Total Hours Per Year
1970	602.9	5601	140140	2.36	255.466
1971	552.2	5149	145664	2.25	245.422
1972	595.4	4879	149265	2.22	268.198
1973	591.7	4744	148121	2.20	268.955
1974	603.4	5247	166701	2.35	256.766
1975	648.4	6168	189880	1.83	354.317
1976	678.7	6161	202280	1.80	377.056
1977	691.3	6077	221428	1.82	379.835
1978	665.1	6230	242295	1.79	371.564
1979	776.3	5837	224203	1.82	426.538
1980	823.6	5598	224938	1.94	424.536
1981	818.4	5569	226250	2.11	387.867
1982	833.5	5363	214400	2.14	389.486
1983	778.0	4265	173543	2.52	308.730
1984	891.8	4902	175746	2.65	336.528
1985	878.9	4547	167009	2.76	318.442
1986	886.0	4203	152668	3.04	291.447

TABLE C.2. Analyses of Coal Production Data and Estimations of EOC

	(1)	(2)	(3)	(4)	(5)
1986	886	886	1.00	NA	NA
1978	1129.56	1313.3	0.8601	27.5	48.2

Column definitions:

(1) Solution to the FGK linear programming problem, all inputs.

(2) Solution to the FGK linear programming problem, only the number of mines (as a measure of fixed inputs).

(3) Capacity utilization, given by (1)/(2).

(4) Percentage increase over 1986 production, all inputs.

(5) Percentage increase over 1986 production, number of mines only.

EOC: Coal Mining

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	30,772	31,697	32,771
PNL Analysis			
Output (millions of tons)	886		
Emergency Operating Capacity	1,129.6		
EOC Utilization	.784		
EOC in millions of 1982 $	39,250		
Alternate PNL Analysis			
EOC 2	1,313.3		
EOC 2 Utilization	.675		
EOC 2 in millions of 1982 $	45,588.1		

Industry: Oil and Natural Gas Extraction

General Discussion: The general concept for measuring EOC for the oil and gas extraction industry is to apply the FGK methodology, using existing wells and reserves as fixed factors. Variable factors are employment, new wells completed, and exploratory wells drilled.

The distinction between fixed and variable factors in this case is somewhat arbitrary. The production process for extracting crude oil or natural gas depends first on having reserves of the resource; then on finding those reserves (i.e., drilling exploratory wells); and finally, on drilling production wells, which may or may not actual tap into the resource. Annual production depends, therefore, on how many producing wells there are, how many new wells are drilled, and how hard it is to extract oil or gas from a given reservoir or pool. Because oil and gas are first extracted from the easiest sources, many current oil reserves are of poor quality, requiring more expensive extraction methods (such as steam or CO_2 injection). At the same time, extraction rates are determined by the market for oil and gas. If crude oil prices increase, then enhanced recovery methods that are currently too expensive to use could be used to increase production.

In the following analysis, we will assume that demand largely controls the rate of extraction and that, in an emergency, existing resources would be used as required. This means that our estimates of EOC will be an upper bound.

A further complication is that natural gas is frequently pumped from oil wells, so that there is a joint product. It is convenient, therefore, to treat oil and gas extraction as a joint product industry, using the multiple output variation of the FGK methodology. However, separate analyses will also be performed on oil and natural gas.

Output Measure: Our data source gives oil production in thousands of barrels per day and natural gas production in trillions of cubic feet. Because we are treating oil and gas as a joint product and because they are not perfect substitutes, we will not calculate a combined measure (either by converting to oil equivalents or Btu or by using an index). Instead, we will retain the separate measures of output and look at percentage increases in output. Note that the measure of natural gas production is the sum of output from gas wells and the output of natural gas from oil wells. Oil and gas production data are listed in Table C.3.

Input Measures: Producing oil and gas wells, new wells, and exploratory wells are measured in thousands. Oil reserves are measured in billions of barrels, and gas reserves are measured in trillions of cubic feet. Employment is measured in thousands of oil and gas extraction production workers (which excludes workers not involved in actual production activities). Input data are listed in Table C.3.

Emergency Operating Capacity Measure: EOC will be measured in terms of a percentage increase over 1986 production for oil and natural gas. In the joint product analysis, the same percentage increase is applied to each fuel. In the individual fuel analyses, a separate percentage increase is calculated for each fuel. Applying the percentage increase to 1986 production produces EOC in barrels per day for oil and trillions of cubic feet for natural gas.

Primary Data Sources:

1. Data on oil and gas production, wells, and reserves is from the Energy Information Administration (EIA) publication, Annual Energy Review, 1987 (U.S. Department of Energy, DOE/EIA-0384(87), May 1988).

2. Data on production workers is from various issues of the Statistical Abstract of the United States (U.S. Department of Commerce). Data on production workers are not available for all years between 1970 and 1986. Data for 1971, 1973, and 1974 are unavailable, and these years have been dropped from our data set.

Secondary Data Sources: None

Preliminary Calculations:

A. Joint Analysis of Oil and Natural Gas Production

- The solution of the linear programming problem for joint oil and gas production using all factors shows that 1986 production could not be increased without increasing some inputs.

- Successively dropping labor and new wells/exploratory drilling showed no increase in production possibilities. Dropping producing wells also showed no increase in production possibilities.

- Dropping reserves, while retaining producing wells, did show an increase in production possibilities of 33.4 percent.

- Since proved reserves in 1986 represented about 10 years of production at 1986 levels for natural gas and eight years of production for oil, increasing annual output by 33.4 percent is feasible. Actual increases in output, however, may depend on increasing capital stock for enhanced oil recovery technology (such as steam plants or CO_2 injection equipment).

  It is not known at this time if it is possible to exploit existing enhanced oil recovery facilities to increase production by 33.4 percent within the six months time frame defining EOC. However, the Wall Street Journal (February 2, 1990) reported that new enhanced oil recovery technologies are under development. Some of these new technologies appear to be easy to implement, e.g., specially bred microbes that improve oil flow or increase well pressure or electrical heating of heavy oil. Other technologies involve complex methods for identifying the locations of small oil pockets to allow more accurate injections of steam or chemicals.

Successfully developing these technologies could allow oil producers to extract oil that is currently classified as unrecoverable. Since unrecoverable oil is estimated to total about 340 billion barrels (compared with some 25 billion barrels of conventional reserves), new technologies could significantly increase EOC. At this time, however, we cannot say for sure when these technologies would be available or how much oil would in fact be recoverable.

B. Analysis of Oil Production

- A separate analysis that looked only at oil production showed that the results in the joint production case were in fact dominated by oil production; thus, both analyses produced the same result.

C. Analysis of Natural Gas Production

- The solution of the linear programming problem for all inputs showed that 1986 production was on the production possibilities frontier.

- Dropping new wells and exploratory wells showed a 10.5 percent increase in production possibilities, which suggests that current natural gas production is demand-driven and that demand is too low to stimulate the level of new explorations (which was a binding constraint in the all-inputs case) to the level seen during peak production years. Subsequent dropping of current production wells as a variable did not change the solution.

- Dropping reserves and retaining production wells as the only input increased production possibilities by 158.3 percent, or one and one-half times current production. This level of increase is valid if existing wells can tap into proven reserves or if new wells could be drilled quickly into known reserves.

TABLE C.3. Oil and Gas Extraction Industry Data

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
9637	23.79	531	117	28.17	7.43	39.0	290.7	178	1970
9441	24.02	508	121	27.93	7.55	36.3	266.1	154	1972
8375	21.10	500	130	38.89	9.46	32.7	228.2	223	1975
8132	20.94	499	138	40.94	9.32	30.9	216.0	237	1976
8245	21.10	507	148	45.86	10.15	31.8	207.4	267	1977
8708	21.31	517	157	50.06	11.04	31.4	208.0	299	1978
8552	21.88	531	170	51.91	10.73	29.8	201.0	327	1979
8596	21.87	548	182	69.84	12.91	29.8	199.0	389	1980
8571	21.59	557	199	90.03	17.50	29.8	201.7	478	1981
8648	20.21	580	211	83.43	15.85	29.4	201.5	491	1982
8688	18.60	603	222	74.90	13.88	27.9	200.2	398	1983
8879	20.19	621	234	84.35	15.22	27.7	197.5	405	1984
8971	19.53	647	243	69.18	12.33	28.4	193.4	387	1985
8680	19.05	623	242	37.89	6.95	28.4	191.6	287	1986

Column (1) Crude Oil and Lease Condensate (thousands of barrels per day)
(2) Natural Gas Production (trillion cubic feet)
(3) Producing Oil Wells (thousands)
(4) Producing Gas Wells (thousands)
(5) New Oil/Gas Wells (thousands)
(6) Exploratory Wells (thousands)
(7) Proved Oil Reserves (billion barrels)
(8) Proved Natural Gas Reserves (trillion cubic feet)
(9) Production Workers (thousands)
(10) Year

Sources: Cols. 1-8-EIA, Annual Energy Review, 1987
Col. 9-Statistical Abstract of the United States, var. years

EOC: Oil and Gas Extraction

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	173,267	168,125	166,280
PNL Analysis			
Output	NA		
Emergency Operating Capacity	NA		
EOC Utilization	.7495		
EOC in millions of 1982 $	231,138.2		

Industry: Railroad Freight

General Discussion: Application of the FGK methodology to the railroad freight industry showed that the trend in recent years (1979-1988) has been toward increasing efficiency. Output, measured in ton-miles of freight, has increased, while inputs (freight cars, track miles, employment, locomotives) have all declined. This is especially true for the Class 1 railroads that handle virtually all long-haul freight. As a result, the FGK methodology fails to show significant available capacity, since current use represents the observed "best-practice." At the same time, the FGK analysis suggested an alternative approach that looks at operating procedures that have resulted in increasing output despite declining inputs.

The two key operating variables that seem to account for the increasing output are revenue carloadings per freight car and revenue car-miles per carloading. Between 1979 and 1988, the average revenue loading per freight car increased from 14.4 per year to 19.0, while the revenue car-miles per carloading increased from 595.7 miles to 700.9 miles (see Table C.4). The key variable for measuring excess capacity in the industry seems to be average capacity per freight car, which increased from 77.7 tons in 1979 to 86.4 tons in 1988, while average freight car load was the same in both years, 65.8 tons (see Table C.4).

EOC can be measured in terms of increasing the freight carried by a freight car, up to the maximum capacity, and increasing the use of each freight car.

Output Measure: Output is measured by revenue ton-miles per year, which is the total amount of freight carried times the total number of miles travelled by freight cars actually carrying freight for which the railroads receive revenue. This excludes moving empty freight cars and other, non-revenue activities.

Input Measures: Input measures are the number of freight cars, average capacity per freight car, number of revenue carloadings per year per freight car, average miles travelled per freight car per carloading.

Emergency Operating Capacity Measure: EOC is measured under the assumption that, in an emergency, freight cars can be loaded to maximum capacity and the number of carloadings per freight car increased. In the absence of specific data, we will assume that the average turn-around per freight car is one week, which includes loading, unloading, and actual transit times. Two weeks per year are allowed for maintenance. These assumptions provide an upper bound to EOC, under two cases:

- Case 1 assumes that the return trip is made empty.
- Case 2 assumes that the return trip is made fully-loaded.

The number of revenue carloadings per freight car in Case 1 is 25 per year and in Case 2 is 50 per year. Essentially, EOC under Case 2 is twice EOC under Case 1.

<u>Primary Data Sources</u>: <u>Railroad Facts</u>, 1989 edition, Washington, D.C.: Association of American Railroads, November 1989.

<u>Secondary Data Sources</u>: None

<u>Preliminary Calculations</u>:

1. Total freight cars was calculated as the sum of cars owned by Class 1 railroads and cars owned by shippers and car companies (see Table C.5). Freight cars owned by regional and local railroads were excluded (in part, because we have no other data on regional and local railroads).

2. Total revenue carloadings were divided by the number of freight cars to get annual carloadings per car.

3. Revenue ton-miles were divided by average freight carload to obtain revenue freight car-miles, which were then divided by the number of freight cars to obtain annual car-miles per freight car. Annual car miles were then divided by annual carloadings per car to obtain car-miles per carloading.

4. <u>Railroad Facts</u> notes that approximately 50 percent of the total freight car miles involve empty freight cars and are not included in revenue car-miles or revenue carloadings. This implies that, on the average, each carloading involves a return trip with an empty freight car. Allowing two weeks per trip for loading, unloading, actual transit, and return trip, this implies a maximum of 26 carloadings per car per year. Further allowing two weeks per year for maintenance on the car, this becomes 25 carloadings per year.

5. Our estimate of EOC for railroad freight is made by multiplying 1137.7 thousand (the number of freight cars in 1988) by 25 (assumed maximum annual carloads per car) by 700.9 miles (revenue car-miles per carloading in 1988) by 86.4 tons (average freight car capacity in 1988). This yields an EOC of 1,722,425.9 million revenue ton-miles of capacity. The actual revenue ton-miles in 1988 was 996,182 million. The estimated EOC is 72.9 percent higher than actual output in 1988. The same calculation was performed for each year 1979 to 1988, using the number of freight cars, miles per carloading, carloadings per car, and car capacity for that year. The results show an almost steady decline in maximum output as a percentage of actual output, implying that the railroad industry is improving its efficiency, by reducing excess capacity and by using capital more intensively (railroad cars).

6. If we assume that the railroads eliminate return trips by empty cars so that annual carloadings per car equal 50, then EOC would double to 3,444,851 million ton-miles, or 345.8 percent of 1988 output. Although eliminating trips by empty cars would probably be unrealizable because of scheduling difficulties, it does represent the upper bound on potential EOC for the industry.

TABLE C.4. Railroad Industry Inputs, 1979-1988

Year	Revenue Ton-Miles (millions)	Average Car Capacity (tons)	Freight Car-Miles (millions)	Revenue Carloadings (thousands)	Piggyback Loadings (thousands)	Average Freight Carload (tons)	Revenue Freight Car-Miles (millions)	Revenue Car-Miles as percent of Total Car-Miles
1979	904956	77.7	29437	23085.9	3278.2	65.8	13753.1	0.467
1980	918958	79.4	29277	22223.0	3059.4	67.3	13654.7	0.466
1981	910169	80.6	27968	21343.0	3150.5	69.8	13039.7	0.466
1982	797759	81.6	23951	18584.8	3397.0	69.2	11528.3	0.481
1983	828275	82.4	24358	19013.3	4090.1	69.5	11917.6	0.489
1984	921542	83.4	26409	20945.5	4565.7	70.2	13127.4	0.497
1985	876984	84.3	24920	19501.2	4591.0	68.8	12746.9	0.512
1986	867722	85.8	24414	19588.7	4997.2	66.2	13107.6	0.537
1987	943747	86.6	25627	20602.2	5503.8	65.5	14408.4	0.562
1988	996182	86.4	26339	21600.0	5716.3	65.8	15139.5	0.575

Source: Railroad Facts, 1989 edition, Association of American Railroads, November 1989.

TABLE C.5. Analysis of Railroad Data, 1979-1988

Year	Class 1 Owned Cars (millions)	Car Comp And Shipper Owned Cars (thousands)	Total Cars (thousands)	Revenue Freight Car-miles per car	Revenue Carloadings per car
1979	1217.1	390.8	1607.9	8553.5	14.4
1980	1168.1	440.6	1608.7	8488.0	13.8
1981	1111.1	460.3	1571.4	8298.1	13.6
1982	1039.1	457.1	1496.2	7705.1	12.4
1983	1007.2	443.7	1450.9	8214.0	13.1
1984	984.2	447.1	1431.3	9171.6	14.6
1985	867.1	443.5	1310.6	9726.0	14.9
1986	798.6	437.3	1235.9	10605.7	15.8
1987	748.5	432.4	1180.9	12201.2	17.4
1988	724.8	412.9	1137.7	13307.1	19.0

Year	Revenue Freight Car-Miles per Car-Loading	Max. Output per 25 Carloadings per Car per Year	Max Output as Multiple of Actual Output	Using 1979 Inventory Max. Output per 25 Carloadings per Car per Year	Using 1988 Inventory Max. Output per 25 Carloadings per Car per Year
1979	595.7	1860693.4	2.0561	1860693.4	1316568.8
1980	614.4	1962065.4	2.1351	1961089.7	1387606.0
1981	611.0	1934518.8	2.1255	1979453.2	1400599.5
1982	620.3	1893335.4	2.3733	2034683.8	1439678.9
1983	626.8	1873427.8	2.2618	2076148.9	1469018.4
1984	626.7	1870354.9	2.0296	2101127.4	1486692.3
1985	653.6	1805425.8	2.0587	2214973.4	1567246.2
1986	669.1	1773893.9	2.0443	2307827.5	1632946.9
1987	699.4	1788017.3	1.8946	2434544.0	1722607.5
1988	700.9	1722425.9	1.7290	2434287.3	1722425.9

EOC: Railroads

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	31,990	35,263	35,388
PNL Analysis			
Output (billions of revenue ton-miles)			996.2
Emergency Operating Capacity			1,722.4
EOC Utilization			.578
EOC in millions of 1982 $			61,184.8

Industry: Trucking

General Discussion: The emergency capacity is derived by assuming that the heavy truck industry is already operating near capacity in regard to length of haul and number of trips per year. However, because of road restrictions, trailers might not be carrying the maximum load of 28 tons for which they are designed. The restrictions would be lifted during an emergency, and so the maximum cargo weight limit was used to calculate emergency capacity. The data on the number of tractors and trailers show that there are about three trailers per tractor. We assume, therefore, that one trailer is loading, one trailer is unloading, and one trailer is in transit towed by the tractor.

Output Measure: Ton Miles

Input Measures: Semi Truck Tractors, Truck Trailers

Emergency Operating Capacity Measure: Ton-miles of cargo, assuming that trailers are loaded to the maximum weight, and assuming the most recent data on the number of trips per semi-truck and the average length of haul.

Primary Data Sources: "Highway Statistics," "Transportation in America" (TIA)

Secondary Data Sources: Track Trailers Manufacturers Assn. (TTMA), American Trucking Assn. (ATA)

Preliminary Calculations:

# Tractor Trucks	1,182,669 (1988, Highway Statistics)
# Full/Semi Trailers	3,557,877 (1988, Highway Statistics)
Avg. Length of Haul	263 (1983, TIA)
Trailer Capacity (Tons)	28 (TTMA)
Avg. # Trips a Year (Per Truck)	187 (Est. From ATA)

Year	# of Tractors	# of Trailers	Ratio
1985	1,150,414	3,413,325	2.967
1986	1,121,417	3,367,218	3.003
1987	1,134,894	3,484,167	3.070
1988	1,182,669	3,557,877	3.008

Of Tractors X Capacity X Length of Haul X # of Trips = Emergency Capacity

1182669 X 28 X 263 X 187 = 1.6286E+12 Ton Miles

1988 Ton Miles = 7.0400E+11

Increase = 231.34 percent

EOC: Trucking

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	83,017	87,702	91,004
PNL Analysis			
Output (billions of ton-miles)			704
Emergency Operating Capacity			1628.6
EOC Utilization			.432
EOC in millions of 1982 $			210,524.3

Industry: Water Transportation

General Discussion: The methodology used for the water transportation industry involves estimating the potential cargo capacity of the existing inventory of ships and barges, then specifying a number for the number of hauls per year per average ton of capacity. The existing inventory of ships and barges includes vessels currently moving cargo, vessels temporarily laid-up and vessels in the U.S. reserve fleet ("mothball fleet").

Water transportation is divided into four categories:

- foreign commerce (U.S.-flag vessels only)
- intercoastal and non-contiguous domestic commerce. Non-contiguous commerce means hauls between the U.S. mainland, Alaska, Hawaii, Puerto Rico, the Virgin Islands, and Guam (and possibly, American Samoa and the Northern Marinas territories).
- Great Lakes commerce
- inland waterways, including all river commerce and all lake commerce, except Great Lakes.

Under Section 27 of the Merchant Marine Act of 1920 (known as the "Jones Act"), all waterborne commerce among the United States and territories must be carried by vessels built and documented in the U.S. Only foreign commerce is excluded. In 1986, cargo carried by U.S.-flag ships accounted for only 4.3 percent of U.S.-foreign commerce (both imports and exports). Most exports carried by U.S.-flag ships involved government-sponsored grain cargoes.

Water transportation involves many different types of vessels, with different operating characteristics. The following types are considered to be relevant for this analysis:

- tanker vessels
- general cargo, including passenger-cargo vessels
- intermodal vessels, i.e., container ships
- dry bulk vessels (specialized ore, grain, lumber carriers, etc.)
- self-propelled barge-tug units
- barges.

Barges and barge-tug units are divided into tanker and non-tanker types. Most general cargo vessels operate as common carriers on regular schedules (and are classified as "liners"). Tankers carry petroleum, liquid chemicals, liquefied natural gas, edible oils and juice, and similar cargoes. Dry bulk vessels carry grain, ore, solid chemicals (such as fertilizers), etc.

Container ships (intermodal vessels) carry cargo containers, which can be loaded from and unloaded onto trucks or railroad cars.

For our purposes, all inland transport is carried by barges. Barges and barge-tug units are also used in Great Lakes, coastal and non-contiguous transport. No barges are used in foreign commerce. A limited number of other vessels, primarily dry bulk carriers, are used in Great Lakes commerce. Most of the cargo carried in coastal and non-contiguous commerce is carried by tankers and tank barges.

Among the important operating characteristics that distinguish different types of vessels are the much slower speed of barges and barge-tug units as compared to other vessels and the longer haul in coastal and non-contiguous shipping versus inland and Great Lakes transport. Foreign commerce, in turn, involves much longer hauls than non-contiguous transport. Also, general cargo vessels typically take longer to load and unload than container ships or dry bulk carriers. Supertankers may also take relatively longer to unload than smaller tankers if the supertanker is too large to enter a harbor and must be unloaded by barge or lighter.

There are two ways to approach the problem of providing an aggregate measure of water transportation EOC, given these different operating characteristics. The first is to separately estimate EOC for the various types of water transport, then aggregate using some form of weighted average. The second is to estimate EOC for the industry as a whole. We will use the second method. There are two reasons for this decision.

First, ships engaged in coastal and non-contiguous commerce (excluding barges) can be used in foreign trade and vice-versa. Similarly, reserve ocean-going vessels can be used in either type of commerce. Also, barges can be used in river, Great Lake or coastal commerce. However, because the average length of haul is different in each type of commerce, the amount of cargo carried during some time period (such as one year) by the same ships will vary depending on the type of commerce. Therefore, estimating EOC for the individual types of commerce requires making a priori assumptions about the allocation of shipping capacity, which reduces the benefits of separate EOC estimations.

Second, there are apparent inconsistencies in some of the data we have obtained to date. For example, data from the U.S. Maritime Administration for 1986 show 92,089 thousand tons of cargo carried on the Great Lakes in 1986, while total capacity of vessels and barges was 3,020 thousand tons. This means that each ton of capacity would have to be used an average of 30.493 times per year to transport the total cargo. However, of the 108 vessels (totalling 2,404 thousand tons of capacity) making up the non-barge fleet, only 46 were active on January 1, 1987, while 18 were temporarily inactive and 44 were laid up (inactive for one year or longer). If we assume that the 46 active vessels were the newer and larger vessels, we can also assume that their capacity equalled 50 percent of the total fleet capacity, or 1,202 thousand tons. Adding the 577 thousand tons of barge capacity yields 1779 thousand tons of capacity. This is equivalent to 51.765 hauls per year to transport the year's total cargo tonnage. If we exclude cargo carried on barges, we have 83,144 thousand tons carried on self-propelled vessels with a capacity of 1,202 thousand tons, equivalent to 69.171 hauls per year. This seems to be excessive.

Similar discrepancies were found in other types of water transport. Part of the problem may be ships that were active for part of the year. In any event, we feel that the data may not be sufficiently reliable in detail to be used to estimate separate EOC for each type of shipping.

Instead, we will measure EOC by estimating the total cargo that the existing inventory of ships and barges (including inactive and reserve capacity) can carry given assumptions about the number of hauls per year. The number of hauls per year for a given cargo carrier depends on the length of the haul, the speed of the carrier, loading and unloading times, and whether or not the return trip is made carrying cargo (which counts as a haul) or empty (which does not count as a haul). Some time is also required for maintenance.

During 1986, total waterborne commerce (domestic and foreign) carried by U.S.-flag ships equalled 1,104,088 thousand short tons. In the same year, the U.S.-flag fleet, including barges and inactive vessels, had a total capacity of 70,048 thousand tons. This would be equivalent to approximately 15.76 hauls per ton of capacity if all capacity were active. Since not all of this capacity was in fact active, the actual number of hauls per ton of capacity was higher. However, because we do not have adequate information on the number and capacity of inactive vessels and barges (other than data on ocean-going vessels), we cannot give a precise number for average hauls per year. However, if we assume that all capacity is active (i.e., 70,048 thousand tons) and that each ton of capacity hauls one ton of cargo 20 times per year, total annual water transport would equal 1,400,960 thousand tons. If we assume 25 hauls per year per ton of capacity, then total transport would equal 1,751,200 thousand tons per year. To be on the conservative side, we will use 20 hauls per year on average and this means an EOC of 1,400,960 thousand tons per year.

Output Measure: Tons per year of cargo

Input Measures: Tons of capacity for U.S.-flag vessels (including barges).

Emergency Operating Capacity Measure: Tons per year of cargo, assuming 20 hauls per year for each ton of capacity

Primary Data Sources: The primary data sources are information sheets supplied by the Office of Domestic Shipping, Maritime Administration, U.S. Department of Transportation, and the article on water transportation from Chapter 51 of the 1988 U.S. Industrial Outlook (U.S. Department of Commerce, January 1989). This article was prepared by the Maritime Administration.

Secondary Data Sources: None

Preliminary Calculations:

Tons of capacity	=	70,048 thousand
Hauls per year per ton of capacity	=	20
Tons of cargo per year	=	1,400,960 thousand

Industry: Water Transportation

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	27,467	27,104	28,328
PNL Analysis			
Output (million short tons)	1,104.1		
Emergency Operating Capacity	1,401.0		
EOC Utilization	.788		
EOC in millions of 1982 $	34,853.1		

Industry: Air Transport

General Discussion: This discussion of the air transport industry will focus on freight transport, not passengers. The approach to measuring EOC uses estimates of the total cargo carrying capacity of the existing U.S. commercial aircraft fleet. Two estimates are provided, one based on cargo capacity under current aircraft configuration (with most aircraft configured for carrying passengers along with cargo) and the other based on reconfiguring all aircraft to carry only cargo. In both cases, no adjustments are made for changes in aircraft routing because of a lack of data on where aircraft would be routed under emergency conditions.

The Air Transport Association of America (ATA) reports that in 1988 the U.S. airline industry had a total load factor (in terms of ton miles of passengers and cargo) of 55.4 percent ("Air Transport, 1989," p. 13). At the same time, passenger mile load factor was 62.5 percent. Using data on total passenger miles, available seat miles, actual cargo ton-miles, and available ton-miles (for cargo and passengers), we estimated available cargo ton-miles to have been 30,332.8 million. Actual cargo ton-miles were 11,469.2 million, giving a load factor of 37.8 percent. This number is entirely consistent with the total and passenger load factors (i.e., weighting the reported passenger load factor and the estimated cargo load factor by actual passenger and cargo carried and summing yielded the reported total load factor of 55.4 percent). This load factor means that the air transport industry could have provided 30,332.8 million cargo ton-miles in 1988 with existing equipment, on existing routes. This is 2.65 times the actual 1988 cargo ton-miles.

To estimate potential cargo capacity if all aircraft were configured to carry only cargo, we used data on the existing inventory of aircraft owned by members of the ATA (which represents the large, national airlines, including cargo-only air carriers such as Flying Tiger Lines and Federal Express) and estimates of aircraft cargo capacity provided by Federal Express. The aircraft range from Boeing 747s with a capacity of 124.5 tons to Cessnas (used by Federal Express). The average cargo capacity per aircraft is calculated to be 38.26 tons of cargo. Multiplying this number by the total revenue miles flown in 1988 yielded a potential capacity of 158,431 million ton-miles, or 13.8 times 1988 actual cargo ton-miles.

Output Measure: Output is measured as ton-miles.

Input Measures: Inputs are the number of aircraft and average cargo capacity in cargo-only configuration.

Emergency Operating Capacity Measure: EOC is measured in ton-miles and as a percentage increase in output.

Primary Data Sources: Air Transport Association of America, "Air Transport 1989," June 1989.

Secondary Data Sources: Data on cargo capacity provided by Federal Express in telephone conversation with PNL staff.

Preliminary Calculations:

A. Cargo capacity with existing configuration (1988 data):

1. Total ton-miles, passengers and cargo - total ton-miles, cargo only = total ton-miles, passengers only (in millions of ton-miles)

   58,338.7 - 11,467.2 = 46,869.5 million ton-miles, passengers only

2. Total ton-miles, passengers only/total passenger miles = tons per passenger

   46,869.5/423,301.6 = .11 tons per passenger

3. Tons per passenger * available seat miles = available passenger ton-miles

   .11* 676,802.3 = 74,938.0 million available ton-miles, passengers only

4. Total available ton-miles (passenger and cargo) - available ton-miles, passengers only = available ton-miles, cargo only

   105,270.8 - 74,938.0 = 30,332.8 million available ton-miles, cargo only

(The actual calculations used thousands of ton-miles, so that the final answer may not match the calculations listed here because of rounding.)

B. Cargo capacity with cargo only configuration:

1. Federal Express provided PNL with data on cargo capacity for various types of aircraft used by Federal Express, Flying Tiger Lines, and other cargo-only air carriers. Using the ATA inventory of operating fleets and assigning cargo capacity to aircraft not included in the Federal Express data based on similar type of aircraft, we estimated a total cargo capacity for ATA airlines of 148,431 tons. The total number of aircraft in the inventory was 3,880. Dividing, we get the average capacity per aircraft of 38.26 tons.

2. The airline industry flew 4,140.9 million revenue miles in 1988. If the same number of miles were flown carrying an average of 38.26 tons per mile, then total ton-miles would be 38.26*4,140.9 or 158,431.3 million ton-miles.

C. Reconciliation:

   The difference in the two methods can be attributed to the potential for using cargo containers in place of passenger seats, allowing for more efficient utilization of aircraft space and lift capacity.

EOC: Air Transport

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	56,938	61,459	64,288
PNL Analysis			
Output (millions of passenger and cargo ton-miles)			58,338.7
Emergency Operating Capacity			105,304.5
EOC Utilization			.554
EOC in millions of 1982 $			116,043.3
Alternate PNL Analysis			
EOC 2 (cargo only)			158,431.3
EOC 2 Utilization			.072
EOC 2 in millions of 1982 $			888,205.6

Industry: Oil Pipeline Industry

General Discussion: Oil pipelines transport crude oil and petroleum products. Data and discussion of trends in this industry suggest that pipeline construction and use are sensitive to market conditions in the petroleum industry. The Oil and Gas Journal (November 27, 1989) notes that declining crude oil production and increasing demand for refined products led to a decrease in crude oil pipeline mileage in 1988, but an increase in product pipeline mileage. A discussion of new pipeline construction in the same report suggests new pipelines can be added fairly quickly and old pipelines removed from service, depending on market conditions. The data on pipeline mileage do show considerable annual variations, with mileage increasing in one year and decreasing in the next. This, in turn, suggests that the oil pipeline industry can expand its capital stock in response to a national emergency, although perhaps not within a 6-month time frame. In addition, data on available but unused pipelines are lacking (and in fact, there may be none). With these factors in mind, the following analysis of EOC in the oil pipeline industry represents a minimum assessment of EOC.

Our approach to measuring EOC for this industry is to use the FGK methodology to measure capacity utilization for a recent year, 1988 in this case. Inputs are pipeline mileage and average length of haul for crude oil and refined products. Output is ton-miles transported.

Output Measure: Our output measure is billions of ton-miles of petroleum transported. We do not distinguish between crude oil and refined product in measuring output.

Input Measures: Input measures are thousands of miles of pipeline and average miles hauled for crude oil and refined products. Both types of pipeline are included in the mileage measure, but separate measures of average miles are included for crude and product.

Emergency Operating Capacity Measure: EOC is measured in terms of a percentage increase in ton-miles for combined crude oil and refined product shipments.

Primary Data Sources: Data on ton-miles and average haul are taken from Transportation in America, Seventh Edition (Eno Foundation for Transportation, Inc., May 1989). Data on pipeline mileage are from the Oil and Gas Journal (November 27, 1989). Pipeline mileage data in Transportation in America are derived from the Oil and Gas Journal, and we believe that the original source in this case is more consistent. The data are listed in Table C.6.

Secondary Data Sources: None

Preliminary Calculations:

A. Solution of the FGK linear programming problem with all three factors showed that 1988 production was on the production possibilities surface.

B. Solution of the linear programming problem with pipeline mileage as the fixed factor showed a capacity utilization of 0.9896 percent. This is equivalent to a 1.1 percent increase in output over 1988.

TABLE C.6. Oil Pipeline Industry Data

Year	Output (billions of ton-mile)	Pipeline Mileage (thousands of miles)	Average Haul - Crude Oil (miles)	Average Haul - Refined Products (miles)
1979	608	169.794	852	436
1980	588	172.673	878	444
1981	564	172.815	834	474
1982	566	172.549	804	480
1983	556	167.819	788	469
1984	568	173.922	799	470
1985	564	171.401	778	471
1986	578	170.014	772	475
1987	587	167.865	795	462
1988	604	170.457	795	462

EOC: Oil Pipelines

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	8,755	8,931	8,888
PNL Analysis			
Output (billions of ton-miles)			604
Emergency Operating Capacity			610.3
EOC Utilization			.9896
EOC in millions of 1982 $			8,981.4

Industry: Electric Utilities

General Discussion: Electric utilities build powerplants, transmission systems, and distributions systems to meet expected peak loads and to provide reserve capacity for unexpected loads and unplanned outages. As a result, there is built-in excess capacity. As long as peak loads do not increase, annual generation can be increased by a large factor, without increasing system capacity. However, available capacity will limit the increase in output during peak periods (typically during afternoon hours in summer and winter). EOC can be considered in terms of planning increased output during nonpeak periods, especially the hours 12 midnight to 6:00 AM.

Output Measure: There two measures of output to consider:

- peak output - This is instantaneous demand on generation and is measured in megawatts (MW).

- annual generation - This is the total amount of electricity generated during a year and is measured in kilowatthours (kWh).

Input Measures: Key input will be capital stock, measured by generating capacity. Transmission and distribution capacity are keyed to generating capacity. There may be capacity constraints affecting individual industrial plants that use electricity, but that involves too detailed a level for our interests in this project. Generating capacity is measured in MWs and is usually adjusted for availability (based on planned maintenance and unplanned equipment failures).

Generating capacity defines output potential; however, fuel is required to actually generate electricity, and fuel may be the most likely constraint on EOC for the electric utility industry. Electric utilities typically are not labor-intensive, except for transmission and distribution maintenance and customer service. Labor supply is a factor only for nuclear powerplants because of the specialized skills involved. However, because nuclear powerplants typically operate at full capacity under normal conditions, labor is not a factor affecting EOC.

Emergency Operating Capacity Measure: Two measures of EOC will be examined, peak capacity and annual generation. Peak capacity will measure the maximum system capacity at a given moment of time, while annual generation will measure actual generation assuming that emergency demand can be spread over the year, as opposed to being concentrated at peak hours.

Primary Data Sources:

- North American Electric Reliability Council, 1989 Electricity Supply and Demand, October 1989. (NERC)

Secondary Data Sources:

- Energy Information Administration, Annual Outlook for Electric Power, 1989.

Preliminary Calculations:

(From NERC)

1989 summer peak load = 529,460 MW

(Summer peak load exceeds winter peak load for the U.S. as a whole)

1989 installed capacity (summer) = 661,580 MW

(Summer capacity is less than winter capacity because higher cooling requirements limit summer generating capabilities)

Ratio of installed capacity to peak load = 1.249537

This represents a potential of about 25 percent for increased output. However, this increase does not allow any margin for unplanned equipment failures or other disruptions, and service would be very unreliable.

1989 net energy for load = 2,768,858 million kWh

Potential net energy for load, based on maximum use of available capacity (assuming summer rating): 661,580*8760 = 5,795,441 million kWh

Potential net energy for load, based on 1989 peak load:
529,460*8760 = 4,638,069 million kWh

This represents a 67.5 percent increase over actual net energy for load in 1989. Key factors that may restrict increased output are

- fuel availability
- possible transmission bottlenecks (which may not be crucial since the peak load generation is deliverable).

EOC: Electric Utilities

	1986	1987	1988	1989
BLS Oata				
Output (millions of 1982 $)	120,297	124,045	129,883	
PNL Analysis				
Output (billion kWh)				2,768.9
Emergency Operating Capacity				4,638.1
EOC Utilization				.597
EOC in millions of 1982 $				217,559.5
Alternate PNL Analysis				
Output (peak load) (MW)				529,460
EOC 2				661,580
EOC 2 Utilization				.800
EOC 2 in millions of 1982 $				162,353.8

Industry: Natural Gas Utilities

General Discussion: As a public utility industry, gas utilities are under an obligation to provide service on demand. There are two constraining factors, availability of natural gas and transmission and distribution capacity. The supply of natural gas is treated in the analysis of the petroleum and gas extraction industry. For the gas utility industry, the supply of natural gas is an exogenous input. The key factor in defining EOC for the pipelines and distribution companies that make up the industry is the capacity of the transmission and distribution system. Because the demand for natural gas is characterized by peaks (especially during the winter heating season), we can use peak demand to identify the minimum EOC by extending peak sales throughout the year. We know that the industry has the physical capacity to provide an amount of natural gas to its customers equal to some peak value and can conclude that the industry could provide that much gas throughout the year, assuming that the gas itself is available.

Output Measure: Output can be defined as physical quantities of gas sold to end users, measured in either cubic feet of gas or Btu of gas energy. Since the data we are using uses Btu as the measure of sales, we will use Btu as our measure of output.

Input Measures: Our peak sales analysis does not require measures of inputs. The critical input is the supply of natural gas, which is treated as an exogenous variable for our purposes.

Emergency Operating Capacity Measure: EOC will be measured as annual sales (in trillions of Btu) based on maintaining a volume of sales equal to the peak monthly sales during the period 1965 to 1987 (the last year for which we currently have data). Data from the American Gas Association show that January 1982 had the highest level of monthly sales for this period.

Primary Data Sources: American Gas Association (AGA), 1988 Gas Facts, (Arlington, VA: 1988)

Secondary Data Sources: None

Preliminary Calculations:

A. AGA data show that 1972 had the highest annual sales = 17,082.1 trillion Btu as compared with 1987 sales of 10,543.2 trillion Btu.

B. January 1972 sales (peak month for the period 1965-1987) = 1,964.4 trillion Btu

Annualized equivalent = 23,572.8 trillion Btu.

EOC: Natural Gas Utilities

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	89,504	85,264	87,059
PNL Analysis			
Output (trillions of Btu/year)		10,543.2	
Emergency Operating Capacity		17,082.1	
EOC Utilization		.6172	
EOC in millions of 1982 $		138,144.8	
Alternate PNL Analysis			
EOC 2		23,572.8	
EOC 2 Utilization		.4473	
EOC 2 in millions of 1982 $		190,635.8	

Industry: Telecommunications Services

General Discussion: The FGK method was used to estimate EOC for the telecommunications services industry. An alternative method would be to assume that peak load on the telecommunications sector could be extended throughout the year. This alternative would imply a very large EOC, but requires the assumption that business (as opposed to personal) calls, data transmission, fax transmission, etc., could be made outside of normal business hours (even assuming longer hours during an emergency), without disrupting business activities and reducing the utility of telecommunications. Nonetheless, this alternative approach does suggest that our estimate of EOC using the FGK method may be conservative and actual EOC may be higher.

Output Measure: Output is measured by revenue in 1982 constant dollars. Using revenue allows us to account for multiple outputs (local calls, long-distance calls, fax, data transmission, etc.), while a single physical measure (such as number of calls) would not.

Input Measures: Inputs are production workers and capital stock.

Emergency Operating Capacity Measure: None.

Primary Data Sources: Data for output and production workers were obtained from the 1989 U.S. Industrial Outlook, published by the Department of Commerce. Data on capital stock are from the Office of Business Analysis, U.S. Department of Commerce, Capital Stock Data Base. Input and output data are listed in Table C.7.

Secondary Data Sources: None

Preliminary Calculations: The FGK analysis showed that the industry was operating on the production frontier for all inputs in 1986. When the linear programming problem was solved using only capital stock as an input, output was $96,570 million or 2.004 percent above actual output. The translates to an EOC utilization rate of 97.96 percent.

TABLE C.7. Telecommunications Services Industry Data

Year	Output (millions of 1982 dollars)	Capital Stock (millions of 1982 dollars)	Labor (thousands)
1979	66450	2.654	789.0
1980	72180	2.817	795.0
1981	77080	2.976	796.0
1982	78890	3.107	790.0
1983	83290	3.229	720.0
1984	89490	3.351	731.0
1985	90860	3.479	694.0
1986	94600	3.616	667.0

EOC: Telecommunications Services

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	96114	99626	105282
PNL Analysis			
Output	94600		
Emergency Operating Capacity	96570		
EOC Utilization	0.9796		
EOC in millions of 1982 $	98115.56		

Industry: Banking

General Discussion: For our purposes, banking activities can be divided into three categories: making and servicing loans, transactions (e.g., deposits and withdrawals) involving bank tellers, and check processing and electronic fund transfers. This division reflects the different types of resources and capacity required to perform each function. For measuring EOC, we will focus on the checking and electronic fund transfers activity. There are several reasons for this decision.

Although transactions involving bank tellers (in person deposits and withdrawals) may typify "banking" for many people and account for a substantial share of a bank's resources, the development of automatic teller machines (ATMs) has enormously increased the capacity of the industry to provide this type of service, especially when combined with electronic fund transfers. Since ATMs operate 24 hours per day and can be located virtually anywhere, we do not see any practical limit on EOC for in-person transactions.

The making and servicing of loans is the other visible aspect of banking for most people. The capacity to make loans (assuming the availability of funds to lend) depends on the bank's capacity to review the often complex technical and legal details of the proposed loan, the borrower's ability to repay the loan, risks, etc. This activity tends to be labor-intensive, so the ability to respond to an increase in the demand for loans requires an increase in the number of loan officers. We do not see any effective way to measure the potential for expanding the number of loan officers.

The check processing and electronic fund transfers are largely invisible to bank customers, but these are processing key activities and a potential bottleneck for the industry. In fact, the movement of funds is the one unique characteristic of the banking industry, since other industries can provide loans or opportunities for savings accounts. (Checking accounts at savings and loans, credit unions, or investment houses are actually serviced by the commercial banks.)

Data on check processing are available from the Bank Administration Institute (BAI). In 1986, labor productivity in check processing was 825 items (checks and other instruments) per hour. In 1982, productivity was 693 items per hour. At the same time, in 1986, 16.1 percent of the institutions covered in the study reported productivity over 1,250 items per hour. While differences in processing and work mix account for part of the differences in productivity, the BAI suggests that it is probable that other institutions could benefit from the methods used by the most productive institutions. If all check processing institutions were able to process 1,250 items per hour under emergency conditions, then EOC would be 51.52 percent above 1986 output, or 80.38 percent above 1982 output, with no increase in labor hours.

Output Measure: Output is measured as items processed per labor hour.

Input Measures: None

Emergency Operating Capacity Measure: EOC is measured as potential items processed per labor hour, assuming no increase in labor hours.

Primary Data Sources: Bank Administration Institute, BAI Survey of the Check Collection System, (no date).

Secondary Data Sources: Federal Reserve Bank, Functional Cost Analysis: 1987 National Average Report, Commercial Banks, (no date).

EOC: Banking

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	103,870	106,242	109,839
PNL Analysis			
Output			
Emergency Operating Capacity			
EOC Utilization	.66		
EOC in millions of 1982 $	157,378		

Industry: Hotels and Lodging Places

General Discussion: Capacity in the hotel and lodging industry can be simply defined in terms of the number of rooms or beds available per night. Usage reflects the percentage of rooms or beds actually occupied per night. However, because of seasonal factors, usage is typically measured in terms of available room-nights or bed-nights per year.

In 1988, there were approximately 2.87 million hotel, motel, and motor hotel rooms. In 1986, the industry as a whole had a 64.7 percent room occupancy rate. Double occupancy accounted for 55.2 percent of occupied rooms. We will apply these rates to the 1988 data on the number of rooms (in the absence of more recent occupancy data). The 64.7 percent room occupancy rate represents 677.76 million room-nights (i.e., one room occupied by at least one person for one night). Of these 677.76 million room-nights, about 374.13 million were double occupancy, accounting for 748.25 million person-nights of double occupancy. Total person-nights, assuming the rest of the rooms were single occupancy, was 1,051.88 million person-nights or bed-nights.

EOC is estimated by assuming that all rooms would be double occupied every night of the year (which also assumes that each room has two beds). This means taking the number of rooms, 2.87 million, and multiplying by the number of days per year, then multiplying by 2. This yields 2,095.10 million person-nights of capacity. If we allow for maintenance, we can assume that full occupancy accounts for 90 percent of available bed-nights or 1,885.59 million person-nights.

Output Measure: Person-nights

Input Measures: Number of rooms, assuming two beds per room

Emergency Operating Capacity Measure: Person-nights per year

Primary Data Sources: American Hotel and Motel Association pamphlet showing the number of rooms in 1988.

U.S. Department of Commerce, 1988 U.S. Industrial Outlook.

Secondary Data Sources: None

Preliminary Calculations: (Included in the general discussion)

EOC: Hotel and Lodging Places

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	44,110	46,126	48,714
PNL Analysis			
Output (million bed-nights per year)			1,051.88
Emergency Operating Capacity			1,885.59
EOC Utilization			.5579
EOC in millions of 1982 $			87,316

Industry: Computer and Data Processing Services

General Discussion: This is one of the fastest growing industries in the United States, and output is currently constrained by available capacity. We assume, therefore, that no additional output is available and the EOC utilization equals 100 percent. Of course, resources within the industry may be redirected into defense-related activities, but at the expense of other users of these services.

Output measure: None

Input measures: None

Emergency Output Capacity Measure: None

EOC: Computer and Data Processing Services

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	56,214	59,849	62,451
PNL Analysis			
Output			
Emergency Operating Capacity			
EOC Utilization			1.00
EOC in millions of 1982 $			62,451

Industry: Automotive Repair Shops and Services

General Discussion: A utilization rate of 60 percent was given by the Duffy-Vinet Institute. This rate was applied to the dollar volumes listed in the 1982 Census of Retail Trade. The emergency capacity was estimated by calculating the dollar volume of business that would be generated at 100 percent utilization.

Output measure: Total Dollar Volume of Sales

Input measures: Service Bays

Emergency Operating Capacity Measure: $19,118,288,333 in Total Annual Sales

Primary data sources: 1982 Census of Retail Trade
Duffy-Vinet Institute

Secondary Data Sources: None

Preliminary Calculations:

# of Service Bays	82,704
# of Establishments	18,932
Total $ Volume of Business	$11,470,973,000
Avg $ Volume	$138,699.13
Util. Rate	60.00%
Emergency Capacity	(Utilization Rate = 100%)
Total $ Volume of Business	$19,118,288,333
Percentage Increase	66.67%
Avg $ Volume	$231,165.22
Percentage Increase	66.67%

EOC: Automotive Repair Shops and Services

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	42,167	43,848	44,939
PNL Analysis			
Output			
Emergency Operating Capacity			
EOC Utilization			.60
EOC in millions of 1982 $			74,732

Industry: U.S. Postal Service

General Discussion: The postal service reports that it handles 161 billion pieces of mail each year. (It is not clear whether this is for 1988 or 1989). One eleventh (1/11) of the volume is handled in the 4-week period between Thanksgiving and Christmas. Using the mail class percentage breakdowns of the 1987 data, the approximate volumes of each class of mail handled were derived. The 1/11 holiday volume was calculated and then multiplied by 13 to get the capacity volume if the holiday volume were to be maintained for an entire year.

Output measure: Pieces of Mail Handled Per Day

Input measures: None

Emergency Operating Capacity Measure: 190,391 Million Pieces of Mail Handled Per Year

Primary Data Sources: "Statistical Abstract of The U.S. 1989"

Secondary Data Sources: Communications Dept., U.S. Postal Service

Preliminary Calculations:

		Pieces of Mail (millions)	Percentage
1987	Total	153931	
	1st Class & Airmail	78933	51.28
	Priority	354	0.23
	2nd Class	10324	6.71
	3rd Class	59734	38.81
	4th Class	615	0.40
	Penalty	2645	1.72
	Franked and Free for the Blind	548	0.36
	International	778	0.51
			100.00%

	Pieces of Mail (millions)	Percentage	1/11	x 13	Percentage Increase
Total	161100	100.00	14645	190391	18.18
1st Class & Airmail	82609	51.28	7510	97629	18.18
Priority	370	0.23	34	438	18.18
2nd Class	10805	6.71	982	12769	18.18
3rd Class	62516	38.81	5683	73883	18.18
4th Class	644	0.40	59	761	18.18
Penalty	2768	1.72	252	3271	18.18
Franked and Free for the Blind	574	0.36	52	678	18.18
International	814	0.51	74	962	18.18

EOC: U.S. Postal Service

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	29,068	30,535	31,092
PNL Analysis			
Output (billions of pieces of mail)			161.1
Emergency Operating Capacity			190.4
EOC Utilization			.8462
EOC in millions of 1982 $			36,743.1

Industry: Doctors and Dentists

General Discussion: Our analysis of doctors' practices will use number of patient visits per hour for physicians, which we will assume also applies to dentists, to estimate the utilization rate for physician services. Data from the American Medical Association (AMA) show that, in 1988, the average physician in active practice spent 58.2 hours per week in professional activities. Of these hours, 49.5 were spent directly caring for the patient. These data suggest that there is little potential for expanding physician hours. Instead, we will focus on the number of patients treated per hour of direct care activities.

The AMA data show that the average physician has 121.1 patient visits per week, or 2.4465 visits per hour. We then looked at regional data, reported by the AMA for Census divisions, to identify a range of patient visits and hours of direct care activities. The East South Central region showed the highest number of hours and patient visits. In that region, the average physician spent 54.0 hours per week in direct patient care activities and saw 158.4 patients per week. This averages 2.9333 patients per hour. We assume that 2.9333 patient visits per hour is maximum output or capacity. This means that, on average, capacity utilization is .834.

Output Measure: Patient visits per hour

Input Measures: Patient visits per week and hours per week for direct patient care activities.

Emergency Operating Capacity Measure: EOC is the inverse of capacity utilization, or 1.199 times 1988 output.

Primary Data Sources: AMA Center for Health Policy Research, Socioeconomic Characteristics of Medical Practice, 1989, Chicago, Illinois, 1989.

EOC: Doctors and Dentists	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	93,242	95,220	100,203
PNL Analysis			
Output (patient visits per hour)			2.4465
Emergency Operating Capacity			2.9333
EOC Utilization			.8340
EOC in millions of 1982 $			120,147.5

Industry: Hospitals

General Discussion: The approach to measuring hospital EOC uses the FKG methodology to measure current capacity utilization. This provides a measure of how much additional output can be obtained from existing fixed factors, using the "best practices" from among current industry operations. Data are used for total hospital patient-days, beds, doctors, other personnel, and admissions for each of nine census divisions. The FKG methodology is applied using two variants. In one, output is measured in patient-days. In the other, output includes patient-days, surgical operations, and outpatient visits. The latter variant is provided for purposes of comparison. In addition, a simple measure of occupancy rates is also provided for comparison.

Output Measure: The primary output measure is patient-days per year. This measure captures the primary function of hospitals as places where patients stay for treatment and/or recuperation. Other hospital functions include surgical operations and other specialized treatment; treatment of outpatients, including emergencies that do not require overnight stays; and other forms of ambulatory treatment that do not require overnight stays. The principal demand on hospital resources is for in-patient care (i.e., situations in which patients spend one or more nights in the hospital). While diagnostic and treatment facilities are increasingly complex and expensive, they are perhaps more appropriately treated as inputs to physician services than as necessary services provided by hospitals. Many of these services can be provided by other types of health care organizations (such as clinics, doctors offices, etc.), while in-patient services are, by definition, provided by hospitals; therefore, we will focus on patient-days. However, other outputs, such as surgical operations and outpatient visits will be discussed.

Input Measures: The essential inputs for hospitals are some measure of physical capacity to provide in-patient care, doctors, other labor (including nurses and non-medical staff), and patients (an intermediate input comparable to crude oil in petroleum refining). Based on available data, we will use beds as the measure of physical capacity. This decision assumes that other physical plant, buildings, kitchens, medical facilities, etc., are scaled to the number of beds in a hospital. Doctors are measured by full-time equivalent (FTE) physicians plus residents, since residents provide much of the medical service in hospitals. Other personnel are also measured in FTEs. Patients are measured by admissions.

Emergency Operating Capacity Measure: The FGK methodology provides an estimate of capacity utilization. If current utilization equals x percent, then EOC is equal to one plus (1-x percent) times current output.

Primary Data Sources: The data source for the hospital industry is the 1989-1990 edition of Hospital Statistics, published by the American Hospital Association. The data are reported for 1988.

Secondary Data Sources: None

Preliminary Calculations:

A. Hospital Statistics provides data by census division on each of the output and input measures we will be using. The only preliminary calculations involve adding FTE physicians, residents, and registered nurses; licensed practical nurses; and other salaried staff to obtain labor input measures. The regional data are listed in Table C.8.

B. The FGK methodology involves solving two linear programming problems for each census division; annual patient-days are the single measure of output. The first problem uses all inputs in the constraint set, while the second uses only fixed inputs, in this case, beds. The ratio of the maximum value in the first problem to the maximum value in the second problem equals capacity utilization. The estimates of regional capacity utilization are given in Column 1 of Table C.9.

C. An alternative approach using multiple outputs (patient-days, surgical operations and outpatient visits) was also tried. This approach was based on Fåre, Grosskopf, and Valdamis (FGV),[a] "Capacity, Competition, and Efficiency in Hospitals: A Nonparametric Approach," Journal of Productivity Analysis (June 1989). Details of the approach using multiple outputs are described in the FGV article and in Fåre, Grosskopf, and Knox Lovell (1985).[a] The results of the use of the FGV methodology are given in Column 2 of Table C.9.

D. A third approach to measuring hospital EOC is simply to take the occupancy rate as our measure of capacity utilization. Data on occupancy rate by census division were obtained from Hospital Statistics. The occupancy rate is calculated as number of beds times days per year (366 in 1988, a leap year) divided into actual patient-days. Occupancy rates are reported in column 3 of Table C.9.

E. The actual measure of hospital EOC is the reciprocal of the capacity utilization rate, which gives EOC as a percentage of current usage. Therefore, if the utilization rate is 0.8, the reciprocal is 1.25, and EOC equals 125 percent of current use (i.e., output can be expanded by 25 percent over current output during an emergency). Table C.10 gives hospital EOC for each of the three measures of capacity utilization. Note that in the case of the multiple-output FGK method, EOC applies to all three outputs proportionally.

F. The occupancy rate approach yields consistently higher EOCs than either version of the FGK approach, while the multiple-output FGK yields lower EOCs than the single-output FGK approach. However, rank order is not consistent across the three approaches. Division 6 has the highest EOC using the single-output FGK method, while Division 7 has the highest EOC using the multiple-output FGK method and the occupancy rate (but has only the third highest EOC under the single-output approach).

(a) See Section D.3 for reference citation.

The single-output FGK method seems to be the most useful for FEMA's purposes. The occupancy rate probably overstates available capacity because it does not take into account other inputs or scheduling problems. For example, assume that a given bed in a hospital is used every four days out of five and that each patient stays four days. This produces an occupancy rate of 0.8 and an EOC of 125 percent. The problem is that the bed is actually available only one day at a time, so that any additional patients that require more than one day of care cannot be accommodated. The single-output FGK approach corrects for this problem by basing capacity utilization on the observed maximum utilization of beds, which takes scheduling into account. The problem with the multiple-output FGK approach is that utilization measures take into account outpatient visits as well as in-patient days, and these are not really tied to the available resources for treating patients in-house (except labor services). If we assume that hospitals will reallocate their resources to concentrate on patients that can only be treated in hospitals (and directing others to doctor offices and clinics), then the multiple-output method understates EOC.

G. If we take the weighted average of the census division EOCs, using beds for weights, national hospital EOC equals 113.38 percent of 1988 patient days.

TABLE C.8. Regional Data for the Hospital Industry, 1988

Census Division	Patient-days (millions)	Physicians and Residents (thousands of FTE)	Other Personnel (thousands of FTE)	Admissions (millions)	Beds (thousands)
1	19.829	11.936	241.836	1.738	69.984
2	64.831	36.941	689.960	5.582	218.041
3	54.994	21.192	653.850	6.093	214.041
4	51.484	22.730	633.479	5.878	211.994
5	21.433	4.985	237.533	2.543	90.267
6	26.447	7.645	299.405	2.588	112.309
7	29.492	9.679	373.475	3.719	135.205
8	13.099	4.423	170.328	1.642	56.447
9	34.164	15.223	456.289	4.324	139.572

Census Division	Surgical Operations (millions)	Outpatient Visits (millions)
1	1.233	21.233
2	3.659	58.809
3	4.033	55.392
4	4.148	62.480
5	1.493	18.251
6	1.777	23.645
7	2.373	29.623
8	1.061	19.486
9	2.765	47.288

Source: Hospital Statistics, 1989-1990 Edition, American Hospital Association, Table 5B.

TABLE C.9. Estimates of Capacity Utilization for the Hospital Industry, 1988

Census Division	Single-Output FGK Method	Multiple-Output FGK Method	Occupancy Rate
1	0.9701	1.0000	0.774
2	1.0000	1.0000	0.813
3	0.8754	1.0000	0.701
4	0.8903	0.9895	0.664
5	0.7986	0.8907	0.649
6	0.7920	0.8661	0.644
7	0.8256	0.8881	0.597
8	0.8394	1.0000	0.636
9	0.8935	1.0000	0.669

Source for occupancy rates: Hospital Statistics, 1989-1990 Edition, American Hospital Association, Table 5B.

TABLE C.10. Estimates of Emergency Operating Capacity for the Hospital Industry, as Percentages of 1988 Output

Census Division	Single-Output FGK Method	Multiple-Output FGK Method	Occupancy Rate
1	1.0308	1.0000	1.2920
2	1.0000	1.0000	1.2300
3	1.1423	1.0000	1.4265
4	1.1232	1.0106	1.5060
5	1.2522	1.1228	1.5408
6	1.2626	1.1546	1.5528
7	1.2112	1.1260	1.6750
8	1.1913	1.0000	1.5723
9	1.1192	1.0000	1.4948

EOC: Hospitals

	1986	1987	1988
BLS Data			
Output (millions of 1982 $)	104,806	110,968	114,943
PNL Analysis			
Output			NA
Emergency Operating Capacity			NA
EOC Utilization			.882
EOC in Millions of 1982 $			130,322.4

APPENDIX D

TECHNICAL NOTES RELATED TO PRODUCTION FRONTIERS

APPENDIX D

TECHNICAL NOTES RELATED TO PRODUCTION FRONTIERS

D.1 NOTES ON THE MEASURES OF CAPACITY UTILIZATION

This section provides some additional technical discussion of how production frontier analysis can be applied to estimate EOC.

D.1.1 General Method

The following methodological discussion is based on a recent article by Färe, Grosskopf, Kokkelenberg (1989). Assume there are k = 1 ... K observations (which can be time series or cross section, and which can be defined over an industry, firms, establishments, or activities). Each observation consists of output, u^k, and inputs x^k. Output is assumed to be a scalar (i.e., $u \in R_+$) and inputs are assumed to be an N-vector ($x^k \in R_+^N$). We assume that each observation uses some input, each input is used by at least one observation, and each observation shows non-zero output.

We then define maximum potential output for each observation, κ, as the solution of the linear programming problem

Find $z^\kappa \in R_+^K$ that maximizes

$$\phi(x^\kappa) = \sum_{k=1}^{K} z^k \cdot u^k \tag{D.1}$$

subject to

$$\sum_{k=1}^{K} z^k \cdot x_n^k \le x_n^\kappa, \text{ for } n = 1 \ldots N, \; z^k \ge 0 \text{ for all } k.$$

The k elements of the z^κ vector are weights or intensity variables that are applied to each of the observed outputs to determine how much each observed output contributes to the maximum of the objective function ϕ for observation κ. In the solution to the linear programming problem (D.1), the non-zero elements of z^κ are included in the basis of the solution and the number of non-zero elements is equal to or less than the number of observations defining the basis, which equals the number of constraints in the linear programming problem. When the number of non-zero elements of z^{κ} is less than the number of constraints, then the basis includes slack variables.

In non-technical terms, the linear programming methodology can be thought of as a way to identify those observations that represent the most efficient use of inputs from among the available observations. These "best practice" observations are included in the basis of the linear programming solution, where the basis in this case is the fewest number of observations needed to define the optimal solution to the problem. Slack variables enter the basis when the optimal amount of one or more factors is less than observed amount.

The linear programming problem can be set up in two ways, depending on the specific problem we wish to address. One way is to use time series data and the other is to use cross-section data. The choice of time series or cross section data depends on the available data for a given industry, and both methods are used in our estimation of capacity utilization. When time series data are available, the constraints of the linear programming problem are defined in terms of the levels of factor inputs in the most recent observation, which is the observation for which we are estimating capacity utilization. In this case, the non-slack variable elements of the basis of the solution identify those years that represent the most efficient use of factor inputs.

When cross-section data are used, the linear programming problem must be solved for each separate observation. Using that observation's factor inputs to define a set of constraints, the linear programming solution finds the set of production relations across the entire set of observations that maximizes output (subject to the input constraints). Capacity utilization is defined by measuring the extent to which the optimal levels of inputs are less than the constraint levels. To develop an overall measure of capacity utilization for the entire set of observations, the results from the individual observations need to be aggregated by means of a weighting procedure.

D.1.2 The Färe-Grosskopf-Kokkelenberg Approach and EOC

As described above, the Färe-Grosskopf-Kokkelenberg (FGK) approach addresses the issues of capacity, factor utilization, and technological progress by applying Equation (D.1) to various combinations of observations and input vectors. Applied to the case of measuring EOC, the FGK approach defines problem (D.1) using only physical capacity. That is, there is only one constraint for each linear programming problem. Designate $\phi^{*}(x_1^{\kappa})$ as the solution to (D.1) for observation κ for capital as the only input (i.e., let n = 1 denote capital). If the observations represent time series data for an industry, firm, plant or activity, we can let T designate the last observation (i.e., the most recent data) and simplify our notation so that ϕ^{*T} designates the maximum output for the observed entity subject to available capital in the most recent observation. It should be noted that in the case of one fixed factor using time series data, the basis of the solution to the linear programming problem identifies the year in which the output/capital ratio is the highest. In this case, there is only one constraint and therefore the basis has only one observation.

ϕ^{*T} satisfies Johansen's[a] definition of capacity, "... the maximum that can be produced per unit of time with existing plant and equipment, provided that the availability of variable factors of production is not restricted." If we then let ϕ'^{T} be the optimal solution for the linear programming problem that includes all of the inputs in the constraints (so that ϕ'^{T} represents the maximum attainable output given the available fixed and variable inputs of observation T), the ratio

$$\frac{\phi'^{T}}{\phi^{*T}} \tag{D.2}$$

is the capacity utilization rate for capital (i.e., plant and equipment). This measure of capacity utilization differs from conventional measures because Equation (D.2) measures output potential corrected for efficiency. ϕ'^{T} corresponds to Output1 and ϕ^{*T} corresponds to Output2 in the capacity utilization equation from Section 6.2.2 [Equation (6.1)].

Corresponding to ϕ^{*T} is a solution vector $\mathbf{z}^{T}$. Applying this vector to the observations on the other (i.e., non-capital) inputs yields a measure of the utilization rates of these other inputs, again adjusted for efficiency. At observation T, this measure is the ratio

$$\frac{x_n}{\sum_k z^k \cdot x_n^k}, \; k = 1 \;..\; K, \; n = 1 \;...\; N. \tag{D.3}$$

Productivity growth (termed "capacity technical progress" by FGK) can be measured (although only for time series data) by solving Equation (D.1) for two different ending observations, say T and T+1. The ratio

$$\frac{\phi^{T}}{\phi^{T+1}} \tag{D.4}$$

(a) Cited in Färe, Grosskopf, and Kokkelenberg (1989).

then is a measure of productivity change over the period k = 1 ... T+1. However, to avoid problems that may arise from using different numbers of observations, a "window" technique can be used so that k = 1 ... T in solving for the numerator of Equation (D.4) and k = 2 ... T+1 in solving for the denominator.

There are two versions of Equation (D.4). Diewert (1980) calculates Equation (D.4) using constraints on all inputs. FGK calculate Equation (D.4) using only capital (or generically, fixed inputs).[a] Note that this concept of productivity differs from the BLS approach. BLS addresses only labor productivity, which is defined as output per labor hour. The measure of productivity defined by Equation (D.4) is total factor productivity and refers to the increase in output over time after eliminating output increases caused by increasing labor, capital and other measured inputs. There is a massive body of literature on total factor productivity but it is outside the scope of this report.

Equations (D.2) and (D.3) are directly applicable to measuring EOC. Equation (D.2) tells us how much additional output could increase, given the available capital stock, by increasing the variable inputs (typically labor and intermediate inputs, such as material and energy). Equation (D.3) provides information about the typical utilization of labor and intermediate inputs as compared with the most efficient utilization. In addition, the solution of the basic linear program [Equation (D.1)] using all inputs as constraints can provide information about which factors of production are constraining factors. For example, if capital stock is not a binding constraint, then capital stock will not be the limiting factor in EOC. Inputs that are binding constraints in the solution to Equation (D.1) are limiting factors in EOC.

Shift factor analysis can also be integrated into the production frontier analysis. If, for example, a given industry faces a binding constraint for labor in the solution to Equation (D.1) and capital is not binding, we can then look at data on shift factors for that industry. An industry reporting multiple shifts, but averaging well below three shifts suggests that the industry operates multiple shifts at various times in response to fluctuations in demand. This in turn implies that output can be expanded by increasing the number of shifts or using multiple shifts for a larger part of the year. If, however, capital is a binding constraint and the industry reports that it operates three full shifts over the year, then output is likely to be constrained to current levels in the short run.

(a) It is also possible to develop a method for decomposing the productivity change given by Equation (D.4) into changes in technology, efficiency, and factor use, although this would likely involve use of pooled time-series/cross-section data.

D.2 PRODUCTION AND COST FRONTIERS

The Färe-Grosskopf-Kokkellenberg (FGK) methodology uses a non-parametric linear programming approach to estimate emergency operating capacity (EOC) based on observed best practice performance by an industry. The use of observed best practice performance can limit the estimate of EOC, especially in the case where the observed best practice does not involve the full employment of available quasi-fixed factors of production (i.e., those factors that are fixed in the short run, such as capital stock). An alternative approach is to develop a parametric model of the production process that can be used to estimate what output would be if quasi-fixed factors were fully utilized.

Cost frontier analysis is a way to define the minimum cost of producing a given output, based on the most efficient observed use of inputs. Much of the interest in production and cost frontier analysis stems from the use of these frontiers to measure the efficiency of production by firms in a given industry or of plants within a given firm. These efficiency measurements are derived from concepts introduced by Farrell (1957).

Figure D.1 illustrates Farrell efficiency measures. The isoquant Q represents the various combinations of inputs x_1 and x_2 that produce output level q. The isocost line is P and E, representing the optimal (least cost) input mix for producing q. Point A is the observed levels of x_1 and x_2. Point B marks the intersection of q and the line from the origin 0 to A. Point C marks the intersection of the isocost line and the ray OA. According to Farrell, overall productive efficiency, OE, is composed of technical efficiency, TE, and allocative efficiency, AE. These are defined as

$$TE = OB/OA$$

$$AE = OC/OB$$

$$OE = TE \cdot AE = (OB/OA) \cdot (OC/OB) = OC/OA.$$

Technical efficiency is a measure of how far the observed input mix is from the isoquant, while allocative efficiency is a measure of how far the isoquant is from the isocost line, both measured along the ray OA. Overall efficiency measures how far the observed inputs, A, are from the isocost line along the

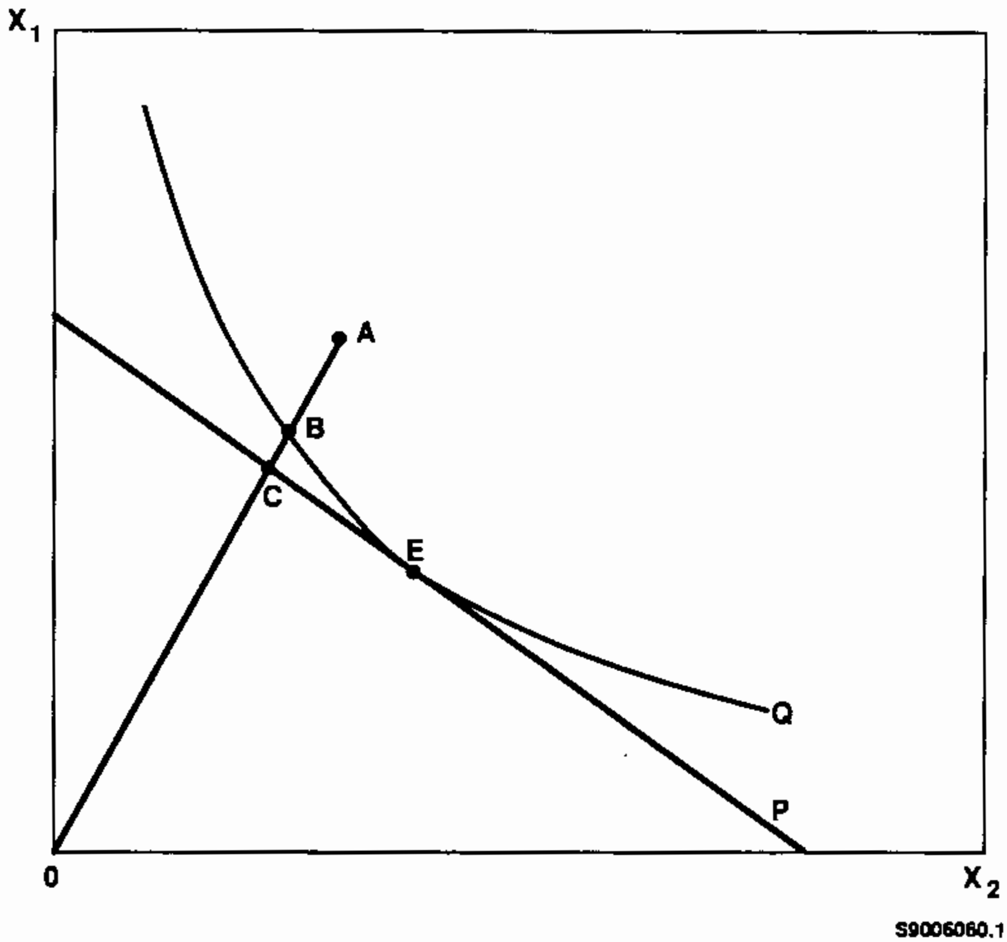

FIGURE D.1. Illustration of Farrell Efficiency Measures

ray OA.[a] The Farrell measures suggest a way to estimate EOC based on the existing capital stock and the long-run competitive equilibrium defined by factor prices.

The basic concept is as follows:

- Estimate the cost frontier for a given industry to correct for technical inefficiency.

(a) We do not address the issue of the properties required of the production technologies necessary to actually implement the Farrell efficiency measures, except to note that the necessary properties are very minimal. See Färe, Grosskopf, and Lovell (1985) and Grosskopf (1986) for details. See also Kopp (1981). The translog cost function that we will use has far stronger properties than are necessary, but this is more a result of the data we are using than of the analytical requirements.

- Estimate the long-run equilibrium demand for labor and materials, given the available capital stock and factor prices, to correct for allocative inefficiency, especially sub-optimal utilization of the available capital stock.

- Estimate the level of output corresponding to the long-run equilibrium factor demand.

Kopp and Diewert (1982) developed a method for solving for the equilibrium point E (in Figure D.1) by specifying a functional form for the cost frontier, which can be any of a broad class of functions, then simultaneously solving for the parameters of the frontier and the set of equilibrium conditions defined by inputs and input prices. Because the system of equations is non-linear, Kopp and Diewert use a variant of the Davidon-Fletcher-Powell algorithm. The Kopp-Diewert method is not directly applicable to this study because the method is used to find the optimal mix of inputs to produce a given level of output, while we are trying to find the optimal mix of variable factors and the corresponding level of output given fixed factors. Nonetheless, the Kopp-Diewert method does suggest how to approach the problem, which is to estimate the parameters of the cost frontier, then use the share equations and input prices, along with the given level of the fixed factors, to solve for the optimal inputs of the variable factors.

There are several methods for estimating production and cost frontiers.[a] Linear programming can provide a deterministic, non-parametric estimate by finding the free disposal convex hull supporting the observations.[b] Linear programming can also provide deterministic and parametric estimates by specifying a functional form for production or cost, then estimating the parameters of the function by minimizing the sum of differences (or squared differences, in which case the problem involves quadratic programming) between the unknown frontier and the observations. Schmidt (1975) showed that this method is equivalent to maximum likelihood estimation when the frontier is in log form and the random disturbance has an exponential distribution (half-normal in the quadratic programming case). There are two objections to the use of linear programming. First, linear programming methods are subject to outlier problems. Second, linear programming provides no statistical information about the frontier and define a "best practice" frontier based on

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(a) Forsund, Lovell, and Schmidt (1980), van den Broek et al. (1980), and Greene (1980a) survey the various methods for estimating frontier functions.

(b) This approach is used by Färe, Grosskopf, and Kokkelenberg (1989), Färe, Grosskopf, and Lovell (1985), and Diewert (1980). The nonparametric approach (also termed "data envelopment analysis) is also used in the operations research literature on productive efficiency. See for example Banker, Conrad, and Strauss (1986) and Banker, Charnes, and Cooper (1984).

the sample observations rather than a "global" frontier applicable in all cases using the technology (Greene 1980a and Forsund, Lovell, and Schmidt 1980).

Statistical methods have been proposed to address these problems, although not always successfully. The simplest statistical method is corrected ordinary least squares (COLS). OLS is used to estimate the parameters of the production (or cost) function, then the residuals are used to adjust the intercept term to ensure that all observations lie below the frontier (or above, for cost functions)[a]

Maximum likelihood methods include using a single error term that has a one-tailed distribution, such as the exponential, half-normal (which uses the absolute value of a normal density function), or gamma distributions, to account for inefficiencies. These models are sometimes termed deterministic. The problem with this approach is that the range of the error term depends on the estimated parameters, and this makes the properties of the maximum likelihood estimator uncertain (van den Broek et al. 1980). An alternative approach is the composed error model, in which the error term is assumed to have two components, one with a normal distribution (to account for purely random disturbances) and the other with a one-side distribution (such as the half-normal) to account for inefficiencies. This approach, termed stochastic frontier models, has the required regularity conditions for interpreting the maximum likelihood estimator. This approach, however, does not always allow for measuring the efficiency of individual observations, only average efficiency for the sample.[b]

In addition to different estimation techniques and specifications of the error term, a variety of functional forms have been used in estimating production and cost frontiers. For the purposes of this paper, frontiers using translog production or cost functions are of the greatest interest. In common with standard econometric estimation of translog production (or cost) functions, estimation of translog frontiers usually involves simultaneous estimation of the frontier and its corresponding factor share equations to avoid multicollinearity problems that occur in single equation estimation. In addition, Greene (1980b) notes that the residuals from the factor share equations in a translog production frontier estimation can be used as estimates of allocative efficiency, although Greene notes that this is not true for the translog cost frontier. For the purposes of this paper, however, simultaneous estimation of the share equations is inappropriate because that implies that the data are consistent with long-run competitive equilibrium, and we are assuming that the data are not consistent with equilibrium. For example, Nishimizu and Page (1982) measure productivity and technological change for Yugoslavia using linear programming to estimate the parameters of a translog

(a) Olson, Schmidt, and Waldman (1980).
(b) van den Broek et al. (1980). However, Jondrow et al. (1982) show that the composed error model can be decomposed after estimation to allow for measuring the efficiency of individual observations if the error term is half-normal or exponential.

production frontier for pooled time-series/cross-sectional data. Nishimizu and Page argued that assuming competitive equilibrium was inappropriate for Yugoslavia because of that country's socialist economy and that using simultaneous equation methods to avoid multicollinearity would produce erroneous results.

The various methods for estimating production and cost frontiers have been used extensively to measure technical and allocative efficiency in various industries.[a] There are also several applications of frontier analysis to measuring total factor productivity (TFP). Diewert (1980) shows how the non-parametric method can be used to estimate TFP. Time series data on inputs and outputs can be used in a linear programming problem to find maximum potential output from the inputs (i.e., the production frontier) for given time periods, t-1 and t. The ratio of the maximum output in period t to maximum output for period t-1, then, is a measure of TFP change. Färe, Grosskopf, and Kokkelenberg (1989) extend Diewert's method by using only fixed inputs as constraints in solving the linear programming problem. This allows them to measure the effects of changes in fixed inputs on potential output, unconstrained by actual limits on the availability or demand for variable factors. The method developed by Färe et al. also can be used to provide a measure of capacity utilization, which we have used to measure EOC in a number of non-manufacturing industries. This method is somewhat limited, however, because it can only estimate capacity utilization based on the observed best practice utilization. The method we are proposing here extends the approach to find what the best practice would be if an industry was operating at competitive equilibrium.

D.2.1 Using the Translog Cost Frontier to Estimate EOC

Based on the preceding discussion, we proceed as follows:

- First, we use a linear programming problem to find the parameters of a translog cost function consistent with a minimum cost frontier.
- Then, we solve the corresponding share equation for capital, using the given capital stock and prices, to obtain the equilibrium value for total cost.
- Next, we solve for each of the other factor demands, using their share equations and the equilibrium total cost.
- Finally, we solve the translog cost equation for output.

The linear programming problem will be defined to minimize the deviations of observed costs from the unknown cost frontier, subject to the

(a) Beside the references cited in this paper, see Färe, Grosskopf, and Lovell (1985) or Banker and Datar (1987) for additional references to the literature.

constraint that the cost in each period be greater than or equal to the cost frontier, plus other technical constraints to impose at least linear homogeneity onto the production technology represented by the cost frontier.

Assume that the production process involves three inputs, capital, labor, and intermediate product, designated K, L, and M, respectively. Let G denote total cost and Y denote output. Then, the translog cost function is given by

$$\begin{aligned}\ln G = {} & \ln \alpha_0 + \ln Y + \alpha_K \ln P_K + \alpha_L \ln P_L + \alpha_M \ln P_M \\ & + \beta_{KK}\, 1/2\, (\ln P_K)^2 + \beta_{KL} \ln P_K \ln P_L + \beta_{KM} \ln P_K \ln P_M \\ & + \beta_{LL}\, 1/2\, (\ln P_L)^2 + \beta_{LM} \ln P_L \ln P_M \\ & + \beta_{MM}\, 1/2\, (\ln P_M)^2.\end{aligned} \tag{D.5}$$

Linear homogeneity requires that

$$\begin{aligned}\alpha_0 + \alpha_K + \alpha_L + \alpha_M &= 1 \\ \beta_{KK} + \beta_{KL} + \beta_{KM} &= 0 \\ \beta_{KL} + \beta_{LL} + \beta_{LM} &= 0 \\ \beta_{KM} + \beta_{LM} + \beta_{MM} &= 0.\end{aligned} \tag{D.6}$$

At equilibrium, input demand is given by the cost share equations:

$$\begin{aligned}\frac{P_K K}{G} &= \alpha_K + \beta_{KK} \ln P_K + \beta_{KL} \ln P_L + \beta_{KM} \ln P_M \\ \frac{P_L L}{G} &= \alpha_L + \beta_{KL} \ln P_K + \beta_{LL} \ln P_L + \beta_{LM} \ln P_M \\ \frac{P_M M}{G} &= \alpha_M + \beta_{KM} \ln P_K + \beta_{LM} \ln P_L + \beta_{MM} \ln P_M.\end{aligned} \tag{D.7}$$

where P_G is the price of final output.

Let

$$\ln \hat{G} = \ln \hat{\alpha}_0 + \ln Y + \hat{\alpha}_K \ln P_K + \hat{\alpha}_L \ln P_L + \hat{\alpha}_M \ln P_M + \hat{\beta}_{KK} 1/2 (\ln P_K)^2 + \hat{\beta}_{KL} \ln P_K \ln P_L + \hat{\beta}_{KM} \ln P_K \ln P_M + \hat{\beta}_{LL} 1/2 (\ln P_L)^2 + \hat{\beta}_{LM} \ln P_L \ln P_M + \hat{\beta}_{MM} 1/2 (\ln P_M)^2 \quad (D.8)$$

denote the minimum cost frontier corresponding to (D.5), where the $\hat{\alpha}$ s and $\hat{\beta}$ s are the parameters to be determined.

Then assume that there are data for time periods t = 1 to T. The linear programming problem used to solve for the parameters of the translog cost function is

$$\text{Min } \Sigma_t \left(\ln G(t) - \ln \hat{G} \right) \quad (D.9)$$

subject to

$$\ln \hat{G} \leq \ln G(t), \; t = 1 \text{ to } T$$

$$\hat{\alpha}_K + \hat{\alpha}_L + \hat{\alpha}_M = 1$$

$$\hat{\beta}_{KK} + \hat{\beta}_{KL} + \hat{\beta}_{KM} = 0$$

$$\hat{\beta}_{KL} + \hat{\beta}_{LL} + \hat{\beta}_{LM} = 0$$

$$\hat{\beta}_{KM} + \hat{\beta}_{LM} + \hat{\beta}_{MM} = 0$$

$$\hat{\alpha}_K + \hat{\beta}_{KK} \ln P_K(t) + \hat{\beta}_{KL} \ln P_L(t) + \hat{\beta}_{KM} \ln P_M(t) \geq 0, \; t = 1 \text{ to } T$$

$$\hat{\alpha}_L + \hat{\beta}_{KL} \ln P_K(t) + \hat{\beta}_{LL} \ln P_L(t) + \hat{\beta}_{LM} \ln P_M(t) \geq 0, \; t = 1 \text{ to } T$$

$$\hat{\alpha}_M + \hat{\beta}_{KM} \ln P_K(t) + \hat{\beta}_{LM} \ln P_L(t) + \hat{\beta}_{MM} \ln P_M(t) \geq 0, \; t = 1 \text{ to } T.$$

The last three constraints mean that factor shares must be non-negative.

The objective function can be rewritten

$$\begin{aligned}\text{Min} \quad & \hat{\beta}_{GY}\,(\beta\Sigma_t \ln G(t) - \Sigma_t \ln Y(t)) - T \ln \hat{\alpha}_0 - \hat{\alpha}_K \Sigma_t \ln P_K(t) \\ & - \hat{\alpha}_L \Sigma_t \ln P_L(t) - \hat{\alpha}_M \Sigma_t \ln P_M(t) - \hat{\beta}_{KK}\, 1/2\, \Sigma_t (\ln P_K(t))^2 \\ & - \hat{\beta}_{KL} \Sigma_t (\ln P_K(t) \ln P_L(t)) - \hat{\beta}_{KM} \Sigma_t (\ln P_K(t) \ln P_M(t)) \\ & - \hat{\beta}_{LL}\, 1/2\, \Sigma_t (\ln P_L(t))^2 - \hat{\beta}_{LM} \Sigma_t (\ln P_L(t) \ln P_M(t)) \\ & - \hat{\beta}_{MM}\, 1/2\, \Sigma_t (\ln P_M(t))^2, \end{aligned} \qquad (D.10)$$

where $\hat{\beta}_{GY} = 1$,

which is a more convenient form for a linear programming problem.

Once we have estimated the $\hat{\alpha}$s and $\hat{\beta}$s, we can solve the factor share equations recursively. Note that all factor prices are taken as given. Since we take capital stock as given, the capital share equation can be solved for the corresponding equilibrium cost $\hat{G}$, which can then be used to solve the labor and intermediate share equations for the equilibrium inputs of those factors, $\hat{L}$ and $\hat{M}$, respectively. $\hat{G}$ can also be used in the translog cost equation to solve for the equilibrium level of output, $\hat{Y}$. We do this for each year.

D.2.2 An Illustrative Example

To illustrate the methodology, we estimate the equilibrium adjusted translog EOC using data from Jorgenson, Gollob and Fraumeni (1987). These data were constructed in the form of translog indexes and were used by Jorgenson et al. to estimate TFP change for some fifty industrial sectors.

It was necessary to make certain modifications to the linear programming problem defined in (D.5) - (D.10) in order to obtain a solution that satisfied both the constraint set and economic logic. First, we were forced to drop the assumption of constant returns to scale, replacing

$$\hat{\alpha}_K + \hat{\alpha}_L + \hat{\alpha}_M = 1$$

with

$$\hat{\alpha}_K + \hat{\alpha}_L + \hat{\alpha}_M \geq 0.$$

The subsequent solution to the LP showed returns to scale ranging from about 0.83 to 0.98.

Next, we replaced the inequality constraints on the factor shares with equality constraints, using an iterative process to determine the actual constraint values. We were forced to do this because the LP solution often resulted in one or more factor shares going to zero, which may have made perfect mathematical sense, but made no sense economically. In the first iteration, we constrained the factor shares to equal the observed factor shares. This resulted in an infeasible LP solution, with most of the calculated factor shares violating the equality constraint. Not incidently, this result tended to confirm our basic assumption that the observed data did not conform to a long-run equilibrium in any of the industries we used in our analysis. We then resolved the model, using the last calculated factor shares reported by the LP program before it declared the solution infeasible in the constraints, and recalculating total costs and output according to the procedure outlined above for calculating optimal total costs and output using the last calculated parameters reported by the LP program. This process was repeated until a feasible and optimal solution was obtained. Typically, only one additional iteration was required and the resulting value of the objective function was close to or equal to zero (meaning that the estimated costs and output were at or close to the frontier).

We estimated the cost frontier for seven of the 51 sectors reported by Jorgenson et al.:

- transportation equipment and ordnance, excluding motor vehicles
- motor vehicles
- machinery, except electrical
- fabricated metal
- chemicals and allied products
- primary metal
- rubber and miscellaneous plastic products.[a]

Because each year of data adds four constraints (one each for total cost, capital share, labor share, and intermediate input share) and because of limits on the size of LP that our software could handle, we were forced to restrict the number of years of data to 10, covering the period 1970 to 1979 (the latest year reported by Jorgenson et al.).

Table D.1 reports the estimated frontier parameters for each sector. The only anomalous parameter estimate was the negative value of $\hat{\beta}_{LL}$ in the

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(a) We also attempted to estimate a cost frontier for the electrical machinery sector, but consistently obtained negative factor shares for capital in several years and were forced to drop this sector.

chemical sector, but the estimate is so small that it can be considered effectively zero. Table D.1 also shows the returns to scale parameter (given by the sum of the α_is, i = capital, labor, intermediate inputs).

Table D.2 shows our estimate of output per sector and actual output (both in the form of a Divisia index). For each observation, our estimate was at least equal to actual output and was higher in all but a few cases. This implies that most industries have considerable available capacity that could be utilized in an emergency.

We suggest that there are two reasons for the differences in output. One reason is the cumulative effects of fluctuations in the level of economic activity in the various sectors. The equilibrium adjusted estimates tend to eliminate these fluctuations, except for price effects. The second reason is that the various industries are not operating on their least-cost frontier, even during periods of prosperity. That is, the firms that make up the various sectors may be using too much of the variable inputs (given capital stock) in producing the observed output or may be using too little of the variable inputs to make the most effective use of the available capital stock, depending on input prices.

Table D.3 reports the projected equilibrium levels of inputs, output, and total costs for each sector during the period 1970-1979, while Table D.4 provides the equivalent data from Jorgenson et al. for comparison. Note that the same series for capital input is used in both tables. In the motor vehicles and especially the primary metals sectors, the equilibrium adjusted estimates of factor use and output show more output from less inputs than the historical data from Jorgenson et al., implying that these industries were not operating at minimum cost and had available, unused capacity. In the other industries, the equilibrium factor use exceeded historical factor use (for most years), suggesting that these industries had available capacity that could be used during emergency situations.

These results show that the proposed methodology can provide information for improving estimates of EOC if the appropriate data are developed for a wider range of industrial sectors.

TABLE D.1. Parameter Estimates

Parameter	Trans.	Motor	Mach.	Fab. Met.	Chem.	Prime Met.	Rubber
$\hat{\alpha}_0$	0.070102	0.05725	0.29484	0.25155	0.44487	0.27787	0.2377
α_K	0.036752	0.15770	0.28599	0.20827	0.49477	0.16772	0.2165
α_L	0.30866	0.18034	0.34849	0.23664	0.18699	0.10979	0.37945
α_M	0.60298	0.61242	0.29448	0.51789	0.24923	0.64999	0.36784
β_{KK}	0.000105	0.05478	0.11251	0.067118	0.22698	0.04181	0.065025
β_{KL}	-0.00010	-0.01141	-2.2E-16	-0.06652	-5.2E-14	-0.04181	-0.00139
β_{KM}	-1.1E-16	-0.04337	-0.11251	-0.00058	-0.22698	0	-0.06363
β_{LL}	0.1762	0.01141	0.03024	0.18592	-2.3E-12	0.04181	0.20436
β_{LM}	-0.17609	0	-0.03024	-0.1194	2.4E-12	6.7E-15	-0.20297
β_{MM}	0.17609	0.04337	0.14276	0.11998	0.22698	-6.7E-15	0.2666

TABLE D.2. Actual and Projected Output, 1970-1979

Year	Transportation		Motor Vehicles		Machinery		Fabricated Metals	
	Actual	Model	Actual	Model	Actual	Model	Actual	Model
1970	37.702	39.231	48.271	60.703	56.315	68.233	41.58	43.86
1971	35.18	52.784	61.696	73.352	53.559	72.389	40.524	45.135
1972	35.474	46.742	65.906	74.445	61.979	69.779	43.824	46.524
1973	39.88	69.197	76.391	77.076	72.52	72.520	48.157	48.157
1974	38.716	53.753	64.142	68.779	77.501	94.457	46.133	48.829
1975	37.166	56.85	57.56	74.558	66.567	99.338	39.706	54.273
1976	35.553	53.414	74.728	82.489	70.567	94.686	43.496	56.164
1977	36.491	52.772	85.176	91.238	77.55	91.981	46.742	58.59
1978	41.509	53.274	89.828	93.582	83.431	96.394	50.2	60.337
1979	47.958	50.975	84.594	104.80	88.204	109.54	52.167	60.876

Year	Chemicals		Primary Metals		Rubber	
	Actual	Model	Actual	Model	Actual	Model
1970	48.743	61.937	56.935	73.596	14.243	15.474
1971	50.229	62.791	53.266	72.490	14.94	17.5
1972	54.861	62.382	62.191	78.164	17.47	18.05
1973	60.141	65.067	75.134	77.954	18.884	19.25
1974	62.835	82.038	77.982	84.918	18.191	20.243
1975	55.557	76.981	57.914	77.448	15.534	22.6
1976	62.077	74.732	58.305	73.059	16.497	22.552
1977	66.572	86.628	63.267	76.219	19.223	23.352
1978	70.625	105.3	70.764	82.369	20.877	24.104
1979	73.151	128.07	72.108	84.922	22.118	28.068

Source: Actual - Jorgenson, Gollop, and Fraumeni (1989)
Model - PNL projections using cost frontier model

TABLE D.3. Projected Factor Inputs, Output and Cost

Transportation Equipment

Year	Capital	Labor	Intermediate	Output	Cost
1970	23.303	11.794	22.959	39.231	35.21950
1971	23.174	16.037	31.165	52.784	49.66497
1972	22.207	14.087	27.494	46.742	45.59508
1973	21.894	21.033	41.307	69.197	72.00243
1974	21.929	16.138	31.506	53.753	62.31486
1975	21.865	17.06	33.164	56.85	72.77700
1976	21.606	15.915	31.025	53.414	72.40678
1977	19.796	15.688	30.653	52.772	76.47011
1978	19.776	15.785	30.841	53.274	82.50839
1979	23.625	14.918	29.103	50.975	85.49005

Motor Vehicles

Year	Capital	Labor	Intermediate	Output	Cost
1970	17.850	11.492	36.111	60.703	49.08728
1971	17.601	12.883	45.546	73.352	67.59270
1972	17.207	13.475	45.992	74.455	71.54316
1973	19.088	13.650	47.179	77.076	77.25410
1974	20.574	11.754	41.290	68.779	70.76751
1975	22.780	12.915	44.121	74.558	87.12118
1976	22.070	14.412	49.107	82.489	107.2540
1977	23.371	15.561	54.707	91.238	129.2050
1978	25.074	15.953	55.504	93.582	140.4006
1979	31.479	17.651	61.338	104.800	163.1875

Machinery

Year	Capital	Labor	Intermediate	Output	Cost
1970	35.009	23.993	31.508	68.233	62.22769
1971	36.424	24.872	33.988	72.389	67.98588
1972	36.234	24.016	32.256	69.779	68.91680
1973	37.51	24.602	33.705	72.520	74.61190
1974	40.147	31.913	44.908	94.457	106.1337
1975	43.808	33.683	46.176	99.338	124.5865
1976	44.147	31.654	43.665	94.686	126.6972
1977	44.947	30.540	41.804	91.981	132.6879
1978	46.924	32.003	43.433	96.394	148.3241
1979	50.227	36.291	49.444	109.540	181.5080

TABLE D.3. (contd)

Fabricated Metal

Year	Capital	Labor	Intermediate	Output	Cost
1970	24	16.008	21.843	43.86	38.92357
1971	24.231	16.236	22.69	45.135	42.06853
1972	24.334	16.377	23.748	46.524	45.75952
1973	24.875	16.815	24.669	48.157	50.17916
1974	26.951	17.955	23.672	48.829	58.04972
1975	29.9	19.411	26.598	54.273	72.56625
1976	29.999	19.694	27.878	56.164	80.85035
1977	30.673	20.312	29.24	58.59	91.16763
1978	31.801	20.964	29.903	60.337	99.84310
1979	33.017	21.314	29.662	60.876	111.5976

Chemicals

Year	Capital	Labor	Intermediate	Output	Cost
1970	38.878	11.467	35.613	61.937	52.92098
1971	40.442	11.583	35.706	62.791	56.61647
1972	41.536	11.197	35.222	62.382	59.88343
1973	42.044	11.774	36.616	65.067	67.18835
1974	44.222	14.801	47.426	82.038	93.63460
1975	44.203	13.651	43.829	76.981	95.26857
1976	46.303	13.252	41.49	74.732	100.1430
1977	49.151	14.948	49.104	86.628	122.7070
1978	52.48	17.984	60.811	105.3	158.0165
1979	54.472	21.765	75.005	128.07	207.8881

Primary Metals

Year	Capital	Labor	Intermediate	Output	Cost
1970	56.913	16.372	46.966	73.596	66.83989
1971	57.827	16.061	45.975	72.490	68.39502
1972	57.11	16.271	50.723	78.164	78.03832
1973	56.327	15.912	50.641	77.954	82.42592
1974	56.271	17.139	54.831	84.918	106.9648
1975	57.239	16.233	48.348	77.448	106.1444
1976	56.676	15.428	45.097	73.059	103.9282
1977	56.923	15.512	47.409	76.219	116.6992
1978	57.777	16.185	51.670	82.369	136.8109
1979	58.252	16.526	52.909	84.922	157.4330

TABLE D.3. (contd)

Rubber

Year	Capital	Labor	Intermediate	Output	Cost
1970	9.166	5.5698	7.2012	15.474	13.43683
1971	9.629	6.4824	8.0422	17.5	16.36426
1972	9.932	6.6849	8.2729	18.05	17.51223
1973	10.642	7.0871	8.8143	19.25	19.83404
1974	11.672	7.0766	9.4646	20.243	23.29409
1975	12.639	7.9905	10.447	22.6	29.40897
1976	12.727	7.897	10.443	22.552	30.72878
1977	13.025	8.2744	10.689	23.352	34.62236
1978	13.698	8.4291	11.061	24.104	37.54349
1979	14.35	9.5276	13.184	28.068	47.51284

TABLE D.4. Inputs, Costs, and Output from Jorgenson et al.

Transportation Equipment

Year	Capital	Labor	Intermediate	Output	Cost
1970	23.303	13.793	22.959	37.702	35.221
1971	23.174	12.166	21.548	35.180	34.135
1972	22.207	12.421	21.390	35.474	35.474
1973	21.894	12.608	24.289	39.880	41.496
1974	21.929	12.568	23.893	38.716	45.751
1975	21.865	12.272	22.715	37.166	48.873
1976	21.606	12.176	21.592	35.553	50.128
1977	19.796	12.508	22.231	36.491	55.058
1978	19.776	13.556	26.464	41.509	67.598
1979	23.625	14.918	31.591	47.958	85.490

Motor Vehicles

Year	Capital	Labor	Intermediate	Output	Cost
1970	17.850	11.813	31.246	48.271	42.475
1971	17.601	12.538	40.585	61.696	58.625
1972	17.207	13.690	43.681	65.906	65.906
1973	19.088	15.085	49.312	76.391	77.251
1974	20.574	13.016	41.911	64.142	70.767
1975	22.780	11.448	37.390	57.560	71.702
1976	22.070	13.467	48.001	74.728	98.969
1977	23.371	14.794	54.069	85.176	120.618
1978	25.074	15.518	57.825	89.828	136.569
1979	31.479	15.046	55.340	84.594	139.102

Machinery

Year	Capital	Labor	Intermediate	Output	Cost
1970	35.009	23.506	26.822	56.315	52.972
1971	36.424	21.451	26.142	53.559	52.294
1972	36.234	23.018	31.215	61.979	61.979
1973	37.510	25.641	37.725	72.520	74.612
1974	40.147	26.982	42.330	77.501	89.731
1975	43.808	24.760	35.209	66.567	89.206
1976	44.147	25.125	36.911	70.567	98.865
1977	44.947	26.236	40.003	77.550	113.987
1978	46.924	28.549	43.487	83.431	132.293
1979	50.227	30.946	44.870	88.204	150.989

TABLE D.4. (contd)

Fabricated Metal

Year	Capital	Labor	Intermediate	Output	Cost
1970	24.000	16.981	21.572	41.580	38.082
1971	24.231	16.060	21.271	40.524	38.964
1972	24.334	16.979	22.913	43.824	43.824
1973	24.875	18.396	24.854	48.157	50.181
1974	26.951	17.955	25.317	46.133	58.049
1975	29.900	16.080	21.259	39.706	57.777
1976	29.999	16.744	22.628	43.496	65.622
1977	30.673	17.382	24.168	46.742	74.944
1978	31.801	18.431	27.514	50.200	87.777
1979	33.017	19.075	27.859	52.167	99.881

Chemicals

Year	Capital	Labor	Intermediate	Output	Cost
1970	38.878	13.227	31.965	48.743	47.501
1971	40.442	12.853	31.435	50.229	49.845
1972	41.536	12.542	32.988	54.861	54.861
1973	42.044	12.943	35.068	60.141	62.100
1974	44.222	13.221	44.917	62.835	82.182
1975	44.203	13.229	42.413	55.557	86.222
1976	46.303	13.711	45.797	62.077	100.141
1977	49.151	14.071	48.501	66.572	111.957
1978	52.480	14.525	49.247	70.625	121.977
1979	54.472	14.815	53.580	73.151	141.501

Primary Metal

Year	Capital	Labor	Intermediate	Output	Cost
1970	56.913	16.102	38.426	56.935	53.858
1971	57.827	15.065	34.665	53.266	51.572
1972	57.110	15.436	41.372	62.191	62.191
1973	56.327	16.804	52.572	75.134	79.448
1974	56.271	17.139	60.948	77.982	106.965
1975	57.239	14.729	42.568	57.914	88.129
1976	56.676	14.991	43.864	58.305	93.900
1977	56.923	15.477	48.359	63.267	109.717
1978	57.777	16.174	54.455	70.764	131.678
1979	58.252	16.671	58.667	72.108	157.428

TABLE D.4. (contd)

Rubber

Year	Capital	Labor	Intermediate	Output	Cost
1970	9.166	6.076	7.229	14.243	13.437
1971	9.629	6.103	7.144	14.940	14.537
1972	9.932	6.669	8.881	17.470	17.470
1973	10.642	7.173	9.047	18.884	19.457
1974	11.672	7.007	9.599	18.191	22.553
1975	12.639	6.022	7.676	15.534	21.609
1976	12.727	6.531	8.336	16.497	24.380
1977	13.025	7.212	9.731	19.223	30.176
1978	13.698	7.626	10.504	20.877	33.915
1979	14.350	7.895	11.439	22.118	39.370

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