Estimating the distribution of the demand for workers by GED/SVP classification

Author: Paul L. Altieri

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ABSTRACT

The purpose of the model which is developed in this paper is to estimate the demand for workers by General Educational Development (GED) and Specific Vocational Preparation (SVP) characteristics under varying conditions of final demand. Most of the labor demand models which have been developed are of limited use in predicting the effect of changes in final demand on employment because of the failure to consider one or more of three basic labor market conditions: (1) the heterogeneous nature of labor demand; (2) the supply characteristics of workers; and (3) changes in the employment/output ratios. The present study incorporates condition (1) directly into the model and identifies those situations in which conditions (2) and (3) would have an effect upon the estimates of the demand for workers.

It is assumed that the level of employment is directly proportional to the levels of industrial output, and that the levels of industrial output are determined ultimately by the final demand facing each industry. An input-output table of the U.S. economy is used to estimate the level of output by industry for a given set of final demands. A set theoretic approach to the labor market is adopted with the set of skill bundles which the labor force possesses and the set of skill bundles demanded by the employers in each industry expressed in terms of joint GED/SVP classifications. A matrix of the demand for workers by twenty-seven joint GED/SVP classifications per dollar of output is constructed which allows the translation of the levels of output into the levels of demand for workers by GED/SVP classifi-
fication. The procedure is illustrated whereby a given change in final demands can be traced through the model to determine the effect upon the demand for workers in each of the twenty-seven different skill bundles.

Through the use of a quadratic loss function, a method is explained which allows the estimation of the levels of final demand which would be necessary to achieve an objective function that includes a given set of target GED/SVP employment levels. Some alternative statements of the objective function are considered which allow the use of a particular subset of industrial final demands as instruments in achieving various employment goals, and place restrictions on the magnitude of the changes in final demand.

The data for the matrix of the industrial demand for workers by GED/SVP classification is obtained from the 1960 census data on occupations by industry, and Department of Labor classifications of occupations by GED and SVP categories. The 1967 input-output study from the Bureau of Economic Analysis is used to estimate the levels of output by industry. The census and input-output industrial sectors are re-defined on the basis of standard industrial classification codes in order to establish a consistent set of industries to be used in the model.

The implications of this study are that it is possible to predict the employment impacts of a change in the final demand for goods and services, and to devise an expenditure program which would offset the employment effects of that change. The
procedure which is demonstrated would be useful as a policy tool in implementing a particular manpower program or in estimating the employment effects of changes in the government's vector of final demands.
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SUMMARY

The purpose of the model which is developed in this paper is to estimate the demand for workers by General Educational Development (GED) and Specific Vocational Preparation (SVP) characteristics under varying conditions of final demand. Most of the labor demand models which have been developed are of limited use in predicting the effect of changes in final demand on employment because of the failure to consider one or more of three basic labor market conditions: (1) the heterogeneous nature of labor demand; (2) the supply characteristics of workers; and (3) changes in the employment/output ratios. The present study incorporates condition (1) directly into the model and identifies those situations in which conditions (2) and (3) would have an effect upon the estimates of the demand for workers.

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The data for the matrix of the industrial demand for workers by GED/SVP classification is obtained from the 1960 census data on occupations by industry, and Department of Labor classifications of occupations by GED and SVP categories. The 1967 input-output study from the Bureau of Economic Analysis is used to estimate the levels of output by industry. The census and input-output industrial sectors are re-defined on the basis of standard industrial classification codes in order to establish a consistent set of industries to be used in the model.

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procedure which is demonstrated would be useful as a policy tool in implementing a particular manpower program or in estimating the employment effects of changes in the government's vector of final demands.
The model developed estimates the demand for workers by general educational development (GED) and specific vocational preparation (SVP). Input-output is used to predict industrial output, and along with a matrix of the demand for workers by joint GED/SVP classifications per dollar of output, the demand for workers resulting from a change in final demand is estimated. A quadratic loss function is used to find the levels of final demand needed to achieve a set of target employment levels. The procedure would be useful in implementing a manpower program or in estimating the employment effects of changes in final demand.
BOSTON COLLEGE
GRADUATE SCHOOL

The thesis of Paul L. Altieri

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submitted to the Department of Economics
in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of Boston College has been read and approved by the Committee:

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Date
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CHAPTER I

INTRODUCTION

Statement of Purpose

Over the past fifteen years numerous articles have appeared in the journals which attempt to estimate the demand for workers in the United States under various economic conditions. The models which are developed in these articles employ the same basic methodology. First, some kind of change in private or public spending patterns is proposed which may be purely political, such as a reduction in military expenditures, or economic, as in the case of programs to increase employment. In either case the final demand for goods and services which stems from the program is translated into the total demand for intermediate and final products. The demand for workers which would be needed to meet that level of total demand is then estimated. The models differ in the manner in which they estimate the amount of total demand that is generated by the spending programs, and whether or not they address themselves to the question of the skills of the workers that are demanded.

In most cases an econometric model is used to determine the level of total demand for goods and services, while only a few researchers have used input-output techniques in their
analyses. The reason for this may be that the only reliable input-output tables for the United States are those which cover the whole economy. There are some regional tables but they contain serious inaccuracies which are caused by the unavailability of the data and problems with the treatment of imports and exports. Since many articles concentrate on regional problems or questions pertaining to specific industries and socio-economic groups, the poor quality of the regional tables and the fact that input-output is not applicable to studies within industries or economic groups, may account for the lack of interest in this type of analysis.

Each of the labor demand models developed so far is of limited use in predicting the effect of changes in final demand on employment because of the failure to consider one or more of three very basic labor market conditions: (1) the heterogeneous nature of labor; (2) the supply characteristics of workers; and (3) changes in the employment/output ratio. All but two of the articles which will be discussed in the next chapter make no

1. Within a region of the United States, such as an individual state, imports from and exports to the rest of the country usually account for a large portion of total sales and purchases. Most regional models treat the national variables as exogenous, and since the interdependencies are so important, the effectiveness of the model becomes severely limited. See William Miernyk, et. al., Simulating Regional Development, An Interindustry Analysis of the West Virginia Economy, 1970, or Frederick Moore and James Petersen, "Regional Analysis: An Interindustry Model of Utah," Review of Economics and Statistics, 37 (November 1955), 368-83.

distinction among the types of workers employed, and only concern themselves with the level of employment. This is a crucial distinction. Even if they estimate that there will be an increased demand for workers in the aerospace industry, they provide no information on whether those jobs are for aeronautical engineers or for janitors. The two articles which do predict both the level and type of employment use an occupational classification system which prevents an examination of interoccupational mobility and limits the applicability of the model.

In addition, in most key articles written on the subject, one important labor market factor is ignored - the supply of workers. In those articles which estimate the aggregate level of employment, no attempt is made to compare the number of jobs with the available labor force. There seems to be an implicit assumption of excess capacity in the economy since no consideration is given to the problem of encountering production constraints. If there is excess capacity in the economy there must be unemployment as well as idle land and capital. The articles which estimate the level of demand for different types of employment offer the possibility of identifying where labor bottlenecks might occur. Unfortunately, since they do not consider the supply of workers with different skills they only offer a description of the type of employment demanded, and fall short of supplying concrete information on structural unemployment.

A third problem with these models is the use of employment/output ratios which remain the same no matter how large the
change in output or whether GNP is rising or falling. For the employment/output ratios to be invariant to the size of changes in GNP, it implies that the demand for workers is not affected by the level of utilization of physical capacity. The assumption of an invariant employment/output ratio also fails to consider the difference between "overhead" and production workers. Although the demand for production workers may be relatively proportionate to the level of output, the demand for overhead workers can remain constant over a wide range of production levels. For the employment/output ratios to remain the same in the face of increases or decreases in GNP also indicates the presence of excess capacity in the economy, otherwise the increased demand for goods and services would run into production constraints. If the constraint is a shortage of capital goods, more workers would be substituted for capital and the increase in employment would be larger than the employment multipliers would indicate. If the constraint is a shortage of workers, the increase in employment would be less than the multipliers would indicate. Neither of these possibilities is discussed in any of the articles.

The Present Model

In this study the heterogeneous nature of labor is built directly into the model. However, the questions of the supply characteristics of workers and changes in the employment/output ratios are handled in a less direct manner.
Unfortunately, there is no data available on the supply of workers in skill categories which are comparable to our predictions on the demand for worker skills. This makes it impossible for us to predict the demand for workers and compare the demand with the existing supply of workers. Therefore, as an alternative, we restrict our analysis to an examination of the changes in the demand for worker skills. When there is a decrease in the demand for workers it is assumed that there is a similar increase in the pool of unemployed workers. The number and skills of those who have been put out of work can be estimated, and this comprises the minimum supply of available workers by skill category. When there is an increased demand for workers, this increased demand must be compared with the availability of workers with the same skills in order to determine if a sufficient supply exists. In this case the skills of the workers that are unemployed must be known. We will make some specific suggestions concerning how the data on the unemployed can be improved in order to make this model useful for policy purposes.

For lack of a better alternative, we employ fixed employment multipliers in our model. Like the other models we assume that the employment/output ratio remains the same in the face of increases and decreases in output, as well as the size of the change in GNP. We recognize this shortcoming and outline the situations in which the level of utilization of physical capacity and the relative use of overhead and production workers would make fixed employment multipliers inadequate tools for predicting
changes in employment. We also use fixed multipliers in order to determine the initial demand for worker skills. In this case, however, we do not assume strict proportionality between the level of output and the use of worker skills. We allow the actual use of skills to diverge from the initial demand by permitting job mobility and the substitution of workers with different skill levels when there is a shortage of workers with the required skills.

Outline of the Paper

In the chapter which follows we will examine seven studies which predict the demand for workers in the United States. One of these articles was chosen as an example of the procedure used by most econometric models, while the other six rely on input-output to predict the level of employment. Of the input-output models, three are national studies, the other three consider regional problems, and two of the national studies examine the demand for workers by occupation.

In Chapter III a set-theoretic approach to the labor market is adopted. The set of skill bundles which the labor force possesses and the skill bundles demanded by the employers in each industry are expressed in terms of joint general educational development (GED), specific vocational preparation (SVP) classifications. An input-output table is used to predict the level of output, and this is translated into the demand for workers by twenty-seven GED/SVP classifications through the use of a matrix of the demand for workers by GED/SVP category per dollar of output.
A procedure is illustrated whereby a given change in final demands can be traced through the model to determine the effect upon the demand for workers in each of the 27 different skill bundles.

In Chapter IV the sources and procedures used in compiling and adjusting the data are explained. Data on employment by industry and GED and SVP classification are adjusted and combined to form a matrix of the demand for workers by GED/SVP classification per dollar of output. Census and input-output industrial sectors are re-defined on the basis of standard industrial classification codes and some of the industries in the input-output table are aggregated in order to establish a consistent set of industries to be used in the model.

In Chapter V a method is explained which allows the estimation of the levels of final demand which would be necessary to achieve an objective function which includes a given set of target GED/SVP employment levels. This is done through the use of a quadratic loss function. Some alternative statements of the objective function are considered which allow the use of a particular subset of industrial final demands as instruments in achieving various employment goals, and place restrictions on the magnitude of changes in final demand.

In the final chapter the summary, conclusions and possible directions for future research are discussed.
CHAPTER II

REVIEW OF THE LITERATURE

Econometric Models

Although we will not make use of an econometric model of the economy to predict employment levels, it will be useful to examine how such a model has been used by others since the linkage between output and employment used by econometricians is very similar to the one used by input-output analysts.

An article by Daniel Suits offers a fair representation of the work done in this area by econometricians. Suits employs a 32 equation model of the U.S. economy in an attempt to determine the possible impact on employment which would be brought about by a reduction in defense spending as a response to a lessening of the Cold War. His model allows him to examine the effects on the economy which would result from a smaller Pentagon budget. It also gives him some insight into what would happen if some measures were taken to reduce the impact of this cut-back.

Four possible alternative offset programs are considered: increased government services (either direct employment in the public sector or purchases from private industry), a change in federal income taxes, stepped up social security payments and

private investment in plant and equipment. For each of these programs he postulates a $1 billion increase, and enters this information into his equations. The difference between GNP levels prior to and after the above mentioned changes forms the basis for the remainder of his analysis. Each change in GNP is assumed to indicate a multiplier for that particular offset program. For instance, increased government purchases from private industry of $1 billion induces an increase in GNP of $1.304 billion. So the output multiplier for government purchases from private industry is 1.304.

The step from GNP to employment is taken by making use of information on the existing number of workers per $1 billion GNP. For each program, the employment/output ratio is multiplied by the increase in GNP to arrive at an employment figure. In effect what Suits does in order to compute the employment impact of a $1 billion change in each program is to derive employment multipliers for these programs. He assumes that the multipliers remain the same despite the size of the change or whether it involves an increase or decrease in GNP. He claims that the employment effect of these actions, taken individually or in combination, can be found simply by multiplying the dollar amount of the programs by the appropriate multipliers and adding the results.

Suits's analysis leaves a number of questions unanswered. There is no attempt to examine the type of employment demanded, only the aggregate level of employment. Although he does not consider the supply of workers, his assumption that output can
be increased without creating production bottlenecks implies the availability of excess capacity and the existence of unemployment. The use of proportionate multipliers ignores the fact that the relative demand for workers can change as the level of capacity utilization changes and that there is a difference in the demand for overhead and production personnel.

Suits attempts to look at the impact of defense cuts at the margin. This necessarily implies relatively small changes in GNP, and given some looseness in the labor market, may not imply bottlenecks. As the economy approaches full employment and bottlenecks do occur, the model's predictions of output will be off the target. Even if this model were accurate at predicting the level of GNP under the given circumstances, it would still be poorly suited to the job of predicting levels of employment.

In the process of performing the calculations two very important pieces of information are omitted: how much of the change in production takes place in each industry, and the different labor intensities in each of these industries. The labor/output ratio varies by industry but Suits uses a composite figure which obscures these differences. At the same time he estimates changes in output but not the particular industries in which these changes will take place. These factors can substantially effect his estimates. If the change in output were concentrated in the oil refining industry, which is highly capital intensive, the change in employment would be relatively small. But if that change were mostly in service industries, which are highly labor intensive, the change would be quite large. Using Suits's
method no difference would be discerned. This additional information can be gleaned from an input-output analysis.

Input-Output

Leontief and Hoffenberg

In a pilot effort to forecast the employment effects of disarmament through input-output analysis, Leontief and Hoffenberg¹ address themselves to the same question as Suits concerning a reduction in the level of Cold War military spending. Unlike Suits, however, they recognize that the problem involved in making a shift from military to private spending is not merely a question of size, but also one of composition:

There would be no problem if the goods that are listed in the typical procurement order for the United States Air Force missile base at Cape Canaveral also made up the shopping list of the average housewife ... even if the total level of expenditure were maintained, the shift from military to nonmilitary budgets must be expected to increase the demand for the products of some industries and reduce the demand for the products of others.²

Their input-output matrix provides Leontief and Hoffenberg with industry-by-industry output projections which allow them to take into account the different labor intensities of the industries and to overcome the previously mentioned objections to the Suits analysis.


²Ibid., 90.
At the time of their study the most recent table of the U.S. economy was for the year 1947, but after a trial check of the coefficients they concluded "that the structural relationships shown for that year still yield a reasonably good description of interindustry relationships in 1958."¹ The final demand vector of their model is partitioned into eight categories which correspond to eight possible alternative spending programs. A transfer of $100 million is made from military expenditures to each of these other final demand categories in succession. The new total production vector is computed, and the difference between the new levels and the entries in the old total production vector are noted. These differences are multiplied by the employment/output ratios for each industry prior to the change in order to arrive at the employment impact of the transfer.

This employment data is presented in terms of increases and decreases in business employment for each industry, the net change in business employment, and the increase, decrease and net change in total employment, after an anticipated release of both civilian and uniformed personnel by the military. The same process is repeated for a proposed 20% reduction in the military budget coupled with increases totaling the same amount in all eight alternative spending programs on a pro rata basis. Individual changes in industry output are again multiplied by the employment/output ratios and the resulting employment effects are presented.

¹Ibid., 92.
Leontief and Hoffenberg leave some of the same questions unanswered as does Suits. No mention is made of the type of labor that will be needed to meet demand, only the level of employment. The use of proportionate employment multipliers for changes in output in either direction and of any size does not allow for variations in demand due to differences in the level of capacity utilization and the distinction between overhead and production personnel. Although Leontief and Hoffenberg do not examine the supply of workers as such, the authors warn the reader of the limits to production capacity and "of the short-run production bottlenecks that could prevent some industries from supplying the additional output called for by changes in the composition of demand."¹ They readily admit that their analysis has some drawbacks and that their empirical results are of limited use since they only apply to the specific changes in the military budget and alternative spending programs noted above. The point that they try to drive home is that the analytical methods of this model can be used to study the impact of most spending programs and to answer questions concerning the industries in which the impact will be felt so that adequate preparations can be made.

Isard and Schooler

National input-output tables are, of necessity, quite aggregate, and this obscures some of the underlying interrelationships among the various industries. Another problem with national

¹Ibid., 98.
tables is that economic conditions which pertain to only one geographical area cannot easily be identified. For instance, the Washington D.C. area is particularly dependent upon federal government expenditures and employment policies. If we were to use the Leontief and Hoffenberg model to predict the employment impact of a 5% reduction in government outlays, even if the results were accurate for the whole country, they would be of little use to the local officials in the Washington area because it would not identify the magnitude of the problem facing them. In order to overcome this difficulty, regional input-output tables have been developed.

In a study which looks at the effects of a smaller budget for the Pentagon on a regional basis, Isard and Schooler adopt a framework very similar to that of Leontief and Hoffenberg. In fact, in the first part of their study they actually use the Leontief and Hoffenberg table of employment effects and transfer funds to the same eight categories of final demand. A 10% across-the-board decrease in military expenditures which amounts to $3.23 billion is proposed. This figure is multiplied by the entries in the Leontief and Hoffenberg table to arrive at the employment impact of this action on the national level.

The second portion of the paper is devoted to studying the regional impacts of a 10% cut in the military budget, coupled with a program to inject the same number of dollars back into

the economy in a different manner. Six different geographic areas are selected for the study, and the analysis is basically the same for each of these areas except where data limitations necessitate some changes. The magnitude of the problem that is faced in each area depends on the size of military contracts to private firms as well as direct military employment and installations in the local economy. In each case this data was obtained from Defense Department sources. Regional input-output models with 25 industries and 7 final demand categories are used. Through a process of iteration a chart is constructed which shows the portion of the output of each industry that is dependent, directly or indirectly, on the 7 final demand categories. Multiplying the output proportions by industry employment allows the authors to convert from the output to the employment in each industry which is dependent on these final demand categories.

A 10% across-the-board reduction in military spending is assumed. Therefore, the employment impact of this action is a reduction totaling 10% of the employment linked to military final demand, plus 10% of Department of Defense employment in the region. Then, one at a time, an injection of funds of the same dollar amount as the cutback is made into the economy through 4 different offset programs: a decrease in personal income taxes, decrease in business taxes, an increase in new housing investment, and government investment for peacetime purposes. In each case the offset program increases one or more categories of final demand which is assumed to cause a proportional increase in all employment that is directly or indirectly dependent upon these
categories of final demand. By balancing the decreases in employment caused by the cutback against the increases due to the offset program, a figure for the net change in employment is calculated.

Although there are some mechanical differences between the Isard and Schooler versus the Leontief and Hoffenberg models, the two formulations are basically the same, and some of the same errors of omission are made. The type of employment is not considered, only the aggregate level, and proportional employment multipliers are used throughout. The analysis is limited to conditions where there is excess capacity and unemployment, however even in those cases where the offset spending program would increase output and employment beyond the original level, no consideration is given to the possibility of production constraints and bottlenecks. Where Isard and Schooler make a contribution to the literature is in the development of a system whereby the impacts of economic programs on a particular region can be identified, and the effects of alternative actions can be weighed.

**Hansen and Tiebout**

In another regional study, this time restricted to the state of California, Hansen and Tiebout use input-output analysis, but with an additional little twist.\(^1\) One of the aims of their research was to see whether it would be possible to estimate employment trends on a low cost basis. They started from the ground floor and went out and collected data on the California

economy through mail surveys, commodity reports, building permits, and personal interviews. In all they sampled firms which employed 25% of all the state's workers in 28 different industries. With this information they constructed an interindustry transactions table with certain final demand categories for the economy of the whole state and selected regions within the state.

Rather than going ahead and conducting an analysis on the input-output table in dollar terms and then transforming that information into employment estimates, as most others have, they construct an input-output table of labor coefficients. First, they take the dollar amount of output of each industry which is delivered to each of the categories of final demand as well as to all of the other industrial sectors. The proportion of the total output going to each of these purchasers is calculated. Then the proportions are multiplied by the total employment of the producing industry to arrive at the amount of employment in the producing industry which is generated by the purchases of each industrial sector. Finally, this figure is divided by the purchasing industry's employment to obtain a coefficient showing the amount of employment needed in the producing industry per unit of employment in the purchasing industry. Except for the fact that the unit of measurement is labor, this coefficient is the same as the usual input-output table entry. Normally the next logical step would be to find the inverse of the employment matrix, but instead the authors assign all of the sales of the industrial sectors into the final demand sectors through a series of successive iterations. (This is similar to what Isard and Schooler do.) The results are
presented as a series of employment multipliers which show the impact of changes in final demand on employment after the initial effect and after each of three other indirect and induced effects have taken place.¹

Just as in the other articles which we have considered, Hansen and Tiebout do not examine the skills of the workers demanded. They make the implicit assumption of excess capacity and unemployment, and use proportionate employment multipliers. Nevertheless, this article offers some new possibilities to the task of finding the employment effects of a change in final demands. It shows that even if there is no published data on the area to be studied, it may be possible to construct an input-output table for a particular geographical area on a limited budget. Also, the use of employment coefficients in the input-output table rather than the usual dollar figures allows the direct estimation of worker requirements. This eliminates the step of transforming output levels to employment levels each time the model is used to test a new hypothesis. This technique could be adopted with little difficulty whenever the availability of the data allows.

¹In all fairness to the authors it should be pointed out that prior to the early 1960's computers with the capacity to invert any but the smallest matrices were not available. This necessitated the use of expansions by power series and iterative methods to calculate the induced effects of interindustry relationships. These methods were much less accurate and much more tedious than the relatively simple computer programs that we use today. This is probably the reason that Hansen and Tiebout were content with just finding the employment multipliers. It also may account for the fact that Isard and Schooler, as well as Leontief and Hoffenberg, calculated the effects of a given change in final demand and derived all additional information from those results, rather than working each of the proposals through their models individually.
Leontief and others

In 1965 Leontief published an article along with four of his associates which contains a natural extension to the model that he developed with Hoffenberg.\(^1\) In this article they integrate the national input-output analysis of employment impacts with 19 regional input-output analyses which cover the entire U.S. economy. This study offers a major refinement over other regional studies in that it insures that all of the separate input-output analyses for all of the regions balance simultaneously.

Had we attempted to study each region separately and then simply to add the results to arrive at corresponding aggregates for the country as a whole ... the results of such isolated regional studies would not comprise a consistent picture of the national economy as a whole. The simple scheme of multi-regional analysis on which the present computations are based provides for simultaneous balancing of all input-output flows from the point of view of each individual region, as well as for the U.S. economy as a whole.\(^2\)

All goods are divided into two classes: national and local. For local goods the balance between production and consumption is accomplished within the region; for the national goods the balance is accomplished on the national level and involves a number of regions. What they do is to use a national input-output study to get the total outputs of all national goods and services, and use these figures as the demand which must be allocated among the 19 regions. When these demands are entered


\(^2\)Ibid., 217.
into the regional studies, they play a role in determining the output of local goods.

In this model the wage and salary bill is used as a proxy for employment. The wage and salary bill is defined as total wages, salaries, and income from unincorporated enterprises in each industry. Instead of identifying the actual number of workers employed, the total payments to the workers in each industry are calculated. A given percentage change in the wage and salary bill is interpreted as indicating a similar percentage change in employment. The set of industry wage and salary bills is divided by the corresponding levels of industry output to arrive at a set of "labor coefficients" (payments to labor per dollar of output) which serve the same purpose as the employment/output ratios in the other models.

The 1958 interindustry transactions table of 86 industries is aggregated to 60 industries to correspond to the classifications in the regional tables. The final demand vector is divided into military purchases, non-household civilian final demand, and private household consumption. The authors postulate a 20% reduction in military expenditures which is entered into the model as a proportional decrease in each element in the portion of the final demand column which pertains to military purchases. This reduction in demand would also reduce employment. Since the authors wish to hold the initial level of employment constant, they increase all categories of the non-military final deliveries proportionally, but the total dollar amount of this increase is larger than the decrease in military demands. The reason for
total wages and salaries paid for all the labor engaged
directly and indirectly in production of one million
dollars' worth of goods and services combined in the
proportion demanded by the military are some 21 percent
larger than wages and salaries paid for labor inputs
required for production of one million dollars' worth
of outputs delivered in amounts reflecting the average
product mix of all non-military final users.¹

The additional increase in non-military final demand is designed
to reflect this difference.²

When this new vector of final demands is processed through
the input-output model, the total production of all goods for the
entire economy which is necessary to meet that level of demand is
obtained. At this stage the authors only concern themselves with
the change in the output of national industries. The total amount
of this change is divided among the regions according to the
proportion of the total production of each national good in the
individual regions prior to the change.

¹Ibid., 219.

²This is not in accordance with the findings of others who
assert that the employment multiplier for military spending is
smaller than for private spending, or those who report mixed
results, depending on the industry mix of private spending. See
Suits, "An Econometric Analysis" or Isard and Schooler, "An
Econometric Analysis of Local and Regional Impacts." This result
may have been obtained from the Leontief model due to the use of
the wage and salary bill as a proxy for employment rather than
the actual number of workers. This inconsistency is resolved by
the fact that military spending is human capital intensive, but
not labor intensive. Military spending uses large numbers of
high skilled, high wage labor. Therefore if you use the Leontief
"labor coefficient" which relies on "payments to labor per dollar
of output", military spending will appear more labor intensive.
Suits and other use employment, not payments, and therefore get
opposite, but consistent, results.
In the regional input-output tables, private households are treated as endogenous to the system in the same manner as the produced inputs. Normally an increase in output is associated with an increase in earnings which will have a multiplier effect through the respending of those earnings. The usual input-output models only allow for the initial change in income through alteration of the final demand vector, and the respending of income by wage and salary earners is ignored. In the regional tables, Leontief and his associates have attempted to correct this problem. A new row and column are added to the tables. The row pertains to the labor inputs used by the various industries (the wage and salary bill) and the column shows the inputs to labor - its consumption purchases from the industries, which is its final demand for goods and services. The private household consumption portion of the final demand vector is eliminated since consumer purchases already appear in the main body of the table.

When final demand for goods and services is increased, it necessitates increased purchases of labor services by the industries. This is accompanied by increased purchases of industrial products by households which necessitates the use of more labor inputs. This model gives the total production by the industries involved in producing the intermediate and final products occasioned by the initial increase in the final demands, as any other input-output analysis would. However it also gives the total production by the industries involved in producing the intermediate and final demands which result from increased consumption purchases when household incomes increase.
Using this model, Leontief et. al. show that within each region three different factors are changing simultaneously. Each of these factors has an effect on final demand, output of goods, and employment. 1) Since the production of national goods is changing, those regions which produce these national goods are experiencing changes in final demand. This is indicated in the results of the national input-output table. 2) The direct purchase of goods and services by the Department of Defense within each region is being reduced. 3) The demand for all non-military goods and services is increasing. These three factors appear in the model as changes in the final demand vectors of the regional input-output tables. When these changes in the final demand vectors are processed through the regional tables, the model yields the new level of total demand for goods and services within each region.

Through the use of the labor coefficients (which are nothing more than the percentage of the dollar output which goes to labor) it is a relatively simple task to find changes in the wage and salary bill, which they equate to changes in employment. For the national industries, the differences in the region's production of national goods before and after the change are multiplied by the labor coefficients. For the local industries the change in local production is multiplied by the labor coefficients. This represents the total payments of wages and salaries for producing the national and local goods. To this is added the change in earnings originating in the military and non-household civilian sectors. The sum of all of these is the total change in the wage and salary bill in the region which the authors interpret as the change in total employment for that region.
Input-output models in general do not provide a framework for the treatment of the multiplier effect upon employment and production which result from increases in income. The authors' inclusion of labor as an endogenous part of the input-output table is an attempt to capture the multiplier effect. The article also points out another deficiency in regional input-output models. On a regional basis imports and exports among the regions usually account for a large portion of the final demands. The other regional models take imports as endogenous, so as internal factors change, imports will vary accordingly. Exports, however, are treated as exogenous which means that no matter what else is happening on the national level, it will not show up in the regional production levels unless it has a direct effect on the final demand vector. By integrating the national and regional studies as they do, Leontief et al. provide a reasonable solution to this problem.

Even though this model makes a major improvement in the estimation of regional output by integrating the regional studies with a national study, the method which is used to estimate employment contains the same inadequacies as the other articles which we have considered. The authors calculate the changes in the total demand for employment, and individual worker skills are not even mentioned. No direct consideration is given to the supply of workers. However there is an assumption of excess capacity which would indicate the presence of unemployment. Finally, the same labor coefficients are used regardless of the size or direction of the changes in output.
Every one of these articles leaves unanswered the major question with regard to the labor force which we are most concerned with in this paper. They look upon labor as being a single, homogeneous factor of production, and they are only interested in changes in the total level of employment. It is assumed that if there is an increase in the demand for workers as a result of a change in government expenditures, any unemployed workers would be able to fill the available positions. In a similar manner it is also assumed that as funds are reduced in one area, workers that are discharged from the affected industries can be re-employed simply by channeling more funds into another area.\(^1\)

Since each worker possesses a number of different characteristics, and each job requires a different combination of skills, it is evident that not every worker possesses the necessary qualifications to fill every position. In order for any model that predicts employment to be complete, it must provide some way of distinguishing between the qualifications which are required by the employer and those that are embodied in the worker. In the two articles that follow one possible way to overcome this shortcoming is proposed. Rather than looking at worker character-

\(^1\) In a statement before the Joint Economic Committee of the Congress, Wassily Leontief explained this deficiency in his and other models and stated that he felt further research into this particular area was warranted. See: Congress of the United States, Joint Economic Committee, hearings of the 90th Congress, first session, April 24-26, 1967, "Economic Effect of Vietnam Spending," (Washington, 1967).
istics per se, the authors try to predict the demand for different occupations in an attempt to determine some of the structural effects of government programs. Since the methodology used by the authors in both cases is so similar, we will explain the procedures for both of them first, and then examine the results and implications.

Bezdek

In an article which reviews the Urban Coalition's Counter-budget, Roger Bezdek points out some of the possible employment effects of the program.¹ The Counterbudget is a suggestion for reordering national priorities through a detailed set of budget proposals on both the local and national levels. Rather than carrying out an analysis for each of the five years he tries to determine what the differential impacts on manpower policy would be in the short-run and in the long-run, in contrast to projected government policy.

Using a dynamic application of the Leontief model, with input-output data of the 1950's and 1960's as the basis for the trends in the coefficients Bezdek transforms his matrix into labor units through information on labor productivity and industry employment requirements in much the same manner as Hansen and Tiebout do.² Two vectors of final demand come from


²Bezdek does not spell out his procedure in detail but it appears that he used the available input-output tables for the 1950's and 1960's as his base and then performed some form of a difference equation or regression analysis on the coefficients
government data. One is for the proposed 1972 budget and the other is what the Bureau of Labor Statistics projects government outlays to be in 1976. Similar vectors of final demand for the Counterbudget proposals of the same years are also constructed. When these vectors are processed through the model, the information on final demand corresponding to each proposal in each of the years is transformed into total employment by industry which is needed to satisfy both the intermediate and the final demands.

Bezdek is not satisfied with just the total manpower demands, however. He carries his investigation one step further in an attempt to examine the occupational impact of the Counterbudget. He constructs an "industry-occupation" matrix which shows the percentage of total workers by industry in each of a number of major occupations. When the industry-occupation matrix is multiplied by the total industry employment, the use of specific occupations by that industry can be estimated.

Oliver and Rutzick

Two articles, which we will treat as one, provide a framework very similar to Bezdek's. The authors, Richard Oliver and Max Rutzick, were both employed at the Bureau of Labor Statistics at the time that these articles were published. Oliver sets out to obtain estimates of the input-output coefficients for the 1970's. See Leontief and others, Studies in the Structure of the American Economy (New York: Oxford University Press, 1953). The method of adjusting labor units to account for changes in labor productivity is not explained either, but it is likely that the trends of the 1950's and 1960's were projected into the 1970's.

to determine the employment effects of defense spending for Vietnam. Detailed information on Pentagon expenditures for non-durable goods is classified according to the industries from which the purchases were made. For durable military goods a major departure is made from the usual government accounting procedures. Normally the purchase of durable goods is recorded when the finished product is delivered, but employment is generated as the work is being done and has ended by the time that the product is delivered. Information on work in progress is what is really needed in order to estimate employment effects. Oliver does this by collecting data on the progress payments which are made at certain stages of completion.

Defense generated production for 1965 and 1967 is estimated by inserting the military demands for those years into the 1958 interindustry model. The output figures are converted to employment estimates by using industry employment/output requirements for the respective years. Employment attributable to Vietnam is calculated by assuming that the increases in military purchases from 1965 to 1967 stem from the war effort. The increases are processed through the input-output model, converted to employment figures through the use of industry employment/output requirements, and adjusted to account for the increased productivity in defense industries and their suppliers.

Rutzick takes Oliver's figures on increases in industry employment and converts them into occupational estimates. In much the same manner as Bezdek, he constructs a matrix of the proportion of workers in each industry engaged in 53 selected pro-
fessional and blue-collar fields. When this matrix is multiplied by Oliver's figures for total defense generated employment, the result is the number of workers in each occupation in each industry whose jobs are dependent upon Pentagon expenditures. The industry occupation figures are added to arrive at national totals for the various occupational groups.

Both the Bezdek and the Oliver and Rutzick studies begin in much the same way as the others which use input-output analysis. Some change in final demands is proposed; this is fed into the interindustry transactions table; and industrial production is calculated and translated into employment requirements via some kind of employment/output statistic. This is where the similarity ends. The final step taken by Bezdek and Rutzick sets them apart from the others. They recognize the fact that just knowing what total employment levels will be gives no indication of what the occupational distribution of that level of employment will be. Although they do not discuss the non-homogeneity of the workers or personal worker skills, the continuation of their studies beyond total employment into the treatment of occupations appears to be a tacit acknowledgement of these problems. Their identification of the numbers of workers in specific occupations is an attempt to fill the serious void in the existing literature.

These studies go a step beyond predicting the total demand for workers, but because a complete set of labor supply data by occupation is not available, the analysis cannot be carried to its logical conclusion. However, Bezdek recognizes the problem of the supply of labor and the labor bottlenecks which might
occur in some occupations, and he discusses it in general terms. He makes note of some occupations where the projected demand will outstrip the supply or even the ability to train individuals to meet the demand. It would be difficult for him to be more specific since he is making projections for five or six years in the future.

Rutzick and Bezdek use fixed multipliers for both employment and the industry occupational structures. This assumes that the employment response to a change in output will remain the same whether output is rising or falling and no matter how large the change in output. It also assumes that the percentage of workers in each occupation in each industry is invariant to changes in output. Rutzick makes no mention of this. Although Bezdek does not offer a solution, he readily admits that his estimates of occupational employment rest on his assumptions that "direct and indirect interindustry output employment requirements vary proportionately with the scale of output, and that the occupational distribution of industry employment remains constant over a substantial range of employment variation." ¹

Bezdek poses another question which Rutzick fails to take into account: with more workers being needed in some occupations while other occupations are suffering losses, the severity of the structural strains will depend, at least partly, upon the degree of interoccupational mobility and transferability of skills. Under the occupational classification scheme used by Bezdek and Rutzick, this appears to be an intractible problem. Since no information is provided on what skills are needed in order to be employed in a particular occupation, the skill requirements cannot

¹Bezdek, p. 180.
be compared. In the present study we offer an alternative to the occupational classification used by Bezdek and Rutzick, which allows us to compare job skills and assess the possibility of interoccupational mobility.

Classification by Worker Skills

The main deficiency of the occupational classification system is its definition of the term "occupation." Bezdek and Rutzick take a few specific job titles, assume that the tasks involved in carrying out each job are the same for the entire occupation and therefore the training and skills required are also the same. This very broad definition of occupation does not allow for any interoccupational mobility but it does allow for mobility among workers in the same occupation in different industries, when in reality such mobility might not be possible. For instance, according to Rutzick's figures, an inspector in the ordnance industry would also be qualified to be an inspector in the electronic computer industry. Chances are that such a transfer of personnel could not take place because the difference in the products of the two industries would also make a difference in the tasks involved in carrying out the job.\(^1\) The worker's

\(^1\)For this classification system on the basis of occupation to work, a more narrow definition of occupation would be needed and this would require the inclusion of all of the different occupations in the economy. The voluminous Dictionary of Occupational Titles lists 14,000 different jobs, and even the modest list in the Census report, Occupations by Industry contains 267 different job titles, and even this can be expanded if recognition is given to the fact that some jobs with the same title may involve different tasks in different industries. Within the ordnance industry alone, there are 25
occupation should not be defined strictly as an inspector, but in a more general manner in accordance with the tasks that his training qualifies him to handle or for which he can easily be trained in light on his present skills.

What we have developed in this thesis is a classification system for workers and occupations based on skill levels which avoids occupational titles. In our system the actual tasks involved in carrying out a job are secondary, while the skills required in order to carry out those tasks are of primary importance. It is a classification system which provides a common unit of measurement for both workers and jobs on the basis of the skills needed to carry out the required job tasks. With such a classification system it is possible to examine the questions of mobility within the same occupation and across occupations. If employment is reduced in one area and there are vacant positions in another job or in a different industry, a comparison of the skills of the unemployed workers with the skill requirements of the job openings will help to determine if the workers are qualified to hold those jobs. Even if the job skill requirements and the worker skills do not match, an examination of the workers' general and specific training would make it possible to ascertain how difficult it would be to retrain the workers to meet the requirements.

In those cases in which the workers have either more or less than the necessary qualifications for the available jobs, they might be able to fill the positions if it became necessary. This can be shown by use of the same example given above. The skill requirements for inspectors in the ordnance industry are higher than those for assemblers in the same industry. Therefore, an inspector also has a sufficient level of skills to be an assembler, or he can be trained for the job in a relatively short period of time. Likewise, with the proper training an assembler might be able to acquire the necessary skills and move up to the position of inspector. The occupational definition of inspector used by Bezde and Rutzick would eliminate the possibility of inter-occupational mobility between inspectors and assemblers although such mobility would be possible, while it would allow for the movement of inspectors between industries, even though it might not be possible. A more restricted definition of the occupation of inspector, which makes the distinction between the skill requirements for the same job in different industries, would eliminate the first problem since it would prohibit the movement of the inspector from one industry to another. However, it would also rule out the possibility of mobility among jobs in the same industry, even though such mobility is commonplace. The classification of workers on the basis of skills avoids the need to define occupations and provides a method of analysis which comes closer to depicting the actual functioning of the labor model.

In its examination of the type of employment, our model goes beyond the work of Bezde and Rutzick. It is more complete
since it includes workers in all occupations in all industries rather than just a few occupations. It is more realistic in the way that it considers the questions of worker skills and interoccupational mobility, instead of restricting the workers to a specific occupation. Our consideration of the supply of workers is inadequate due to the unavailability of the required data, and we use fixed employment/output multipliers for lack of a better method. Nevertheless, by focusing on worker skill levels and job skill level requirements, our model offers a significant improvement over the others which have been developed in the past.
CHAPTER III

THEORY

Explanation of the Basic Theory in Terms of the Structural Hypothesis

A combination of neoclassical and Keynesian employment theory

Neoclassical theory begins with a number of assumptions about the workings of the labor market. Since labor power is a factor of production, its demand curve is derived from its marginal revenue product and is assumed to be downward sloping. The supply schedule for labor services slopes upward to the right because higher wages are assumed to induce more workers to enter the labor force. With prices constant, the equilibrium wage and level of employment can then be found at the intersection of the two curves. As long as the neoclassical assumptions of perfect competition hold, the equilibrium will be at the full employment level. Therefore, a market clearing equilibrium wage will be established where there will be just as many jobs available as there are people who are willing to work. This is depicted in Figure 3-1. The neoclassical supply curve for labor services, $S_N S'_N$, is shown as a solid line. The intersection between $S_N S'_N$ and the demand for labor services, $D_D$, yields the level of full employment, $E_N$, and the money
Figure 3-1. Neoclassical and Keynesian Supply and Demand for Labor
wage rate in the neoclassical system, $W_N$.\(^1\)

If money wages are inflexible in the downward direction, as is assumed in Keynesian theory, then full employment is no longer assured. The Keynesian supply curve of labor services is shown as the dashed line, $S^K_S^K'$, in Figure 3-1. Above wage rate $W^K$ Keynesian and neoclassical supply curves coincide. The horizontal portion of $S^K_S^K$ indicates that workers will supply any quantity of labor services between 0 and $E$ at wage $W^K$, and that nothing will be supplied at a money wage rate below $W^K$. If the demand curve intersects the rising portion of the supply curve, the neoclassical and Keynesian equilibria will be the same. If the demand curve intersects $S^K_S^K$ in the horizontal portion, the Keynesian equilibrium will be at a higher money wage rate than in the neoclassical case, and there will be unemployment. The number of workers who would be willing to supply their services at the wage rate $W^K$ is $E$, and the number of workers that the firms would be willing to hire at $W^K$ is $E^K$. Therefore, with an inflexibly downward money wage rate the equilibrium is one of less than full employment, with the level

\[^1\]Full employment usually does not mean the total absence of unemployment. In an industrial society there are always some people temporarily out of work because they are in transition between jobs. These workers are classified as frictionally unemployed. Frictional unemployment is considered to be a natural outgrowth of competitive labor markets under imperfect information, and it is considered necessary for the proper functioning of the economy. It is not thought to pose a problem unless it reaches a high level. We recognize the existence of frictional unemployment, but we do not discuss it in this study because it is outside the scope of our model. See: Edmund S. Phelps, Inflation Policy and Unemployment Theory (New York: Norton, 1972).
of unemployment shown as the distance $(E - E_K)$ in Figure 3-1.

If the price for goods were to increase, the demand curve for labor services and the classical portion of the labor supply curve would shift up proportionately. Since the horizontal portion of $S_K$ is unaffected, this would also move the equilibrium employment level, $E_K$, to the right and reduce the level of unemployment. Because this type of unemployment can be reduced or eliminated by increasing the demand for goods, it is often called demand deficient unemployment.

One of the fundamental labor market problems of a developed economy which is ignored by the analysis presented here is that of matching the skills of individual workers with job skill requirements. As the technology of the economy becomes more developed, the specialization of labor becomes greater. As the required skills change and increase in number, it becomes more difficult to find workers with the qualifications to fit the jobs. As long as the skills of the labor force are changing along with the changes in requirements, there is no problem. In those cases where such changes in the skills of the labor force do not take place, the economy can be thought of as having a "structural unemployment" problem. Eleanor Gilpatrick outlines some of the ways in which this can occur:

The key to the structural problem is the mismatching of specific labor skill demands and supplies where there is (1) limited transferability of skills and (2) limited substitutability among skills. When technical change involves the absolute uselessness of a skill, ..., no amount of increase in demand or the increased supply of any other skill will provide employment for the displaced workers unless they are qualified and willing to do some other work.
... if the technological change creates new coefficients which simply increase the proportions of one kind of skill to the detriment of others, and if the one in greater demand is not available in adequate supply in the population, then all those with skills which are the complements of the one in short supply will be structurally unemployed.  

Let us go back to our original neoclassical labor market where at a given wage and price level the number of workers offering their services was just equal to the number of jobs available. In that case there was full employment but mainly because no recognition was given to the fact that there is great heterogeneity in the skills of workers as well as in job skill requirements. Now add the condition that for a worker to be employed his skills must match the required job skills. Unless this condition is met for every worker and every job, there will be some form of structural unemployment.

Figure 3-2. Venn Diagram: Workers and Job Slots by Skill Bundle

In Figure 3-2 the number of job slots equals the number of workers, and the skill requirements and worker skills are denoted by the subscripts. The figure is drawn for a given price level and wage rate, and assumes inflexible wages in the short-run. Since their skills match the employers' skill

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1Eleanor G. Gilpatrick, Structural Unemployment and Aggregate Demand (Baltimore: Johns Hopkins, 1966), pp. 4-5.
requirements, workers $X_1$ and $X_2$ are employed in jobs $O_1$ and $O_2$. Job slots $O_3$ and $O_4$ are vacant because there are no workers with the required skills, while workers $X_5$ and $X_6$ are idle due to the lack of jobs which require their skills. These idle workers are structurally unemployed, and the empty job slots are structural vacancies.

The standard neoclassical analysis allows the existence of unemployment or vacancies, but not both simultaneously. The beauty of the structuralist analysis is the fact that both unemployment and vacancies can exist simultaneously, and indeed this is factually true in the real world. However, we must be careful in this analysis because the simultaneous existence of both conditions can occur for several reasons. Some of the more recent adherents to neoclassical theory claim that a mismatching of skills will not occur because the price mechanism will tend to correct any excess supply or demand for particular skills. When an imbalance does occur it will be as a result of imperfect information. The structuralists point out that even with perfect information, imbalances can still occur, even if only in the short-run. Any large shift in final demand, such as a change in government expenditures, will bring about a change in the demand for skills. This will cause an imbalance between the supply and demand for skills which will take time to correct.

There seems to be some disagreement among labor economists in terms of determining which part of total unemployment is of the structural type and which part is caused by deficient
demand. The definitions which follow are the ones that will be used in this paper.

The skill bundle associated with each job includes a set of attributes and a set of requirements. The requirements might include a certain level of education and training, and some particular personality traits. The attributes of the job might be an offer wage, pension rights, working conditions, etc. Each worker also has a set of attributes and requirements. Among his attributes might be his level of education and training and his personality traits. His requirements might be his reservation wage, pension demand, working conditions, and other things. In order for a job and worker to match, the attributes and requirements must match up. In those cases where there are both job vacancies and unemployed workers and the attributes and requirements of the jobs and workers do not match, those unemployed workers are structurally unemployed and the job vacancies are structural vacancies. If at the same time there are more workers looking for jobs than there are job vacancies, the excess of unemployment above the level of vacancies is demand deficient unemployment.

This is shown in Figure 3-3. The number of job slots is less than the number of workers willing to offer their services, so there is some demand deficient unemployment. Even though there are people out of work, there are some unfilled job slots. As long as there are jobs available while people are looking for work we must assume that those jobs remain unfilled because the requirements and attributes of the workers and jobs
do not match. Therefore, the three job vacancies $O_6$ through $O_8$ which remain in the midst of unemployment, are structural vacancies, and three of the unemployed workers, $X_9$ through $X_{13}$, are structurally unemployed. Even if all of the jobs were filled there would still be people looking for work, and these individuals would be victims of demand deficient unemployment. In our example three of the five unemployed workers are structurally unemployed, so the other two must be unemployed due to inadequate demand. In some abstract sense all five workers are structurally unemployed because there are no jobs that fit their skills.

Set theoretic approach to the labor market

In the present model it is our contention that each job has attached to it a set of attributes and requirements which must match the worker's attributes and requirements in order for the worker to "technically" perform adequately in a given position. ¹ Since the job requirements are usually defined in

¹There may be some characteristics which an employer might feel a worker must have although those characteristics are not related to adequate performance. For example, if the buyers are racist, an employer might not want a black salesman. Although his skin color would have no effect on his performance of the job tasks in a color blind society, it could have an influence on his effectiveness in the position given racist tendencies.
terms of the minimum levels of necessary characteristics (and possibly maximum levels), and the job attributes are expressed as the maximum wage, pension, and working conditions, etc., the worker attributes and requirements do not have to match these exactly. There may be cases of overskilled workers or jobs whose attributes are greater than the worker's requirements. For instance, a particular worker may have as one of his attributes a higher level of education than the job requires, or his reservation wage may be lower than the job wage offer. In this case we would still say that we have a match between the job and worker skill bundles.

Since the market is composed of employers who are looking for particular sets of attributes and requirements, and workers who have different sets of attributes and requirements, the market supply and demand for labor services is really a set of n markets one for each set of skill bundles. What is needed is a whole set of supply and demand functions, with a different set pertaining to each set of skill bundles. In order to depict the situation more adequately, we will use matrices of the supply and demand for labor, whose elements represent different combinations of requirements and attributes. In Figure 3-4 we have one set of supply elements and one set of demand elements, and each set is classified according to two characteristics, A and B.\(^1\) We assume that each cell has a given fixed wage.

\(^1\)This analysis is shown in two dimensions for expository purposes only and could be expanded to n dimensions.
Figure 3-4. Set Theoretic Approach to the Supply and Demand for Workers by Skill Bundle

Supply
\[
\begin{bmatrix}
s_{11} & s_{12} & \cdots & s_{1n} \\
\vdots & \vdots & & \vdots \\
s_{m1} & \cdots & \cdots & s_{mn}
\end{bmatrix}
\]

Demand
\[
\begin{bmatrix}
d_{11} & d_{12} & \cdots & d_{1n} \\
\vdots & \vdots & & \vdots \\
d_{m1} & \cdots & \cdots & d_{mn}
\end{bmatrix}
\]

\(s_{ij}\) is the supply of workers with level \(i\) of characteristic \(A\) and level \(j\) of characteristic \(B\).

\(d_{ij}\) is the demand for workers with level \(i\) of characteristic \(A\) and level \(j\) of characteristic \(B\).

A necessary, but not sufficient, condition for labor market equilibrium is that the sum of the supplies of workers over all of the sets of skill bundles be equal to the sum of the demands for workers in the corresponding cells.

\[
\sum_{i=1}^{m} \sum_{j=1}^{n} s_{ij} = \sum_{i=1}^{m} \sum_{j=1}^{n} d_{ij}
\]  \hspace{1cm} (3-1)

Under the conditions given in equation (3-1) there is still the possibility of structural unemployment if the supply of workers is greater than the demand in any of the skill markets \((s_{ij} > d_{ij})\), or structural vacancies if the demand for workers is greater than the supply in any of the skill markets \((d_{ij} > s_{ij})\).

In order to avoid carrying out the analysis for an excess supply of workers where there is structural unemployment, and
then repeating it for an excess demand for workers where there are structural vacancies, we will restrict our study to the case in which the aggregate supply of workers is greater than the aggregate demand.

\[
\sum_{i=1}^{m} \sum_{j=1}^{n} s_{ij} > \sum_{i=1}^{m} \sum_{j=1}^{n} d_{ij}
\]  

(3-2)

Equation (3-2) tells us that there are more workers than jobs, so there will be some demand deficient unemployment in the system, but there is still the possibility for structural unemployment or job vacancies. In the individual skill markets, if \( s_{ij} < d_{ij} \), there is full employment in that segment of the market and, in fact, there may be "price adjustment" pressures caused by the structural bottleneck. In those instances where \( s_{ij} > d_{ij} \), there is unemployment, but it is unclear what portion is a result of deficient demand and what portion is structural. This can be determined on the aggregate level.

Take all of the cases where there is an excess demand for workers, \( d_{ij} > s_{ij} \), and calculate the number of job vacancies.

\[
\sum_{i=1}^{m} \sum_{j=1}^{n} (d_{ij} - s_{ij}) \quad \text{(vacancies)}
\]  

(3-3)

Then take all of the cases where there is an excess supply of workers, \( s_{ij} > d_{ij} \), and calculate the total amount of unemployment in the system.

\[
\sum_{i=1}^{m} \sum_{j=1}^{n} (s_{ij} - d_{ij}) \quad \text{(unemployment)}
\]  

(3-4)
As long as unemployment exists in the economy (3-4), simultaneously with job vacancies (3-3), the number of job vacancies equals the level of structural unemployment. Even if all of those vacancies were filled, there would still be some workers unemployed due to deficient demand. So the difference between the total amount of unemployment and the number of job vacancies \((3-4)-(3-3)\), represents demand deficient unemployment. What all of this says is that if unemployment exists for the economy as a whole while there are unfilled positions in certain sectors of the labor market, the total of those openings is structural unemployment and the additional unemployment above that amount is caused by deficient demand. Therefore, the amount of structural unemployment is equivalent to the unfilled job vacancies.

**Demand deficient vs. structural unemployment**

Exactly what the connection is between these two types of unemployment, how to measure them, and the steps that must be taken to combat them, is at the core of the inadequate demand-structural controversy. There seems to be agreement on both sides that demand deficient unemployment is that which exists because the level of production generated by aggregate demand is not sufficient to maintain full employment at existing wage levels. There is also agreement that if demand were increased

---

1 Some of these job vacancies are certainly frictional, so the actual level of structural unemployment is really less than the number of vacancies. However, we do not refer to this problem specifically in this study since it is outside the scope of our model. See: note 1, page 37.
enough, full employment could be reached. Where the two groups part company is in determining how much demand would have to be increased to reach the goal of full employment, and what kind of inflationary pressure would arise in the process.

The basis for the structuralist viewpoint is the presence of labor bottlenecks caused by the lack of workers with skills that employers want.\(^1\) If demand should increase sufficiently employers may be induced to hire less qualified workers which would increase their costs of production. Structuralists agree that this would reduce unemployment but at the cost of a higher rate of inflation. They feel that the proper action would be to educate and retrain workers. This would be more of a long-run solution but could ultimately be less costly than the inflation brought about by a policy of increasing aggregate demand.

Inadequate demand adherents point out that if the problem is not really structural, the training process will not reduce unemployment and will lead to a group of frustrated workers with new skills and no jobs.\(^2\) The problem seems to be one of

\(^1\) Another possibility is the existence of geographic bottlenecks. On the aggregate level, even with an equal number of jobs and workers with a given set of requirements and attributes, there may be job vacancies and unemployment. If the jobs are in California and the workers in New York, bottlenecks will still occur unless geographic mobility is assumed. Our model does not address this question but some of its implications are discussed in the concluding chapter.

determining the cause of unemployment. If that could be determined the appropriate steps could be taken to combat unemployment.

What is needed is a method to identify which skills would be in excess demand, and which ones would be in excess supply when final demand increases. In those cases where there is an excess demand for skills there would be structural job vacancies and potential production bottlenecks; where there is an excess supply of skills there would be demand deficient unemployment. With this kind of information increases in demand, at least in the government sector, could be tailored so that they are concentrated in those sections of the economy which are suffering from inadequate demand, and have the maximum impact upon unemployment without exacerbating the structural unemployment problem. This is the purpose of the model that is developed in this paper. Implicit in the model is a recognition of both structural and demand deficient unemployment, and it attempts to locate the bottlenecks so that the inadequate demand problem can be reduced, while minimizing inflationary pressures.

General Educational Development and Specific Vocational Preparation

Definitions of the terms

In the present study, the rationale behind classifying jobs according to skill bundles is to establish a basis for estimating the demand for workers who possess particular requirements and attributes. Ideally all of the arguments in the skill bundles should be considered in order to come as
close as possible to the actual conditions in the labor market. However, it would be virtually impossible to list all of the arguments of the skill bundles. Even if they could be listed, there would still be the task of obtaining information on each of these skills. Therefore, a set of criteria is established to delineate which skills should be included and what type of information on these skills is needed.

Every job has among its requirements certain "ability traits" while different jobs which demand the same ability traits may require different "ability levels". Therefore included in each job requirement is both the type and level of ability needed to perform the tasks associated with that job. For instance, an economist needs to have a high cognitive ability level, and in addition he needs some other specific abilities (mathematical, statistical), which others who require an equal cognitive ability level do not need. As a logician, a philosopher also needs a high cognitive ability level, but he does not have to be a good mathematician.

The same argument holds in terms of "skills" and "skill levels". Each job requires a worker to have certain types of skills in order to carry out the job tasks, but different jobs requiring the same skills may demand different levels of those skills. Both a registered nurse and a practical nurse must have the skills needed to administer medication to patients, dress wounds, recognize signs of illness, etc. A registered nurse, however, must also be able to give injections, assist surgeons, and perform other tasks which are not required of the practical
nurse. Although both nurses need the same types of skills, the practical nurse does not need the same level of expertise in those skills as is required of the registered nurse.

In keeping with the concepts of ability vs. ability levels and skills vs. skill levels, the worker characteristics which were selected for use in this study are General Educational Development (GED) and Specific Vocational Preparation (SVP). Measures of GED and SVP are based on observations and interviews at the jobsite. The GED and SVP classifications as reported by the Department of Labor in the Supplement to the Dictionary of Occupational Titles, reflect the level of expertise that is needed to perform the tasks associated with the job, rather than what the worker actually possesses. These are the requirements determined by objective job analysis as necessary and sufficient to achieve average performance in the specific tasks of the jobs. Such estimates try to focus on the tasks performed in relation to the things, the data, or the people involved in those tasks. 3


2 The extent to which this is true depends upon the objectivity of the rater. If a particular position is staffed by mechanical engineers, but the job could be handled by someone with an associate degree in engineering, it would be unlikely that the rater would classify that job as requiring the lower level of training. In such a situation the qualifications of those who are presently employed could easily affect the rating.

General Educational Development is not a measurement of the level of formal education a worker needs, although Eckaus did make an attempt to translate GED categories into school year equivalents. Fine claims that a years-of-schooling classification was avoided because the same grade level can mean different things for different times and in different places, and also that years-of-schooling is not always relevant to specific job tasks. What is done instead is to try to rate each job on the basis of what degree of reasoning development, mathematical development, and language development is necessary to perform the tasks given in the job descriptions found in the Dictionary of Occupational Titles. A scale of 1 through 6 is used to indicate each level of development, with higher numbers reflecting higher levels. If a job does not require the same GED level for each of the three criteria, it is classified according to the one which is most relevant. With this system two occupations that involve the performance of different tasks or require different levels of formal education, can still receive the same GED rating as long as at least one of the three development criteria is judged to be at the same level for both occupations. A complete explanation of the GED classification system is given in Appendix A.


2Fine, p. 366.

Specific Vocational Preparation is measured in terms of the actual number of years of training necessary to achieve an average level of expertise required in the performance of a job. SVP is a measure of the job specific skills necessary to carry out a particular job. What constitutes this kind of training is best described in the *Supplement*.¹

Specific Vocational Preparation: The amount of time required to learn the techniques, acquire information, and develop the facility needed for average performance in a specific job-worker situation. This training may be acquired in a school, work, military, institutional, or a vocational environment. It does not include orientation training required of even every fully qualified worker to become accustomed to the special conditions of any new job. Specific Vocational training includes training given in any of the following circumstances:

a. Vocational education (such as high school, commercial or shop training, technical school, art school, and that part of college training which is organized around a specific vocational objective);
b. Apprentice training (for apprenticeable jobs only);
c. In-plant training (given by an employer in the form of organized classroom study);
d. On-the-job training (serving as learner or trainee on the job under the instruction of a qualified worker);
e. Essential experience in other jobs (serving in less responsible jobs which lead to the higher grade job or serving in other jobs which qualify).²

For each type of job the amount of time spent in each of the activities a. through e. is calculated and added together to arrive at the SVP classifications 1. through 9. given in table 3-1.

²Supplement to the Dictionary of Occupational Titles, Appendix 5.
TABLE 3-1

SVP CLASSIFICATIONS

<table>
<thead>
<tr>
<th>Level</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Short demonstration only.</td>
</tr>
<tr>
<td>2.</td>
<td>Anything beyond short demonstration up to and including 30 days.</td>
</tr>
<tr>
<td>3.</td>
<td>Over 30 days up to and including 3 months.</td>
</tr>
<tr>
<td>4.</td>
<td>Over 3 months up to and including 6 months.</td>
</tr>
<tr>
<td>5.</td>
<td>Over 6 months up to and including 1 year.</td>
</tr>
<tr>
<td>6.</td>
<td>Over 1 year up to and including 2 years.</td>
</tr>
<tr>
<td>7.</td>
<td>Over 2 years up to and including 4 years.</td>
</tr>
<tr>
<td>8.</td>
<td>Over 4 years up to and including 10 years.</td>
</tr>
<tr>
<td>9.</td>
<td>Over 10 years.</td>
</tr>
</tbody>
</table>

Some of the weaknesses of GED and SVP

There are some drawbacks in using GED and SVP as measures of requirements in the context outlined above. The GED classification system uses both ability and ability level in determining the job's GED category, however, the levels of the different kinds of abilities used in this determination are obscured in the final reporting. Even though reasoning, mathematical, and language development are considered, if the required levels of these types of abilities are different, only the level of the one which is deemed most important is assigned to the job classification. In an example we noted that economists and philosophers require a high level of reasoning ability, but that there is a difference in the mathematical ability level
needed. The GED classification for both occupations is given as level 6, which relates to the common high level of reasoning ability; the GED classification gives no indication of the difference in the mathematical ability requirement.

The SVP scale measures the level of job specific skills required on an occupation, however, it does not indicate the type of skills needed to perform the tasks associated with the job. Since the particular types of skills can differ among occupations, SVP provides a basis of comparison among skill levels but not skill types. Through additional training a worker's SVP is increased, which would allow movement among a number of jobs which require the same basic skills. But a transfer from one job to another which is completely unrelated in terms of the basic skills, is not possible. For two unrelated occupations with the same SVP rating, such as a secretary and a carpenter with SVP level 6, Table 3-1 indicates that both require "over 1 year up to and including 2 years" of training. Since the type of training is different in each case (although there could still be a common general minimum of acquired skills), mobility between jobs is not possible. This would not be evident from an examination of SVP levels alone.

GED, on the other hand, is a measure of ability which can be transferred from one field to another. But even with the required level of ability, the worker would first have to receive the training necessary to achieve the level and type of skills to do a particular job. Both a secretary and a carpenter require GED level 4. This means that they both have the level
of ability to handle the other's job, but they must also have the required skills and skill levels to actually carry out the job. If the carpenter doesn't know how to use a typewriter and the secretary can't handle a miter box, ability alone won't get the job done. Therefore a worker with a particular level of GED or SVP alone would not qualify to do a job. The worker must possess the combination of ability, ability level, skills, and skill levels that the tasks of the job require.

This points out an important consideration in determining the possibility of interoccupational mobility. GED is an indicator of an individual's ability level and it is unlikely to change very much after completion of formal schooling. As long as we want to move a worker into another job which requires the same or lower GED, he will have the ability level needed to carry out the job. An individual's SVP level can be changed, but the same level is not applicable to all job tasks. Therefore with SVP we must consider two factors: the skill level and the type of skills. For the carpenter who has the same ability level as is required of the secretary, but not the same type of skills, he could be trained to be a secretary but he would have to start from the beginning because most of his present skills are not transferable. A practical nurse has the same ability level as a registered nurse, but a lower skill level. However, a practical nurse can advance to the skill level of a registered nurse without starting at the very beginning because the basic types of skills are common to both occupations, and can be transferred from one to another.
Why GED and SVP are useful measures

GED and SVP levels were chosen as useful measures of job requirement bundles for use in the present study because they meet three selection criteria: (1) they reflect job requirements which are relevant to employment decisions; (2) they are quantifiable and ordinal; and (3) they indicate functional occupational requirements.

First, only a few job requirements could be used in the model, so only those which we felt were important were selected. Education, either formal or acquired, and vocational training and/or experience seem to us to be the most important considerations. The relevant factors in vocational training are formal training, in plant or on-the-job training, and the experience acquired in related employment. SVP provides this information. It is not as simple to get a handle on education. If an individual lacks the required amount of formal education, he may be tested to determine if he has a sufficient level of general education. Because the process of testing workers is time consuming and expensive, quite often successful performance in a previous position is accepted as evidence of ability. What an employer would probably be interested in is whether the worker has sufficient intelligence to handle the job. He would want to know about the worker's innate ability and what he has acquired from experience and retained from schooling. GED is a reliable indicator for these purposes because it is concerned with the necessary intellectual ability in terms of mathematical, language, and reasoning development. Therefore, with job requirements
expressed in terms of GED and SVP, it is possible to compare these levels with similar measures of a worker's ability and skills.

Second, it is important that the data be available in a form that allows identification by occupation, and quantifiable so that it fits into the model. The data was collected by the U.S. Employment Service through 75,000 studies of individual job situations. Most jobs were surveyed in two different establishments in two different states, and the results were correlated for 14,000 different jobs. The training time requirements are available in a single volume and classified according to a six digit code which comes from the job number reference in the Dictionary of Occupational Titles.\(^1\) Since the Dictionary contains complete descriptions of the jobs, there is little danger of confusing job titles. The numerical classifications provide the necessary information in a form which is easily adaptable to the analytical framework of the model. In this respect GED and SVP appear to be well-suited to our purpose.

On the question of requirements, Sidney Fine\(^2\) makes the observation that there are really three different sets of requirements that are used in the labor market but that only one set is relevant to actual performance on the job. Functional or Performance requirements comprise the set he feels are most

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\(^1\) *Dictionary of Occupational Titles, Vol. I, Definitions of Titles.*

relevant. This is made up of those factors which are deemed to be "necessary and sufficient to achieve average performance in the specific tasks of the jobs." Employer or hiring requirements are less useful because they are affected by conditions in the labor market. For instance, there is often a minimum level of education or experience required in order to be considered for some jobs. This level may have nothing to do with what is needed for the actual performance of the job, but acts merely as a job credential. This level of education or training will often fluctuate depending on the tightness or looseness of the labor market and therefore provides no standard form of comparison. The third set of requirements, educational attainment, is sometimes confused with requirements. Just because those employed in a certain occupation have a particular level of education and training does not mean that this is a functional requirement for job performance. Fine concludes:

Each of the three meanings of "educational and training requirements" cited above is relevant to a different context ... for the purposes of measuring educational investment and meeting manpower needs (i.e., of anticipating and fulfilling the requirements of industry), it is the first set of estimates which is relevant. That is we need estimates here of the functional requirements of jobs.

These functional requirements are the ones that Fine feels should be used to anticipate industry manpower requirements and this is basically what we want to do here. Fortunately, this definition

1Fine, p. 365.
2Fine, p. 366.
of functional requirements is the basis for the measurement of GED and SVP.

**Joint GED/SVP distributions**

Even though GED and SVP statistics provide the kind of data that is needed for this study, they must be compiled and adjusted before they can be put to use. The training time information contained in the Supplement\(^1\) is nothing more than a list of thousands of occupations with GED and SVP scores for each of them. Somehow these occupation specific GED and SVP scores must be distributed over industries for use in our analysis.

In an attempt to determine the cost of training workers to meet the needs of the economy, Richard Eckaus\(^2\) constructs separate distributions of the GED and SVP requirements for a number of different industries. He looks at two sets of information: a list of workers in the industry which allows the distinction to be made between different education and training requirements by industrial sector; and for each of these job categories, the amount of education and training needed for an average level of performance on the job. For this second set of information he uses GED and SVP. He takes these occupation-based GED and SVP categories and translates them into the percentage of workers that each industry requires by GED and SVP category. Eckaus concludes that the cost of providing a labor

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\(^1\)Supplement to the Dictionary of Occupational Titles.

\(^2\)Richard S. Eckaus, "Economic Criteria."
force which meets these requirements can be found by calculating the cost of educating workers to acquire these specific skills.

We ultimately want to predict the number of workers in each of the GED and SVP categories that will be needed in order to operate the economy under given conditions of final demand. The total production of goods and services will be found through input-output analysis and then translated into total employment demands. Some manner must be devised to translate total employment demands into the demand for workers by GED and SVP category. What we have adopted is a methodology similar to Eckaus's. Since all workers must have some level of both GED and SVP, these two job requirements must be considered jointly. The method which will be used here involves the construction of matrices showing the percentage of required employment in joint GED and SVP classifications for each industry. We call each of these joint classifications GED/SVP categories. Multiplication of the individual matrix elements by the level of employment provides the required number of workers in each of the GED/SVP categories. This is the matrix formulation of the demand for workers according to different characteristics as shown on the right hand side of Figure 3-4.

In Figure 3-5 each cell of the array represents a segment of the labor market where element \( p_{gs} \) indicates the percentage of the demand for workers in the economy with level \( g \) of GED and level \( s \) of SVP. Since every job in the economy falls into one of the categories in Figure 3-5, the set of elements taken together represents the total demand for workers and
Figure 3-5. Percentage Demand for Workers by GED/SVP Category for One Industry

\[
\begin{pmatrix}
  p_{11} & p_{12} & \cdots & p_{19} \\
p_{21} & \cdot & \cdot & \cdot \\
\cdot & \cdot & \cdot & \cdot \\
p_{61} & \cdot & \cdot & p_{69}
\end{pmatrix}
\]

In theory, if the \( p_{gs} \) elements are multiplied by total employment (a scalar), we obtain a matrix of the demand for workers in each of the GED/SVP categories. This matrix can then be paired with the matrix which contains the supply of workers in each of the categories and we can play the same structural-demand deficient game as we did before. Each of the demands can be matched with the individual supply categories to determine where bottlenecks might occur, and where there would be unemployment.

Unfortunately, supply information on the skills of the total labor force in categories comparable to the demand data is not available for the U.S. economy. This forces us to restrict our discussion to changes in the demand conditions instead of total demand. When final demand increases, we can use the model to find the increases in demand for different combinations
of worker skills (the GED/SVP characteristic levels). By comparing these changes in demand with the known characteristics of unemployed workers, we can still locate where the bottlenecks might crop up and where there would be unemployment. If final demand should decrease, the model can estimate how many workers in different skill categories would be laid off, without requiring an examination of the labor supply conditions.

For policy purposes this method of concentrating on changes in demand simplifies the examination of the labor market. When a program is formulated to change demand, the policy makers need not concern themselves with the total supply of workers that are presently employed. As demand increases, the assumption is that existing employment remains the same and they need only look at the increased demand for workers and the existing supply of unemployed workers. When demand falls, the reduced demand for workers is assumed to trigger a corresponding increase in the supply of unemployed workers.¹ In both cases there is no need to consider the total supply of workers; only that portion of the labor force that is unemployed. This also simplifies the task of collecting supply data, since the number of employed

¹There are some limitations to these assumptions. (1) When demand increases, some of those workers who are already employed may quit their present jobs and move on to new ones. Thus, increases in demand can affect workers other than those presently unemployed. (2) The supply of workers is also affected by the demand for workers through the "additional" and "discouraged" worker effects. Therefore, measured unemployment may not rise when the demand for workers falls because discouraged workers leave the labor force instead. Likewise, when the demand for workers rises measured unemployment may not fall because the increased demand may induce additional workers to enter the labor force.
workers can be ten or twenty times as large as the number of unemployed workers.

Since all workers possess some degree of both education and training, and we have six GED and nine SVP classifications, there are $6 \times 9 = 54$ possible categories of worker characteristics. The distribution of worker characteristics is different in each industry. If only one aggregate matrix is used to show the distribution of worker skills over the whole economy, the model might overstate or understate the actual demand for a particular set of worker skills. For instance, in the lumber and wood products industry one-third of the workers are lumbermen whose GED is 2 and SVP is 6. (For convenience we abbreviate this skill classification to [2,6].) This low GED coupled with a high SVP is uncommon, and as a matter of fact most industries do not have any workers who fit into this category. Therefore in a model which uses one aggregate classification matrix for the whole economy, the [2,6] slot would be quite small, even though it is large for lumber and wood products. Suppose that there was an increase in the demand for new houses. A national model would predict a small increase in the demand for GED/SVP [2,6], when in reality much of that increased demand would be for lumber, and there would be a large increase in the demand for lumbermen.

The solution to this problem is to construct separate matrices for each industry. In this way the output of the lumber industry would be paired with a matrix of the worker characteristics that are used in the lumber industry. This matrix would have a third of the workers in category [2,6] and the model
would predict that a third of the increased demand for workers in the lumber industry would be in that category.

This makes it necessary to obtain employment information by industry. Fortunately, the input-output table provides output information on an industry-by-industry basis which can be converted to employment figures via industry employment/output ratios. This can then be combined with the industry matrix of required worker characteristics to obtain a matrix of the distribution of the demand for workers by GED/SVP category in each industry. The number of possible demand categories which will have to be considered will grow from 54 to 54 times the number of industries.

We have matrices of the distribution of worker skills for 55 industries, therefore the total number of classification categories that we can possibly consider is 2,970. Some of these categories were eliminated in order to simplify the analysis. First, the SVP category 9, training time over 10 years, was deleted and its entries were placed in SVP 8. SVP 8 which previously included training periods "over 4 years up to and including 10 years", was redefined to be "over 4 years". In addition, for 21 different joint GED/SVP categories, the entries in the distribution matrices for all 55 industries are zero, so these categories do not have to be considered.\(^1\)

---

\(^1\)There is a positive correlation between GED and SVP levels, and most of the high GED/low SVP and low GED/high SVP levels are non-existent. For instance, there are no workers in categories [1,8] or [6,1] in any of the industries included in this study.
leaves us with 27 entries for each of the 55 industries, or a total of 1,485 categories to consider.

The matrix of $p_{gs}$ elements in Figure 3-5 is now reduced to a set of elements which is clustered along the diagonal, with blanks to the top right and bottom left as shown in Figure 3-6. We have a whole series of these matrices, one for each industry. In order to put this in a form which will be easier to manipulate, we redefine the $p_{gs}$ matrix into a column vector of $h_{gj}$ elements.

Figure 3-6. Relevant Categories of the Percentage Demand for Workers by GED/SVP Category for One Industry

\[
\begin{pmatrix}
p_{11} & p_{12} & - & - & - & - & - \\
- & p_{22} & p_{23} & p_{24} & p_{25} & p_{26} & - \\
- & - & p_{32} & p_{33} & p_{34} & p_{35} & p_{36} & p_{37} & p_{38} \\
- & - & - & p_{42} & p_{43} & p_{44} & p_{45} & p_{46} & p_{47} & p_{48} \\
- & - & - & - & p_{55} & p_{56} & p_{57} & p_{58} \\
- & - & - & - & - & p_{67} & p_{68}
\end{pmatrix}
\]

$p_{gs}$ is the percentage of total industry employment in GED/SVP category $[g,s]$ in a given industry.

The $g$ denotes the GED/SVP category, and the $j$ indicates the industry. The $g$'s range from 1 to 27, corresponding to a consecutive numbering of the subscripts from left to right, top to bottom: $p_{11}=h_{1j}$; $p_{12}=h_{2j}$; $p_{22}=h_{3j}$; $p_{68}=h_{27,j}$, etc. Now we can rewrite the P matrices for all of the worker distributions for all industries into one, all inclusive matrix as shown in Figure 3-7.

The H matrix gives the percentage of employment by GED/SVP characteristic in each industry. Each column pertains to a
different industry and each row denotes a different GED/SVP category. For prediction purposes we are interested in the number of workers in each category, not just the percentage.

Figure 3-7. Percentage Demand for Workers by GED/SVP Category for All Industries

\[
\begin{pmatrix}
    h_{1,1} & h_{1,2} & \cdots & h_{1,55} \\
    h_{2,1} & & & \\
    \cdot & & & \\
    \cdot & & & \\
    \cdot & & & \\
    h_{27,1} & \cdots & h_{27,55}
\end{pmatrix}
\]

\( h_{gj} \) is the percentage of workers with GED/SVP characteristic set \( g \) in industry \( j \).

In order to obtain the number of workers we multiply the \( h_{gj} \)'s by industry employment, \( e_j \). This is shown in Figure 3-8 as the matrix of \( b_{gj} \) elements.

Figure 3-8. Demand for Workers by GED/SVP Category for All Industries

\[
\begin{pmatrix}
    b_{1,1} & b_{1,2} & \cdots & b_{1,55} \\
    b_{2,1} & & & \\
    \cdot & & & \\
    \cdot & & & \\
    \cdot & & & \\
    b_{27,1} & \cdots & b_{27,55}
\end{pmatrix}
\]

\( b_{gj} \) is the number of workers with GED/SVP characteristic \( g \) in industry \( j \).

\( b_{gj} = h_{gj} e_j \)
The demand for workers by GED/SVP category is shown by industry in Figure 3-8, therefore the total demand for workers in each GED/SVP category for the whole economy can be found by summation over all industries.

\[ \sum_{j=1}^{55} b_{gj} = B_g \quad g=1, \ldots, 27 \]

where \( B_g \) is the sum of the demands over all industries for workers with GED/SVP characteristic \( g \).

**Linking the Distributions to the Economy Through Input-Output**

**Theory of Leontief production functions**

The contention of this paper is that once the required level of industry employment is known, the distribution of the demand for worker skills can be determined. We assume fixed "labor factor" proportions according to skills, analogous to fixed factor proportions in Leontief production functions, but it is necessary to predict the required level of employment.

The demand for labor is derived from the demand for the final product of the firm or industry, as is the case with the other factors of production. The demand for the final product of an industry is a function of both the demand for the final users of the industry's product, and the demand by other industries which need the product as an intermediate good in the production of their own products. The level of production in the other industries is a function of the same two factors.
Since the intermediate demands are dependent upon the final demands, the key to the demand for the output and employment of any industry is the level of final demand for the output of that and all other industries in the economy. We will not go so far as to try to determine the level of final demands because that task is beyond the scope of the present study. Instead we will assume that the final demands are exogenously given and proceed from there to find the levels of production and employment in the individual industries.

We will use input-output analysis to predict levels of industry output because it permits an examination of the effects of a change in final demand for the goods of one industry on the demand for intermediate goods from all industries, including the original one. For instance, increased demand for furniture would necessitate larger purchases of wood, metal, varnish, material, stuffing, and any other inputs used in making furniture. The producers of the inputs would, in turn, buy more from their suppliers. The varnish producers would buy more linseed oil and pigments from the agricultural sector, metal for cans, etc. In theory, this whole process would continue to branch out until the incremental demands became negligible. The same chain of events would be set in motion for each of the other inputs that the furniture industry acquired. In one unified mathematical operation input-output analysis permits the summation of all of the changes in the outputs of all of the affected industries as a result of that one increase in final demand.
Before going into the actual operation of the input-output system, we should examine the Leontief production function which is the theoretic basis for the system. A key assumption of a Leontief production function is that of constant returns to scale with no substitution among the factors. If output is to be increased or decreased, it can be accomplished by increasing or decreasing all inputs by the same proportion. The technical coefficients are constructed for a particular level of output, and there is no provision in the production function for changes in the relative input proportions, no matter how much output deviates from that level.

Take the case of an economy where each industry uses the output of the other industries in order to produce its product, and there are no primary factors of production. Let $q_j$ be the output of industry $j$, let $x_{ij}$ be the use of the output of industry $i$ as an input of industry $j$, and $a_{ij}$ be the unit requirement of input $i$ needed by industry $j$ in producing one unit of output of industry $j$.\(^1\) Then

$$q_j = \min \left( \frac{x_{1j}}{a_{1j}}, \ldots, \frac{x_{nj}}{a_{nj}} \right) \quad j=1, \ldots, n \quad (3-6)$$

This is in recognition of the fact that some portion of the actual inputs used may be more than the amount required, and since the inputs are required in a fixed proportion, the maximum

---

The level of output which can be produced is restricted by the input whose unit requirement is in the smallest supply. Another way of expressing this is

\[ q_j \leq \frac{x_{ij}}{a_{ij}} \quad i=1,\ldots,n; \quad j=1,\ldots,n \]

If we assume that all producers are rational and do not waste any inputs

\[ q_j = \frac{x_{ij}}{a_{ij}} \quad \text{and} \quad x_{ij} = a_{ij} q_j \quad i=1,\ldots,n; \quad j=1,\ldots,n \quad (3-7) \]

In terms of its use of inputs, for industry \( j \) to produce a given level of output, \( q_j \), it requires quantity \( x_{ij} \) of each of the various inputs which enter into its production function. Substituting from equation (3-7), the production function for industry \( j \) is

\[ q_j = a_{1j} q_j + \cdots + a_{nj} q_j \quad j=1,\ldots,n \]

Similarly, this can be stated in terms of the uses of the industry's outputs. The output of any industry can be used either as an intermediate input of other industries or to satisfy final demands.

\[ q_i = x_{i1} + x_{i2} + \cdots + x_{in} + f_i \quad i=1,\ldots,n \]

where \( f_i \) is the final demand for the output of industry \( i \). Substituting from equation (3-7) this can be written in the form
\[ q_i = a_{i1}q_1 + a_{i2}q_2 + \ldots + a_{in}q_n + f_i \quad i = 1, \ldots, n \]

The input-output table provides the empirical data necessary to construct the production functions and to indentify the use of the outputs of all of the major industries in the U.S. economy.

**General Leontief model**

The cornerstone of input-output analysis is the interindustry transactions table. This table presents the dollar value of transactions (in producer's prices) among the various industrial sectors. Each row of the table shows the total sales by the industry named at the left to the industry indicated at the top, and each column shows the purchases of inputs by the industry shown on top from the one listed on the left.

This interindustry transactions table provides for the tracing of the movement of goods and services as they are sold by one sector as an input to another sector as many times as necessary until the final product is completed. It is the movement of these goods and services from one industry to another, not just to final demand, which sets input-output apart from other methods of analysis.

There is additional information in Figure 3-9 usually published along with the interindustry transactions table. It is part of the input-output system but not strictly part of the table. Below the bottom line is a category known as value added which allows for the identification of payments made to inputs which are not produced by other industries. Included here are
Figure 3-9. The Input-Output System

\[
\begin{pmatrix}
x_{11} & \cdots & x_{ij} & \cdots & x_{in} \\
x_{21} & \cdots & \cdots & \cdots & \cdots \\
& \text{INTERINDUSTRY}
\end{pmatrix}
\begin{pmatrix}
f_1 \\
\end{pmatrix}
\]

PURCHASES
OF
INPUTS
\[
\begin{pmatrix}
x_{il} \\
& \text{INTERINDUSTRY}
\end{pmatrix}
\begin{pmatrix}
f_i \\
\end{pmatrix}
\]

\[
\begin{pmatrix}
x_{nl} & \cdots & x_{nj} & \cdots & x_{nn} \\
\end{pmatrix}
\begin{pmatrix}
f_n \\
\end{pmatrix}
\]

ABOVE THE LINE

BELOW THE LINE

\[
\begin{pmatrix}
va_1 & \cdots & va_j & \cdots & va_n \\
\end{pmatrix}
\]
VALUE ADDED

\[
\begin{pmatrix}
q_1 & \cdots & q_j & \cdots & q_n \\
\end{pmatrix}
\]
TOTAL OUTLAYS

\( f_i \) is the final demand facing industry \( i \)

\( q_j \) is the total output, (total outlays, total demand) for industry \( j \)

\( va_j \) is the value added for industry \( j \)

\( x_{ij} \) is the dollar output of industry \( i \) which is purchased by industry \( j \)
employee compensation, indirect business taxes, property-type income and capital consumption allowances. Total outlays is the sum of industry purchases and value added, and is also referred to as the total value of goods produced, or just total output.

The total dollar output of industry \( j \) is equal to the sum of the purchases made by industry \( j \) from all of the other industries plus its value added (payments to employees, government, property-type income and capital consumption allowances).

\[
\sum_{i=1}^{n} x_{ij} + v_{aj} = q_j \quad j=1,\ldots,n
\]

If the outputs of all \( j \) industries measured in terms of value added are summed together, the total output of the economy is obtained. This is equivalent to the computation of Gross National Product by the flow of payments approach.

\[
\sum_{j=1}^{n} v_{aj} = GNP
\]

In the column to the right of the table is the vector of final demands for all goods and services. It is composed of personal consumption expenditures, gross private domestic investment, net exports of goods and services, and government purchases of goods and services. The sum of the sales of output by one industry to all other industries as intermediate inputs, plus the output going to final demand, equals the total dollar value of the output of that industry.
\[ \sum_{j=1}^{n} x_{ij} + f_i = q_i \]

The total of the outputs of all industries going to final demand equals the Gross National Product,\(^1\) but this time it is computed by the folow of goods approach.

\[ \sum_{i=1}^{n} f_i = \text{GNP} \]

In this study we are interested in examining the production functions for each of the industries listed in the table. A production function usually lists the quantity of inputs required per unit of output, while the table lists the total dollar purchases of inputs needed to achieve a given dollar level of output. All of the industries produce a number of different outputs and since it would be difficult to identify the number of units of output produced by each industry and sold to the other industries, the accepted convention is to look at the dollar use of inputs per dollar of total outlays.

---

\(^1\)Strictly speaking, GNP equals the total output of all goods and services, plus changes in inventories. The Bureau of Economic Analysis enters these inventory changes into the final demand column "in order to provide the balance between the output of each industry and the total consumption of its products." They do not identify which industry holds the inventory, as is normally done. Instead they classify inventories by the product, no matter if the inventories are held by the primary producer as the industry's final product, or by another producer which holds the product in its inventory of inputs. See: Definitions and Conventions of the 1967 Input-Output Study, U.S. Department of Commerce, Bureau of Economic Analysis, Interindustry Economics Division (BE-51), October, 1974, p. 16.
The matrix of total dollar transactions is transformed into the A matrix of direct requirements per dollar of gross output.

Figure 3-10. The A Matrix of Input Requirements Per Dollar of Output

\[
\begin{bmatrix}
a_{11} & \cdots & a_{1n} \\
a_{21} \\
\vdots \\
a_{n1} & \cdots & a_{nn}
\end{bmatrix}
\]

A is the matrix of direct requirements per dollar of gross output

\[a_{ij}\] is the dollar use of input \(i\) by industry \(j\) in producing one dollar of output of industry \(j\)

For industry \(j\) to produce a desired level of output of value \(q_j\), the dollar value of its use of produced inputs is found by taking the elements in column \(j\) of the A matrix and multiplying by \(q_j\).

\[x_{ij} = a_{ij}q_j \quad i=1, \ldots, n; \quad j=1, \ldots, n\]

The A matrix is, in effect, a set of linear production coefficients for all of those industries which are contained in the table. The only difference between this and a normal production function is that the units are measured in dollars rather than physical output. Because the production level in every industry may be dependent upon the production levels in all other industries, the equations in the A matrix must be solved simultaneously in order to obtain a consistent set of outputs. The solution to the
Leontief system does just this.

Define \( Q \) as the vector of total demands (both intermediate and final). Then \( A \), the matrix of direct requirements per dollar of gross output, times \( Q \), the vector of total outputs, is the amount of intermediate inputs that will be needed by the industrial sector in order to achieve total output level \( Q \). Then

\[
Q - AQ = F
\]

where \( F \) is the vector of final demands. Equation (3-8) is an identity that tells us that the portion of total output which is available to meet final demands is whatever remains from total production after some of the output has been used in the production process as intermediate inputs.

Final demand is not usually treated as a residual by economists, so a more useful form of this equation would make final demand the exogenous variable and total output endogenous.

\[
F = Q - AQ
\]

\[
F = (I-A)Q
\]

\[
(I-A)^{-1}F = Q
\]

(3-9)

In this form a given vector of final demands can be translated into the vector of the total production necessary to meet that demand. The \( (I-A)^{-1} \) is the matrix of total requirements, both direct and indirect, per dollar of delivery to final demand. It is also called the Leontief inverse matrix.

There is a very practical problem with the use of the \( A \) matrix as a set of production coefficients which should be noted.
It is the assumption of the input-output system that any industry
can increase its level of production as much as it wants, the only
restriction being that its use of produced inputs must be increased
in the same proportion as its increase in output. This assumption
is internally consistent with the input-output model because the
table contains only the produced inputs, and the supply of these
inputs can always be increased by producing more output. There
is no provision in the table for the supply of primary inputs
which could place a limit on industrial production. In the real
world, the scarcity of primary inputs is an economic fact of life.
Limited supplies of workers, capital and natural resources place
a limit on the production of produced goods. In the present case
we are concerned with the availability of workers with the proper
skills to fill the available job slots. A large increase in the
demand for final output could increase the demands for worker
skill bundles beyond the levels possessed by the existing labor
force. The excess demand for certain types of labor could create
severe problems with "structural" job vacancies and bring about
upward price adjustments in the affected industries.

**Linearity for labor**

In the present study we are concerned with labor services
as a factor of production, and since the input-output table does
not provide coefficients for it, we must develop a set of labor
coefficients. These coefficients are used along with the level
of output to predict the demand for workers who have given skill
and ability levels. The level of output is calculated by way of
the input-output table under the assumption of fixed coefficients
for all of the produced inputs. In order to be consistent with the fixed coefficient production functions in the input-output table, we make the assumption of linearity for the labor coefficients as well.

We have already explained that we intend to treat labor as non-homogeneous and that a distinction will be made among workers with different GED/SVP capacities. The actual number of jobs in each of these categories is estimated by way of a matrix of joint GED/SVP demands for each industry, and the level of total industry employment is estimated from input-output and employment/output information. Since we assume that the employment/output ratios are fixed, each of the GED/SVP categories is handled in the same manner. Any change in the level of employment demanded is assumed to be accompanied by a proportional change in the demand for workers in each of the GED/SVP categories.

Production functions with primary factors

In the production functions which we discuss above, the only arguments are the intermediate inputs which are produced by the various industries. In order for the production functions to be complete they must also include the requirements for primary inputs. Let \( W_i, N_i, C_i, M_i \) represent the total use of workers, natural resources, capital and management in industry \( i \), and \( w_i, n_i, c_i, \) and \( m_i \), represent the use of workers, natural resources, capital and management per dollar of output of industry \( i \). Then, equation (3-6) should be rewritten in the form

\[
q_j = \min \left( \frac{x_{ij}}{a_{ij}}, \ldots, \frac{x_{nj}}{a_{nj}} \right) \quad (3-10)
\]
and \[ \sum_{j=1}^{n} x_{ij} = \min \left( \frac{W_i}{w_i}, \frac{N_i}{n_i}, \frac{C_i}{c_i}, \frac{M_i}{m_i} \right) \quad i=1, \ldots, n; \]

Equation (3-10) retains the constraint introduced in equation (3-6), that the total production of good \( j \) is limited by the intermediate input whose unit requirement is the shortest supply. Applying the same assumption of linearity for the primary inputs as for the produced inputs, equation (3-10) adds the condition that the total supply of intermediate inputs is limited by the primary input whose availability is in the shortest supply.\(^1\) Therefore, the ultimate real constraints in the system are the supplies of the primary factors of production. Since we are not concerned with natural resources, capital, and management in this study, we will not discuss these factors in the remainder of the analysis.

Labor services as a factor of production is the focal point of the present study. In equation (3-10) the supply of workers \( W_j \), is treated as if it is one-dimensional, with one worker fully interchangeable with any other. In the real world the demand for labor is dependent upon the skills that the various jobs call for, and there is no such thing as the demand for workers per se; the demand is for the individual worker skill levels. GED and SVP are the characteristics which we use to classify the labor force

\(^1\)The intermediate input \( x \) in the lower portion of equation (3-10) is summed over all \( j \)'s because the requirement for primary inputs to produce the intermediate input is assumed to be the same no matter which industry purchases that input. Therefore, depending on the distribution of available supplies, it would be possible for there to be an aggregate shortage of some intermediate products with some industries experiencing the shortage while others would still be able to purchase the desired amount.
in the present study; therefore the GED/SVP classifications are entered directly into the production function in place of labor as a primary input. Each of the different GED/SVP categories is treated as a separate factor of production whose demand must be determined.

Let $b_{gi}$ be the number of workers in GED/SVP category $g$ in industry $i$, and $w_{gi}$ be the use of workers in skill category $g$ per dollar of output of industry $i$. Rewrite equation (3-10) to include the produced inputs and labor as a heterogeneous input.

\[
g_j = \min \left( \frac{x_{ij}}{a_{ij}}, \ldots, \frac{x_{nj}}{a_{nj}} \right) \tag{3-11}
\]

and

\[
\sum_{j} x_{ij} = \min \left( \frac{b_{li}}{w_{li}}, \ldots, \frac{b_{27,i}}{w_{27,i}} \right) \quad i = 1, \ldots, n;
\]

\[
\sum_{j} w_{ij} = \frac{w_{gi}}{w_{gi}} \quad j = 1, \ldots, n
\]

Just as in the case of the general Leontief production function, the maximum output of goods which can be produced is equal to the minimum unit (dollar) requirement of intermediate inputs available, with the added condition that the total supply of intermediate inputs is equal to the minimum unit requirement of labor skill levels available.

Assuming that all producers are rational and that there is no waste of inputs, equation (3-11) can be expressed as

\[
q_j = \frac{x_{ij}}{a_{ij}} \quad \text{and} \quad \sum_{j} x_{ij} = \frac{b_{gi}}{w_{gi}}
\]
Rearranging terms

\[ a_{ij}q_j = x_{ij} \quad i=1, \ldots, n; \]
\[ j=1, \ldots, n; \]
\[ g=1, \ldots, 27. \]  

and

\[ \sum_{j=1}^{n} w_{gi} x_{ij} = b_{gi} \]

Alternatively the \( b_{gi} \)'s can be broken down into individual industry requirements for worker skill levels.

\[ \sum_{j=1}^{n} w_{gi} x_{ij} + \ldots + w_{gi} x_{ij} + \ldots + w_{gi} x_{in} = b_{gi} \]

where \( b_{gi}^j \) is the requirement for workers with skill level \( g \) in industry \( i \) to satisfy the demand for good \( i \) by industry \( j \).

The dollar value of each intermediate input used equals the unit requirement times the number of units of output that are produced. The amount of each worker skill level used equals the unit requirement times the number of units of intermediate inputs produced. With the linearity assumption and substitution from equations (3-12) and (3-13), the equations for any quantity of output of industry \( j \), \( q_j \), can be written in terms of its produced and labor inputs.

\[
\begin{align*}
\text{produced} &= a_{1j}q_j + \ldots + a_{ij}q_j + \ldots + a_{nj}q_j \\
\text{inputs} &= (x_{1j} + \ldots + x_{ij} + \ldots + x_{nj}) \\
\text{labor} &= w_{g1}a_{1j}q_j + \ldots + w_{gi}a_{ij}q_j + \ldots + w_{gn}a_{nj}q_j \\
&= (b_{g1}^j + \ldots + b_{gi}^j + \ldots + b_{gn}^j) \\
i &= 1, \ldots, n; \quad j = 1, \ldots, n; \quad g = 1, \ldots, 27
\end{align*}
\]
The empirical identification of the unit requirements for the linear production functions is greatly simplified by the existence of the input-output table. The $a_{ij}$ coefficients of unit requirements for produced inputs are nothing more than the $A$ matrix of direct dollar requirements per dollar of gross output (see figure 3-10). The construction of labor coefficients will make it possible to estimate the industry unit requirements and total requirements for labor by GED/SVP category.

Translating industry output into the demand for labor

Once the assumption is made that the use of labor varies in direct proportion to the level of output, it is a relatively simple task to translate the demand for goods into the demand for workers, as well as the demand for workers with particular skill level characteristics. Changes in demand are proportional to the level of output; therefore one particular level of output must be established as the base so that all other levels can be expressed as deviations from the base level. Since industrial production levels are estimated by way of input-output analysis, the base period selected is the year for which the input-output table is constructed. Three pieces of information for that base period are needed: the level of industrial production; the level of employment by industry; and the percentage of the total number of workers in each industry in each of the GED/SVP categories. Industrial production is obtained by processing the final demands for the base year through the input-output table. Employment by industry which is consistent with the input-output table can be found in the Department of Labor publication Employment and
The H matrix shown in Figure 3-7 gives the percentages of workers in each industry in each of the GED/SVP categories.

Let $q_j^b$ be the dollar output of industry $j$ in the base period and $e_j^b$ be the employment in industry $j$ in the base period. The division of the $e_j^b$ elements by the $q_j^b$'s gives the employment per dollar of output (employment/output ratio) in each industry in the base period. The different labor intensities and skill requirements of the industries account for the differences among the elements. For the purpose of this study the $e_j^b/q_j^b$ ratios become constants in all subsequent calculations so let

$$
\frac{e_j^b}{q_j^b} = k_j \quad j=1,\ldots,n
$$

where $k_j$ is the employment/output ratio in industry $j$ in the base year. Since the use of workers in the various GED/SVP categories is proportional to the total labor requirement, analogus to the employment/output ratios we can also define GED/SVP/output ratios.

Partition the H matrix into column vectors for each industry.

Figure 3-11. Percentage Demand for Workers by GED/SVP Category for All Industries

$$
\begin{pmatrix}
  h_{11} \\
  h_{21} \\
  h_{27,1}
\end{pmatrix}
\begin{pmatrix}
  h_{12} \\
  h_{22} \\
  h_{27,2}
\end{pmatrix}
\begin{pmatrix}
  h_{1n} \\
  h_{2n} \\
  h_{27,n}
\end{pmatrix}
$$

$h_{ij}$ is the percentage of workers with GED/SVP characteristic $i$ in industry $j$.

---

Scalar multiplication of column $j$, the percentage of workers in industry $j$ in each of the GED/SVP categories in the base period, times $k_j$, the employment/output ratio in industry $j$ in the base period, gives the requirement of workers in each category per dollar of output in the base period (GED/SVP/output ratios). These are the unit requirements (labor coefficients) of equation (3-14). This is shown in Figure 3-13.

Figure 3-12. Demand for Workers by GED/SVP Category Per Dollar of Output for All Industries

$$
\begin{bmatrix}
  w_{11} & w_{12} & w_{1,n} \\
  w_{21} & w_{22} & w_{2,n} \\
  w_{27,1} & w_{27,2} & w_{27,n}
\end{bmatrix}
$$

$w_{gj} = k_j h_{gj}$

$w_{gj}$ is the use of workers in GED/SVP category $g$ per dollar of output of industry $j$.

The $W$ matrix provides the same information on the purchase of different types of labor services as the $A$ matrix provides on the purchase of produced inputs. Twenty-seven new rows can now be added to the $A$ matrix of direct requirements per dollar of gross output.

Figure 3-13. Requirements for Produced and Labor Inputs Per Dollar of Output for All Industries

$$
\begin{bmatrix}
  a_{11} & a_{1n} \\
  a_{21} \\
  a_{n1} & a_{nn} \\
  w_{11} & w_{1n} \\
  w_{27,1} & w_{27,n}
\end{bmatrix}
$$

$a_{ij}$ is the use of the output of industry $i$ to produce one dollar of output of industry $j$.

$w_{gj}$ is the use of workers with GED/SVP characteristic $g$ per dollar of output of industry $j$. 
We now have all of the coefficients which are necessary to calculate industrial input requirements, both produced and labor inputs. The link between the use of the produced inputs (the upper portion of the matrix) and the labor inputs (the lower portion of the matrix) is found by collecting terms in both portions of equation (3-14).

produced inputs = \( (a_{1j} + \ldots + a_{ij} + \ldots a_{nj})q_j \)

labor inputs = \( (w_{g1}a_{1j} + \ldots + w_{gi}a_{ij} + \ldots + w_{gn}a_{nj})q_j \)

\[ i=1,\ldots,n; \ j=1,\ldots,n; \ g=1,\ldots,27. \]

The common term in every element is the level of output, \( q_j \), so in order to find out how much of each input industry \( j \) uses to produce \( q_j \), we must know what \( q_j \) is.

As we have already seen, industry \( j \)'s production is a function of the levels of production of all \( n \) industries in the economy, so a simultaneous solution is necessary. This is found through the use of the input-output model. Take the vector of final demands, enter it into the model, and multiply this by the \( (I-A)^{-1} \) matrix to obtain \( Q \), the vector of total industrial production levels. Within the \( (I-A)^{-1} \) matrix the \( a_{ij} \)'s have already been used to determine the direct and indirect requirements of produced inputs. The result of that calculation, the levels of industrial production, can be multiplied by the labor requirements, the \( w_{gj} \)'s, in order to determine the number of workers demanded in each GED/SVP category in each industry. This is the \( B \) matrix (Figure 3-8). The demand for workers by GED/SVP
characteristic in each industry can be converted into the demand for worker skills for the entire economy by summation across industries.

\[ \sum_{j=1}^{n} b_{gj} = B_{g} \quad g=1, \ldots, 27 \]

where \( B_{g} \) is the sum of the demands over all industries for workers with GED/SVP characteristic \( g \).

**Reduced Form of the Model**

The model in the present study is constructed so that final demands can be converted into the demand for workers with different skills under the assumptions of proportionality between the levels of output and employment, and fixed coefficients for the inputs in the production function. The following data is needed for the base period in order to set up the model:

- \( X \) is the matrix of \( x_{ij} \) elements which show the total sales made by industry \( i \) to industry \( j \), the interindustry transactions table.
- \( Q \) is the vector of \( q_{j} \)'s, the total level of production in industry \( j \). The information necessary to calculate \( Q \) is published along with the interindustry transactions table.
- \( E \) is the vector of \( e_{i} \)'s, the employment by industry used to produce output level \( q_{j} \). The information necessary to determine \( E \) is obtained from the publication Employment and Earnings Statistics for the U.S.
$\mathbf{H}$ is the set of column vectors of $h_{gj}$ elements which indicate the percentage of workers in industry $j$ who are in GED/SVP category $g$. The construction of this matrix will be explained in a later chapter.

This information allows the computation of three data sets which are used repeatedly in the following operations.

1) The entries in the $X$ matrix are divided by the entries in the $Q$ vector to obtain the $A$ matrix. This allows the computation of the $(I-A)$ matrix and the Leontief inverse, $(I-A)^{-1}$.

2) Division of the elements in the $E$ vector by the elements in the $Q$ vector yields $K$, the vector of employment/output ratios. $K$ times $H$ gives $W$, the set of $w_{gj}$ elements of labor coefficients of GED/SVP requirements per dollar of output.

Figure 3-14. Reduced Form of the Model

Given any set of final demands at time $t$, $F^t$, the employment demands can be found. The inverse matrix times $F^t$ gives the total level of production, $Q^t$, needed to achieve that level of final demand.

$$(I-A)^{-1} F^t = Q^t$$

$Q^t$ times the set of GED/SVP/output coefficients, $W$, gives the demand for workers in the various GED/SVP categories in time $t$. 
Summation of the number of workers in each of the $w_{gj}$ categories across industries gives the number of workers by GED/SVP category for the entire economy needed to produce final demand level $F_t$.

$$\sum_{j=1}^{n} b_{gj} = B_g \quad g = 1, \ldots, 27$$

This is the distribution of the demand for worker skills.
CHAPTER IV

SOURCES AND ADJUSTMENT OF THE DATA TO SATISFY THE MODEL

Now that we have specified the form that our model will take, we face the task of collecting and adjusting the available data to meet the requirements of the model. As has already been explained, four sets of data for the base year are needed: (1) the interindustry transactions table; (2) output by industry; (3) employment by industry; and (4) the percentage of workers in each GED/SVP category in each industry. The first three sets of data are readily available and require only minor adjustment. There is no published source for the fourth set, the industry distribution of workers by GED/SVP category, so we must construct these distributions ourselves.

GED and SVP

Data requirements and sources

In a 1964 study Richard Eckaus\(^1\) constructed separate distributions of GED and SVP characteristics by industry, and concluded that two sets of data are necessary:

(1) a complete listing of employment, sector by sector, in job categories which permit the distinction of the differential education and training requirements for each sector; and (2) a description for each job category of the amounts of the various types of education which are required for an average level of performance on the job.¹

At the time of his study these data requirements could only be approximated for the United States. The first set is found in the census publication Occupation by Industry.² Eckaus suggests that this is a poor source because the data are not obtained directly from the firms, but from households. The census take usually questions housewives and others rather than the worker himself. The job categories and industry classifications obtained in this manner are subject to error due to ignorance or biases due to such factors as self-inflation. Other problems with the census report are the lack of detail on occupations, as well as an inconsistent amount of the detail for various broad occupational groups.³ Even with these drawbacks, Eckaus reluctantly used this report because it was the only occupational census available at the time.

Eckaus obtained the second set of data from Estimates of Worker Traits for 4,000 Jobs⁴ which lists the SVP and GED require-

¹Ibid., 183.


³Eckaus, p. 184.

ments for each job category. The requirements are set by "the judgment of labor placement specialists as to the attributes required for an average level of success." The criteria used in the Estimates to rate the jobs by GED and SVP classifications are the same as those which are explained above. The only difference is that GED levels one and two appear to have been combined together and there is no GED 7. With this information Eckaus calculated the average level and the distribution of general education and specific training for each industry.²

The validity of Eckaus's results rests on an assumption which he does not mention in the article. He claims that his calculations indicate the requirements of general education and training, while the census data on occupations reflects the actual use of occupations in each industry. Unless the assumption is made that the use of occupations is at the required level when the census is taken, his results show only the use of general education and training, and not the requirements for these skills.

Since we wish to construct distributions which are similar to those constructed by Eckaus, our data requirements are basically the same: (1) the required level of employment by occupation in

¹Eckaus, p. 184, n. 11.

²Eckaus does not explain his procedure, but it appears that he calculates the percentage of industry employment in each occupation, and finds the GED and SVP levels for those occupations. The average level is found by weighting the number associated with each occupation's GED and SVP category by percentage employment in that occupation and adding all of the results. The distributions are the sums of the industry occupation percentages associated with each of the individual GED and SVP classifications.
each industry; and (2) a list of the GED and SVP statistics for each occupation. The first set of data can still only be obtained from the census report *Occupation by Industry*. Eckaus uses the report prepared from the 1950 census; the results of the 1960 census are used in this study. We have the same objections to the 1960 report as Eckaus has concerning the 1950 report since both reports are subject to the same inaccuracies as noted above. Also, because the report lists the use of occupations, rather than the demand for occupations, we make the qualifying assumption that the number of workers reported as being employed by occupation in each industry at the time the census was taken indicates the demand for occupations in those industries. The second set of data is obtained from the Department of Labor's *Supplement to the Dictionary of Occupational Titles*.¹ This publication lists GED and SVP requirements in addition to other information, for thousands of different occupations, and in many cases it also gives the requirements for the same occupation in different industries. It is the successor to the *Estimates* and it contains over 14,000 entries. This is the most comprehensive and complete study of this kind published to date.

**Adjustment of the data**

The calculation of the distribution of GED/SVP characteristics from the data in the *Supplement* and *Occupation by Industry*

was carried out in three steps. (1) **Occupation by Industry** contains the number of workers in each of 297 occupations in 157 different industries, which was converted to the percentage of workers employed in each occupation in each industry. (2) All of the occupations were paired with the GED and SVP ratings for the occupations as given in the **Supplement**. (3) This data was compiled and adjusted to arrive at the distributions.

The first step was to take each industry individually and calculate the percentage of total workers in the industry who were employed in each occupation. The occupations in **Occupation by Industry** are broken down into 11 major occupational groups, as well as an additional category for workers whose occupation is not reported. Each of the occupational groups is further broken down into specific occupations as well as numerous sub-groupings and Not Elsewhere Classified (NEC). For every one of these categories figures are given for both male and female employment. Since we were only interested in the total employment for each occupation, the male-female statistics were added together before performing any other calculations. The "Professional, Technical and Kindred Workers" section of the Coal Mining industry as given in **Occupation by Industry** is reproduced in the first

---

1 These occupational groups are: Professional, Technical and Kindred Workers; Farmers and Farm Managers; Managers, Officials, and Proprietors, except Farm; Clerical and Kindred Workers; Sales Workers; Craftsmen, Foremen, and Kindred Workers; Private Household Workers; Service Workers, except Private Household; Farm Laborers and Foremen; Laborers, except Farm and Mine.

2 The figures in column (2) do not actually appear in **Occupation by Industry**. As explained above, separate figures are given for both male and female workers. We have presented the totals of these two categories in column (2).
In order to reduce the number of calculations that would have to be made, we decided that an occupation had to account for at least 1/20 of 1% of total industry employment in order to be included in the study. In general, any occupation which did not reach this cut-off level was deleted and added to the NEC entry. In the case of the coal mining industry at least 100 workers had to be employed in a particular occupation for that occupation to be included in the study. The adjusted totals in column (3) are the levels of occupational employment after these adjustments were made. Finally, each of the totals in column (3) is divided by total industry employment to get column (4), the adjusted percentage of total employment in each occupation.

The next step was to find the GED and SVP classifications for each of these occupations. The occupation titles in the Supplement were paired with the ones obtained from Occupation by Industry. In those cases where there was some question concerning the equivalency of job titles, the job descriptions in the Dictionary of Occupational Titles were consulted. Then each of the GED and SVP levels from the Supplement was entered next to the percentage of employment as shown in columns (5) and (6).

The final step was to determine what percent of the workers in each industry required each of the GED/SVP levels. This step turned out to be the most involved. If there had been no NEC entries, we could have just gone down the lists of occupation percentages and added the percentage figures for corresponding
### TABLE 4-1

**COAL MINING INDUSTRY: EMPLOYMENT, GED, AND SVP**

<table>
<thead>
<tr>
<th>OCCUPATION</th>
<th>NUMBER WORKERS</th>
<th>ADJ NUMBER</th>
<th>% OF TOTAL</th>
<th>GED</th>
<th>SVP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Employment</td>
<td>201,285</td>
<td>201,285</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Professional, Technical and Kindred Workers *</td>
<td>3,390</td>
<td>3,390</td>
<td>1.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accountants and Auditors</td>
<td>582</td>
<td>582</td>
<td>.29</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Pilots</td>
<td>58</td>
<td>0</td>
<td>0</td>
<td>5/7</td>
<td>.0022</td>
</tr>
<tr>
<td>Draftsmen</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>5/8</td>
<td>.0151</td>
</tr>
<tr>
<td>Engineers</td>
<td>1,531</td>
<td>1,531</td>
<td>.76</td>
<td>6/8</td>
<td>.0027</td>
</tr>
<tr>
<td>Chemical</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Civil</td>
<td>98</td>
<td>98</td>
<td>.05</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Electrical</td>
<td>81</td>
<td>81</td>
<td>.04</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Industrial</td>
<td>166</td>
<td>166</td>
<td>.08</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Mechanical</td>
<td>118</td>
<td>118</td>
<td>.06</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Mining</td>
<td>1,028</td>
<td>1,028</td>
<td>.51</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Sales</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>4/6</td>
<td>.13</td>
</tr>
<tr>
<td>NEC</td>
<td>0</td>
<td>40</td>
<td>.02</td>
<td>5/5</td>
<td>.06</td>
</tr>
<tr>
<td>Foresters and Conserv.</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>5/7</td>
<td>.1922</td>
</tr>
<tr>
<td>Lawyers and Judges</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>5/8</td>
<td>.8651</td>
</tr>
<tr>
<td>Natural Scientists</td>
<td>282</td>
<td>282</td>
<td>.14</td>
<td>6/8</td>
<td>.2427</td>
</tr>
<tr>
<td>Chemists</td>
<td>221</td>
<td>221</td>
<td>.11</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Geologists</td>
<td>61</td>
<td>61</td>
<td>.03</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Nurses</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel and Labor Rel</td>
<td>121</td>
<td>121</td>
<td>.06</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Public Relations</td>
<td>39</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Scientists</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statisticians</td>
<td>21</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surveyors</td>
<td>217</td>
<td>217</td>
<td>.11</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Teachers, secondary school</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>5/7</td>
<td>.2180</td>
</tr>
<tr>
<td>Technicians, eng &amp; phys sci</td>
<td>139</td>
<td>139</td>
<td>.07</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Technicians, nec</td>
<td>122</td>
<td>122</td>
<td>.06</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Professional, Technical &amp; Kindred NEC</td>
<td>19</td>
<td>396</td>
<td>.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Titles for occupations which contained no workers are omitted.
GED/SVP levels. In Table 4-1, for instance, two occupations are in GED/SVP 4/6, which we abbreviate as [4,6]. Their entries in column 4 are .07 and .06, so the GED/SVP 4/6 percentage for the professional, technical and kindred group is .13. The same can be done for all of the other GED/SVP levels. The problem is that the total of the percentages corresponding to the various GED/SVP categories is only 1.47, while professional, technical and kindred accounts for 1.69% of the industry's employment. The remaining .22% lies in the two NEC entries.

There is no way to attach GED/SVP levels to the NEC figures. They cannot be ignored because in some cases they are quite large. They cannot be distributed proportionally over all of the percentages because there is an NEC for each major occupation group and there is a difference in the general education and training categories between groups. For instance, in the present case we have .22% of the workers unclassified whose GED/SVP range is from [4,6] to [6,8] in the professional, technical and kindred group. If operatives, whose GED/SVP scale runs from [2,4] to [3,7], had an NEC which contained 10% of the industry's workers and we apportioned the total of unclassified workers over all GED/SVP levels by increasing each by 10%, it would result in an artificial inflation of the higher classifications and a deflation of the lower classifications. Since we were able to determine which major occupation group the unclassified workers came from, and in some cases even the general occupation, we decided to apply a weighted average of the GED/SVP levels of the occupations in that particular occupation group to the NEC.
Again referring to Table 4-1, .76% of employment is made up of engineers, .74% is classified according to five kinds of engineers, and .02% is NEC. Of that .74%, 8/74 is in category [5,7], 56/74 is in category [5,8], and 10/74 is in category [6,8]. Therefore the unclassified .02% is apportioned accordingly. In this case 8/74 x .02 = .0022 = .0027 goes to [6,8]. These figures are added to the totals obtained for those occupations for which there is a GED/SVP entry, and are shown as sub-totals in column (7). The sub-totals for all five categories add up to only 1.49% while the total of industry employment is professional, technical and kindred is 1.69%. The difference is the NEC entry for the whole major occupation group. This remaining .2% is apportioned according to the same weighting scheme as was done for engineers NEC, 13/149 to [4,6], 6/149 to [5,5], etc. When these figures are added to the sub-totals the result is the percentage of total industry employment in the professional, technical, and kindred occupation group according to GED/SVP category.

This same procedure was carried out for all 11 major occupation groups and the totals were added together. Then we had to contend with "Occupation Not Reported." There was no way to determine, even approximately, which occupation the workers in this category were engaged in, so the percentage of employment given in this entry was distributed among the GED/SVP classifications according to the proportion of the industry's classified employment in each category. This same procedure was carried out for each industry.
There are 148 industries in Occupation by Industry so we could have computed as many as 148 different sets of distributions. Since the GED/SVP distributions would have to be combined with the employment and output figures from the input-output table, we had to be certain that the industries included in the distributions corresponded to the industries found in the input-output table. There are fewer industries in the input-output table than in the census report, so it was not necessary to construct a set of distributions for every census industry.

The 1967 input-output table contains 85 industries, so this set a limit on the number of industries that could be included in the study. Fortunately the Departments of Labor and Commerce both identify the industries in their publications by Standard Industrial Classification (SIC) codes, and a comparison of the codes allowed us to identify which input-output industries corresponded to the census report industries. In each case where more than one census industry corresponded to only one input-output industry, the census industries were joined together into one. Likewise, when more than one input-output industry corresponded to only one census industry, the input-output industries were combined.

For example, coal mining in the census report has SIC 11, 12, and in the input-output table it has the same SIC codes, so there is a one-to-one pairing and no changes were made. The census places all metal mining in one category with SIC 10.
Input-output has iron and ferroalloy ores mining, SIC 1011,106, listed separately from nonferrous metal ores mining, SIC 102-105,108, 109. Since we did not have the data to compute separate distributions for each of these two input-output industries, the input-output industries were combined and paired with the single census classification for metal mining. This was done by adding the column and row entries for the two different industries in the interindustry transactions table.

Input-output places petroleum refining and related industries with SIC codes 291,295,299 into one category. The census reports petroleum refining, SIC 291, separately from miscellaneous petroleum and coal products, SIC 295,299. The two separate distributions must be joined with only one level of output from the input-output table. Therefore, for the two census categories, we added the number of workers in each occupation prior to the computation of the distributions, and obtained only one distribution. The result of all of these combinations is a set of 55 comparable industries for which we have both a distribution of GED/SVP categories and an input-output classification. These labor-force-input-output pairings will be referred to as "industry groups."

Table 4-2 shows the GED/SVP distribution for industry group number 4, the coal mining industry. An examination of the table shows that over 60% of industry employment is concentrated in category [3,7]. As one might expect, this is because [3,7] is the GED/SVP category for coal miners who comprise 59% of the
industry's labor force. Another large concentration is in [4,7] which includes managers and most craftsmen such as electricians, and mechanics. The smaller percentages in the other categories reflect the number of professional, clerical and service workers employed in the coal mining industry.

**TABLE 4-2**

GED/SVP PERCENTAGES FOR THE COAL MINING INDUSTRY

<table>
<thead>
<tr>
<th></th>
<th>SVP 1</th>
<th>SVP 2</th>
<th>SVP 3</th>
<th>SVP 4</th>
<th>SVP 5</th>
<th>SVP 6</th>
<th>SVP 7</th>
<th>SVP 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>GED 1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>GED 2</td>
<td>0.0</td>
<td>0.0</td>
<td>1.58</td>
<td>1.27</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>GED 3</td>
<td>0.0</td>
<td>0.51</td>
<td>4.97</td>
<td>5.26</td>
<td>3.95</td>
<td>0.16</td>
<td>60.07</td>
<td>0.0</td>
</tr>
<tr>
<td>GED 4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.96</td>
<td>0.0</td>
<td>0.29</td>
<td>1.08</td>
<td>17.93</td>
<td>0.0</td>
</tr>
<tr>
<td>GED 5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.07</td>
<td>0.35</td>
<td>0.22</td>
<td>1.03</td>
</tr>
<tr>
<td>GED 6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.28</td>
</tr>
</tbody>
</table>

**Input-Output**

Studies available

The modern day use of input-output analysis was pioneered by Nobel Prize winner Wassily Leontief. With the support of the Harvard Committee on Research in the Social Sciences, he constructed the first input-output table for the United States in 1931. During the War the Bureau of Labor Statistics (BLS) became interested in Leontief's technique, and with government funding he produced a table for 1939. In 1952 the BLS released its own table which covered the year 1947, and, like Leontief's tables,
the one by the BLS was not integrated with the National Income and Product Accounts.

When the Bureau of Economic Analysis (BEA) undertook the task of preparing the input-output tables for the United States, it set out to integrate the tables with the National Income and Product Accounts and to make all future tables consistent in terms of the industries included and the conventions used in collecting and adjusting the data. So far the BEA has completed three studies for the benchmark years of 1958, 1963, and 1967. Other published tables for 1961 and 1966 are not the result of complete studies, but an estimation of changes in the coefficients since the previous study. The 1958 table is only available with an 86 industry classification, while the 1963 and 1967 tables can be obtained in both an 85 industry version, or the more detailed 367 and 484 industry breakdowns. The only major change in the basic 85 and 86 industry classification between the 1958 and the 1963 and 1967 tables, is the treatment of research and development. In the 1958 version, research and development is aggregated over the whole economy into industry #74, while the 1963 and 1967 tables leave research and development expenditures where they originate. Industry #74 is simply omitted in the later studies and the numbers of all other industries remain the same to maintain consistency and avoid confusion when making inter-study comparisons.

The data sources used by the BEA consist primarily of U.S. government publications from agencies such as the departments of Agriculture, Commerce, Labor, Transportation, The Interstate Commerce Commission, Internal Revenue Service, and the Federal
Reserve System. The publications include the Censuses of Agriculture, Manufacturing and Mining, Business, Mineral Industries, Transportation and Business, and Wholesale and Retail Trade. Some of the reports are published as often as monthly, while others are released at five or six year intervals. Since all of the reports for a particular year are needed in order to prepare an input-output table, this explains why the tables are published at irregular intervals and provide interindustry transactions data for a period five to six years earlier.

Attempts are being made to obtain the information directly from the agencies involved so that the tables published in the future will be more up-to-date.

Input-output coefficients exhibit a degree of change over time, so when using the table for predictive purposes it is important to select the table which depicts the interrelationships in the year closest to the ones being studied. Since we are interested in predicting the levels of industrial output for the recent past, we will use the 1967 input-output table. This table, which was first released in the 85 industry classification in February of 1974, is the most recent available.

Adjustment of the table

In order to adapt the 85 industrial sectors in the 1967 interindustry transactions table to our model, the table was aggregated to 59 industries. Of these 59 industries, 55 are used for purposes of predicting employment demand. The reduction in the number of industrial classifications is caused by the overlap
of some input-output and census industrial categories, the inclusion of some input-output industries for accounting purposes only, and the lack of employment information on some input-output industries.

The input-output table contains three sectors known as the "special industries", all of whose entries appear below the line in value added or in the final demand sector. They are used for accounting purposes only so that the row and column totals balance, and the BEA eliminates them before performing operations on the table. We have also eliminated them.

Three "dummy industries", which are a conglomeration of diverse products made by other industries, have entries in the main body of the table and they must be retained in order to preserve the internal consistency of the system. There are no SIC codes for the dummy industries, no corresponding census data, and no GED/SVP distributions. These industries have an effect on the employment in other industries in so far as purchases of inputs by the dummy industries stimulate production in other industrial sectors, however, since there is no information on the workers in the dummy industries, employment levels and worker skill requirements cannot be estimated for these sectors.

The imports sector, like the dummy industries, has entries in the main body of the table and must be retained in order to preserve the internal consistency of the model. The production of imported goods takes place in other countries so it does not have a direct effect upon employment in the United States, therefore employment levels and worker skill requirements are not
estimated for this sector.

Of the 85 industries in the original table, we have eliminated three completely. For four of the others which we have retained we will not be able to predict the distribution of worker skills. This leaves 78 industrial sectors which are identified by SIC codes, but not all of these can be matched with a set of worker skill requirements. As has already been explained, there are some industries for which there is only one census classification corresponding to more than one input-output industry, and in those cases the input-output industries have been combined into one. Since this is the case for 19 industries, the final input-output table used in the present study consists of a 59 sector interindustry transactions table. The three dummy industries and imports are used only in predicting total industrial production levels, and the remaining sectors comprise the industry groups. That is, there is a corresponding set of GED/SVP distributions for each of 55 industries. For these 55 the predicted levels of total output can be translated into the demand for worker skills.

The method of aggregating the industries in the interindustry transactions table is simply the addition of the corresponding row and column entries in the table. We assume that this consolidation on paper has no effect on the operation of the individual industries. In terms of the actual industries this means that the sales of final goods to other industries will remain the same, as will the purchases of inputs from other industries. The only difference is that in the interindustry transactions table all of the sales of goods by the industries that are combined
appear in one row, and all of their purchases from other industries appear in one column. Whenever aggregation occurs, the question of aggregation bias must be considered. In a sense all of the industries in the input-output table are aggregates of smaller industries, and are therefore subject to aggregation bias. By combining some of these industries together, we have increased the potential for such a situation to occur.¹

The last two sets of data needed for this study, the levels of industrial output and employment, are the easiest to adjust to the necessary form. The level of industrial output is published along with the input-output table in the 85 industry classification. These figures for all 85 industries can be reduced to the 59 industries used in the study by adding the levels of output for the industries which are combined. The levels of industrial employment by SIC code are given in Employment and Earnings Statistics for the United States, 1909-68.² By correlating the SIC codes in this publication with the ones for the input-output table, the level of employment for each of our final 55 industries can be obtained.


Stability or Instability of the Employment/Output Ratios

Since the demands for workers and for worker skills are estimated through the use of fixed labor coefficients, the accuracy of the resultant employment estimates are of great importance. The labor coefficients are the industry employment/output ratios (E/Q) multiplied by the distribution of worker skills. We assume that changes which occur in the distribution of worker skills take place in a slow and orderly fashion and are more of a long-run than short-run occurrence. Therefore, we also assume that short-run changes in the labor coefficients come about primarily as a result of changes in the E/Q ratios.

The employment/output ratios are calculated from the actual employment data for the base year and the level of output as given in the input-output industrial classifications. Any change in the E/Q ratio from the base year relationship will affect the accuracy of our employment predictions. In addition, because the labor coefficients are multiplied by the output predictions of the input-output table in order to predict employment, changes in the factors which underlie the interindustry transactions table can also cause changes in employment predictions. Therefore the basic arguments concerning the stability or instability in the coefficients for produced inputs apply to the employment coefficients as well.

Factors pertaining to the linear production functions

One source of instability stems from the fact that production coefficients change over time and with changes in the
level of output, while the input-output coefficients reflect the relationships for one particular point in time and for a single set of output levels. Predictions of future output are extrapolations from those previous relationships. As a result, the factors which bring about changes in the coefficients over time are also instrumental in determining how much future production and employment will deviate from predicted levels.

Changes in Technology—Technological change can be either capital augmenting, in which less capital is needed to produce the same level of output, or labor augmenting, in which less labor is required to produce the same level of output. No matter which form changes in technology take, they will have an effect upon the input-output coefficients and the employment/output ratios. In the case of labor augmenting technological change, the employment/output ratio is reduced directly through reductions in the level of employment, or increases in the level of output, while for capital augmenting there is usually a substitution of new types of capital for labor, which reduces the ratio indirectly. Any change in the E/Q ratio will have an effect upon the employment estimates, so the severity of the problem depends upon the rate at which technological change takes place.

In an established industrial economy such as the U.S., it is a reasonable assumption that technical change for an entire industry occurs slowly. When changes occur, the effects are usually felt more in the long-run than in the short-run. When new equipment or processes become available, they are usually
incorporated into new enterprises, while older firms retain their existing capacity in the short-run. Since the employment coefficients are an average of the E/Q relationships for all of the firms in the industry, the incorporation of new technology by some firms does not have as much of an effect on the industry coefficients as would be the case if all firms adopted the new processes simultaneously. Therefore we would expect that changes in the coefficients would occur slowly and in small doses. An example of this is the basic oxygen furnace which was a major innovation in the production of steel. It was introduced in 1954, but 14 years later only 37% of the steel making capacity in the U.S. was using this process. Had all of the steel firms adopted this new process over a short period of time, it would have caused a substantial and rapid change in the E/Q ratio. Under the circumstances which actually occurred, the change was small and occurred slowly.¹

Non-linearity in the production functions—The Leontief production function requires linearity in the inputs, while in practice substitutions and non-proportionality among inputs is commonplace. As the level of output changes from the one which the linear production function was constructed to cover, the non-linearities in the actual production function can cause differences between the estimated and the actual levels of production. Just how accurately do fixed employment coefficients

predict employment in a world of non-linear production functions? The answer to this question depends on the relative size of overhead employment\(^1\) and the level of capacity utilization in the industry.

Because an industry is an aggregation of all of the firms that produce a product, we assume for the moment that all firms in the industry employ the same level of capacity utilization. We will relax this assumption later. The employment coefficient is the average $E/Q$ ratio of all of the firms and includes both variable and overhead employment. When there is excess capacity, an increase in production in the short-run is accompanied by increased purchases of variable inputs, while the fixed inputs, including overhead employment, are the same.

Our estimate of the increased employment which would accompany the increase in production would overstate the actual increment because it would include a proportionate increase in all kinds of personnel. The severity of the overestimate of employment would depend upon the relative size of overhead employment to total employment in the particular industry.\(^2\)

\(^1\)We define overhead employment to be those workers who would continue to be employed in the short-run without regard to the level of output. This would probably include management personnel, research staff, most clerical workers, etc. Variable employment refers to the production workers and others whose jobs depend upon the level of output. In the short-run as output changes, the level of variable employment is assumed to change in proportion to the level of output. In the long-run overhead employment would also be subject to change.

\(^2\)To get around this whole problem, Leontief develops his input-output matrix for a hypothesized level of output. For instance, the 1958 I-O matrix is built for a GNP of $600$ billion. Therefore, implicit in a matrix is a level of capacity utilization.
If the industry is at or near complete utilization of capacity, the incremental E/Q ratio could be larger than the computed employment coefficient because of the need for additions to fixed overhead employment. When the existing facilities and processes are already being strained, an increase in production in the short-run can be brought about by an increased use of variable inputs, especially labor, per unit of output. Plant and equipment would be increased in the long-run, but in the short-run we would expect that the use of labor would be increased.\(^1\) With the variable and overhead labor components changing simultaneously, and variable labor growing faster than when there is excess capacity, our estimate of increased employment using the fixed E/Q ratio would understate the actual change.

These predictions of overestimates of employment for an excess capacity situation, and underestimates with full capacity utilization, rest on the assumption that all the firms in the industry use the same degree of capacity utilization. This is not necessarily true. In fact, if some firms are operating at full capacity while others had idle facilities, the overestimates in one area and underestimates in the others, could offset one another. Just how much of an effect this would have would depend on the distribution of the change in demand among the firms, and how much

\(^{1}\)It should be noted that capital account transactions appear in the final demand vector, not in the main body of the input-output table, so even if firms make expenditures to increase facilities, the expenditures will have no short-run effect upon the input coefficients. In the long-run there can be changes in the coefficients of the capital goods industries and those industries that supply the capital goods producers directly and indirectly.
the actual E/Q ratio increases with increased capacity utilization, as opposed to the lower marginal E/Q ratio for firms with excess capacity.

The size of the change in demand is also an important factor in the stability of the employment coefficients. If the change is large, the industry might move from a situation of excess capacity to one of full capacity utilization, and the difference between the computed and actual E/Q ratio could be large. But if the change in demand is small, there will be little change in the industry's production level, and the difference in the coefficients might be quite small. Therefore, in evaluating calculated changes in employment through the use of fixed employment coefficients, notice should be given to the size of the change in final demand, the degree of capacity utilization, and how additional production is distributed among the firms in the industry.

Factors pertaining to conventions used in compiling the data

There are some conventions that the BEA uses when compiling and classifying the data in the input-output table that can cause instability in the production and employment coefficients.

Secondary products—The basic unit of classification in the SIC system is the establishment. An establishment is classified in an industry according to the basic product that it produces, and all of its input is counted as part of the output of that industry. Sometimes a firm produces a subsidiary product which is known as its secondary output. Secondary outputs are handled by the BEA in two different ways. One is redefinition whereby the secondary pro-
duction is removed from the industry which produces it and it is placed in the industry where it is the primary activity. All receipts from the sale of the product are subtracted from the industry's output and added to the industry that produces it as a primary product. The inputs and value-added components used to produce the secondary output are also subtracted from the producing industry and added to the inputs of the primary industry. This is the practice used for the trade, construction and service sectors.

The second approach is the transfer method. In this case secondary production is left where it occurs but it also appears in the industry where it is the primary product. The secondary output is treated as if it is sold by the actual producer as an input to the primary producer, and it becomes part of the primary producer's output which is available for sale. This method is used for the mining and manufacturing sectors.

When either the transfer or redefinition method is used it will have an effect on the estimation of employment levels. Employment estimates are based upon the E/Q ratio in each industry, and any procedure which causes either the employment or output figures to deviate from their actual levels will affect both the E/Q ratio and estimated employment. The industry employment levels used to calculate the employment/output ratio are the actual levels used to produce both primary and secondary products in the industry where they are produced. The output levels come from the totals given in the input-output study. When the redefinition method is used the output of the producing industry is reduced while its
employment level remains the same, so the calculated E/Q is larger than the actual E/Q ratio. The output of the primary producer is increased while its employment level also remains the same, so the calculated E/Q is smaller than the actual ratio. With the transfer method, output and employment remain the same for the producing industry so the E/Q ratio is unaffected, but the output of the primary industry is increased with employment constant, so the computed ratio is again smaller than the actual value.

Both treatments of secondary products build into the table a set of relationships that are unrelated to the true production requirements. These relationships vary randomly over time, and build a degree of instability into the employment coefficients. Unfortunately, there is no known way to remedy this problem.

Imports - The treatment of imports depends upon whether or not a domestic counterpart is produced. If the same product or a substitute is produced in the U.S., it is called a competitive import and treated in the same manner as a transferred secondary product. It is shown as a purchase by the domestic industry that produces the product and added to the total sales of that industry. If the good has no domestic counterpart, it is a non-competitive import and is shown as a direct purchase by the consuming industry. In the case of the competitive import, the level of output of the domestic producer of the good is given in the input-output table as being higher than it really is. Since the level of employment remains at its actual level, the calculated E/Q ratio for the industry will be lower than the actual ratio. For our purposes this will not
pose a problem as long as the composition of production between domestic and foreign producers remains the same, because a change in output would still be accompanied by a proportionate change in domestic employment. But if that composition of production should undergo a change, our estimates of industry employment would no longer be reliable. The treatment of competitive imports creates the same problem as transferred secondary products: it builds into the table a set of relationships that vary over time because they are unrelated to the production requirements, and it causes instability in the employment coefficients.

Aggregation in the table—The question of aggregation takes on added significance in the present case where we have combined input-output categories beyond the published level of aggregation. All of the industries in the input-output table are formed through the combination of industries which produce similar products. As more industries are added to the same industrial classification, the number of different products that the classification encompasses increases. The employment/output ratio for a single input-output industry is a weighted average of the ratios of all of the component industries but we would not expect the E/Q ratio for each of the component industries to be the same. If the individual E/Q ratios for the component industries remain unchanged but the proportion of total industry output contributed by each of the industries varies over time (changes in the product mix), the employment coefficients of the input-output industry would also undergo a change. Since the input-output table depicts a relationship which existed five or ten years earlier, the calculated E/Q ratio
may no longer reflect the actual labor coefficients.

For example, one of the industries in the table is "Office, Accounting, and Computing Machines," which includes calculators, computers and typewriters. In recent years there has been a major increase in the production of calculating machines due to the advent of the electronic calculator. Calculating machines now account for a larger portion of the production of this input-output industry than they did in 1967. Therefore the coefficients in the most recent input-output table we have today do not reflect the actual industry input requirements. Because of the question of product mix, the more aggregated the table, the more unstable we would expect the coefficients to be.

Measurement in dollars—The use of dollars as a unit of measurement instead of physical units, also poses a problem. When the production function is expressed in terms of physical units, the relationship between the level of output and the input requirements will remain the same as long as technology is constant. When the production function is expressed in terms of dollars, changes in relative prices can cause changes in the dollar input requirements over time. If the price of i rises with respect to j, then \( a_{ij} \), the dollar use of i per dollar output of j, no longer represents the actual input requirement. The same number of dollars will now purchase fewer units of i. With technology unchanged, the \( a_{ij} \) which was constructed under the original price relationship will understate the actual use of i per dollar output of j. Therefore the predicted levels of output and employment should be viewed accordingly.
All of the factors which we have mentioned can lead to instability in the levels of employment and/or output, and in the actual employment/output ratios. Since it would be extremely difficult to estimate the effects of each of these factors upon the employment coefficients, our only recourse is to use fixed coefficients based upon the base year relationships. Therefore, when evaluating the results of our employment predictions, the influence of these factors should be taken into account.

**Why the Model Can Only be Used to Examine Changes in Employment**

In the articles reviewed in Chapter 2, the assumption is made, if only tacitly, that there is always an abundant supply of workers, and that the only real concern is the demand for workers. When considering aggregate employment this assumption may be fine under most circumstances, but it falls apart when the labor market gets tight, such as in wartime. When considering employment according to worker skills, the supply conditions become more important because even with an aggregate surplus of workers, there can still be shortages of workers with particular skills. A discussion of the labor market which does not consider both the supply and demand for workers is not complete. In the present case such a discussion is not possible since our predictions of the demand for workers are not complete and comparable supply data are not available. While we cannot estimate the actual supply of workers, we can at least indicate where supply bottlenecks might develop.
Incomplete information

Our predictions of the demand for workers by GED/SVP category are not complete because they do not contain the demand from all of the industrial sectors. The three dummy industries have no SIC codes and no employment estimates attached to them, even though output and employment are generated in this sector. The census provides data by SIC codes for federal, state, and local employees who are engaged in operating government enterprises or in government administration, while the input-output system includes government enterprises, but no government administration. Therefore, the workers employed in government enterprises (post office, utilities, transit systems, etc.) are included, while those who are in administration are excluded from our employment estimates.

The census also has a category for private household workers. These workers are identified by SIC codes, but just as in the case of government administration, the input-output system does not include them in any of its industrial sectors. Therefore, these workers are not included in our estimates, either. Finally, the census places those workers whose industry was not determined in a separate classification at the end of the survey. Since these workers cannot be placed in any input-output industry, they are also excluded from our estimates. The total of all of the workers in the dummy industries, government administration, private households, and those whose industry is not classified, comes to over 7 million. This means that about 11% of the workers in the 1960 labor force are excluded from our estimates of the demand for workers by GED/SVP category.
Even if the demand data were complete, it would still be impossible to estimate unemployment because comparable data on the supply of workers are not available. There is no published report on the amount of general education and specific training the workers in the U.S. labor force have, nor are there reports on each of these skills individually. There is a census publication that gives the level of educational attainment for the entire population, the labor force, and numerous sub-categories, however formal education and general educational development are two very different things and no meaningful comparison can be made between our estimates of GED and the census figures on education.¹

Since the estimates of demand are incomplete and comparable supply data are not available, we cannot construct one set of the estimated demand for workers and another set of the supply of workers in the various GED/SVP levels. Therefore, we cannot

¹James Scoville attempted to compare GED requirements with educational attainment. He calculated the GED and SVP requirements for every occupation in Occupation by Industry for the entire economy, translated his GED figures into educational equivalents as Eckaus did, and evaluated his results in light of the actual educational attainment of the population. His reasoning was that if his estimates were accurate his figures for the amount of education required in each occupation would be fairly equal to the level of education that the workers had. He was surprised to find that the median educational attainment of over 70% of the workers in 53% of the occupations in 1960 was above the level required for their line of work. He concluded that either the basic data or the estimating procedure was at fault. Scoville completely missed the point that he was comparing two completely different things. This caused Sidney Fine to note "Since Scoville found discrepancies in the two sets of data, he questioned the functional requirements data, apparently believing the two sets of data should have yielded a consistent set of results." Fine, op.cit., p. 366, n. 7. See: James G. Scoville, "Education and Training Requirements for Occupations," Review of Economics and Statistics XLVII (November 1966), 387-94.
compare the supply and demand for worker skills for a particular level of output, estimate the level of unemployment, and identify where bottlenecks might occur as our theory suggests. What we can do is to examine the effects of changes in the demand for workers. One should keep in mind that these predictions will always underestimate the changes since not all workers are encompassed by the study.

When a program is enacted which decreases the demand for output, and therefore the demand for workers, the number and type of workers that will be put out of work can be estimated. Then a program can be designed which would reemploy these same workers. In this case no labor supply information would be required since the necessary data would be generated by the model. In the case of a program which increases the demand for workers, this increased demand must be compared with the availability of workers with the same skills in order to determine if a sufficient supply exists. In this case the skills of the workers that are unemployed must be known. If the skills that a particular program uses are not the skills of the unemployed, the inadequacy of the program and potential bottlenecks can be recognized long before time and resources are wasted.

The problem with this method is that data on unemployed workers by GED/SVP classification are not available. In order to implement an effective manpower policy it is necessary to have complete information on the type and number of workers who are unemployed, as well as the type and number of jobs available.

This very issue was raised by a number of labor economists at a conference held by the National Bureau of Economic Research
Among the participants at the conference was the current Secretary of Labor, John Dunlop. Dunlop contends that "the present eleven-fold system of occupational groups (professional, technical and kindred workers, etc.) is an archaic scheme with which to describe or to analyze the changing occupational structure of a modern industrial economy." These categories are not fruitfully related to training, education or compensation levels. In a word, they are a hodgepodge.\footnote{Dunlop, p. 39.}

What Dunlop suggests as an alternative is an occupational matrix whose cells would include data on compensation, vocational training, general education, and the characteristics of current employees by age, race, and other characteristics. On the supply side he believes that this information is related in a "systematic and analytic way" by virtue of the number of different attributes being embodied in a single worker.\footnote{Ibid., 44-5.} A comparable set of data containing the same variables is needed on the demand side, i.e. job vacancy data.\footnote{Ibid., 29.} A comparison of these two matrices would provide valuable information to industry, government and labor organizations for planning purposes.


\footnote{John Dunlop, "Job Vacancy Measures and Economic Analysis," in The Measurement and Interpretation of Job Vacancies, op.cit., p. 27.}
Need for a set of supply data

Dunlop's proposal would require a matrix of the current supply of unemployed workers according to a particular set of characteristics, as well as a matrix of job vacancies fashioned along the same lines. Although the present study is somewhat limited in scope, we have developed a method for predicting a matrix of the demand for workers on the basis of two of the six characteristics which Dunlop mentions. Unfortunately, we cannot translate this demand for workers into a matrix of job vacancies due to the incomplete estimates on the demand side and the unavailability of data on the supply side. What we can do is to examine the change in the demand for workers as estimated by the model and use this as a proxy for the changes in the number of job vacancies. In order to complete this analysis we also need a corresponding matrix of the supply of available workers. The machinery to construct this matrix in terms of GED/SVP classifications already exists in the form of the employment service and the "archaic" occupational classification scheme.

Ideally, each person who registers at a state employment office could be tested to determine his level of GED and his SVP could be determined during the initial interview. This procedure would be time-consuming, costly, and require special skills on the part of employment service employees at the local level to conduct interviews, and to administer and evaluate test results. An alternative would be to assign to the individual the GED and SVP requirements of his previous occupation. This would not provide the actual supply of unused skills, but it would at least
give the minimum level of unused skills available. Since the employment service already collects occupational data on a national basis, this assignment of GED/SVP requirements could be handled on the national level and would not require any special expertise on the part of local personnel.

This data could then be used for planning and policy purposes. Simulations of the model would provide estimates of the change in the demand for worker skills, the supply matrix would provide the information on the skills of the workers available, and a comparison of the two would yield estimates of the excess demand for different types of skills. Then either final demand could be altered in order to approach an equilibrium in the various skill markets, or a program could be initiated to retrain the available workers to meet the industry requirements.

Although the matrix developed here is incomplete in the sense that it only includes two of many worker characteristics, the procedure outlined appears to be practical, feasible, and inexpensive and could be implemented in a relatively short period of time. However, the ease of implementation could be reduced and the cost increased once the model is altered to include specific skills, geographic immobility and other characteristics.
CHAPTER V

SIMULATION OF THE MODEL

In the previous chapters we have described the form of our model and the adjustment of the necessary data in order to allow for the estimation of its equations. In the present chapter we will explain how the model can be put to use in formulating a manpower plan, and the methodology will be demonstrated by way of a specific example.

Statement of the Problem

Quite often a particular economic plan, or a political policy with economic implications, can be expressed in terms of changes in the government's vector of final demands for goods and services. Through the use of our model we can translate that change in final demand for goods and services into the change in the final demand for different types of worker skills.\(^1\) \(W\) is the matrix of the use of workers per dollar of output. Let \(\Delta F\) represent the change in the government's final demand vector. Then \(\Delta Q\) is the change in

\(^1\)Normally a change in the government's vector of final demands will trigger an initial change in output and employment, plus additional changes in output and employment through the multiplier process. In the analysis which follows we will attempt to offset the effects of a change in government spending so that the original change in final demand + the change in final demand from the offset program \(\approx 0\). Therefore, the multiplier effects will be unimportant and will not be discussed.
industrial production and \( \Delta B \) is the vector of the sum of the changes in employment by GED/SVP category over all industries as a result of \( \Delta F \).

\[
(I-A)^{-1}\Delta F = \Delta Q \\
W\Delta Q = \Delta B \\
W(I-A)^{-1}\Delta F = \Delta B
\]  

(5-1)

This tells only half of the story. All we have done here is to estimate the increase or decrease in employment by GED/SVP classification as a result of a change in the government's final demand vector. We know in the case of a decrease in final demand how many and what type of workers by skill category will be unemployed by the change. In the case of an increase in final demand, we know what kinds of workers will be needed to fill the new positions. In order to carry this analysis to its logical conclusion, the next step would be to develop some program to re-employ the unemployed workers, or to reduce the demand or re-train workers to fill the new positions for which there are not enough qualified workers.

Once the policy-maker has this information on the change in the demand for workers we would not expect the government to stand by and watch as unemployment increases, or structural bottlenecks trigger upward price adjustments in the affected industries. What course of action might be undertaken would depend upon the government's objective function and what type of policy tools it would be willing to use, and the initial state of the economy. Just how great a role the government would
play in developing and implementing a manpower policy would depend upon the philosophy of the particular administration. Nevertheless, we would expect that the government would take some steps to correct the employment effects of its initial change in final demand.

The Choice of Instrument Industries

We will assume in this section that the initial distribution of employment among GED/SVP categories was optimal.\(^1\) Since a change in final demand brought about the original change in employment, the problem can be at least partially remedied by effecting a compensating change in final demand. The most obvious solution would be to restore the levels of industrial demand to their original levels, but this might negate the purpose of the government's economic or political policy which started the whole chain of events. For the moment let us ignore this problem and assume that the government can change all 55 final demands. Then the question is: how great a compensating change in final demand must take place, and in which industries, in order to restore the levels of the demand for workers by GED/SVP category as close as possible to the levels which existed prior to the original government action?

We have a basic problem to be solved in which we have 27 conditions which we would like to meet: one for each of the GED/SVP categories. We have theoretically 55 different instruments with which to accomplish this task: one for each of the industries

\(^1\)This assumption will be relaxed below.
in our input-output table. If we were to use the final demand of all 55 industries as instruments in solving the problem (or, in general, more than 27 of them), the number of instruments would be greater than the number of targets, the system would be overdetermined and the problem would have multiple solutions. If we were to use exactly 27 final demands as the instruments, there will be one set of values for the 27 final demands that will allow the system to hit all 27 targets.¹

The use of a large number of instruments in this instance is unrealistic for two reasons: the government may not be able to operate on all 55 final demands, or even as many as 27, and it may be costly to make use of the instruments. Therefore, we may be forced to use less than 27 instruments which would not allow us to hit our 27 targets.

The inability to affect final demand

The government's ability to operate on the final demand of an industry depends upon the size of the government's purchases and its need for the products of that industry. Government spending can be broken down into two general classifications: federal, and state and local. Since our model is based on the national economy, the actions of the states would be ineffective

¹This is assuming that each of the final demands is independent from the others, which must be true if \((I-A)^{-1}\) exists, and also that the instruments are not inconsistent. For a general proof that when the number of instruments is greater than the number of targets there will be multiple solutions, and when the number of targets and instruments are equal there will be a unique solution (as long as the instruments are independent and not inconsistent) see: Leif Johansen, Public Economics (Amsterdam: North Holland, 1965), 9-12.
unless the spending by all of the states could be coordinated. Even then, most state and local governments do not have the authority to incur a deficit, so their discretionary spending would be limited. A manpower policy might require large amounts of government expenditures which could only be directed on the national level through spending by the federal government.

The final demand for the goods and services of some industries by the federal government is quite small. When the purpose of a manpower program is to reduce the demand for workers with particular sets of skill bundles, final demand would have to be decreased. In those instances it would be senseless to include these industries among the instruments. On the other hand, there are some industries which produce products which are of little use to the government, such as Tobacco Manufacturing and Radio and TV Broadcasting. Therefore, such industries are clearly inappropriate as policy tools when the government needs to increase its final demand.

There are a number of other reasons to explain why the government would not be able to operate on the final demand of some industries. However, no matter what the reason, once the number of instruments is reduced below 27, it will, in general, no longer be possible to hit all of the employment targets. Therefore, it becomes necessary to have an objective function to weigh the alternatives. It is not the job of the economist per se to specify the objective function. That is the role of the policy-maker.  

of the economist to find the best way to achieve that objective.

Although it is the job of the policy-maker to specify the objective function, a frequently used form is a quadratic loss function which minimizes the sum of the squared deviations from the targets.\(^1\) Let \(W(I-A)^{-1} = T\) in equation (5-1), and rewrite equation (5-1) in terms of the levels of final demand, output and employment, instead of changes in these variables. The superscripts represent time periods, and subscripts represent the number of industries included in the matrix. For example, \(F^0_r\) is the vector of final demands for \(r\) different industries in period 0. \(B^0_{55}\) is the vector of the sum of the original levels of demand for worker skills over all industries. It is found by multiplying the \(T\) matrix by the original level of final demand.

\[
T_{55} F^0_{55} = B^0_{55}
\]

After the initial government policy brings about a change in final demand, we have a new vector of final demands and levels of demand for worker skills.

\[
T_{55} F^1_{55} = B^1_{55}
\]

The difference between the two levels of demand for worker skills, \(B^0_{55} - B^1_{55}\), is the change in the demand for workers by GED/SVP category as a result of the change in final demand. Choose \(r\) industries, where \(r < 27\), to be used as the instruments in

correcting this change in employment demands. We must first
determine how much employment must be generated by these \( r \) industries in order to restore the levels of employment by
category to their original level.

We can determine this by calculating the amount of employ-
ment being generated by the other 55-\( r \) industries, and sub-
tracting these figures from \( B_{55}^0 \). Set the final demand of the
\( r \) industries equal to zero, and calculate the amount of employ-
ment that the 55-\( r \) non-instrument industries are generating.

\[
T_{55-r} F_{55-r}^1 = B_{55-r}^1
\]

The difference between this level of employment and the original
level \( (B_{55}^0 - B_{55-r}^1) \) is the amount which must be generated by the
\( r \) instrument industries in order to achieve our goal. We can
express this goal as:

\[
T_r F_r^2 = B_r^2 \quad (B_r^2 = B_{55}^0 - B_{55-r}^1)
\]  

(5-2)

where the superscript 2 refers to the period after the compensating
changes in final demand have been made. Our goal is to minimize
the difference between both sides of equation (2). If we take
the sum of the squares of these differences and minimize them
with respect to \( F_r^2 \), we will obtain the set of final demands which
will come the closest to minimizing the square of the difference
between \( B_{55}^0 \) and \( B_{55}^2 \), where \( B_{55}^2 \) is the sum of the demands for
workers over all 55 industries by GED/SVP category after com-
sating changes in final demand have been made.
Therefore, our objective function can be expressed as:

\[(T_r F_r^2 - B_r^2) - (T_r F_r^2 - B_r^2)\]

\[(F_r^2 T_r' - B_r^2') (T_r F_r^2 - B_r^2)\]

\[P_r^2 T_r' F_r^2 - P_r^2 T_r' B_r^2 - B_r^2 T_r F_r^2 + B_r^2 B_r^2\]

Differentiating with respect to the vector \(F_r^2\) we get the first order condition:

\[\frac{\partial}{\partial F_r^2} = 2T_r' T_r F_r^2 - T_r' B_r^2 - B_r^2' T_r = 0\]

\[2T_r' T_r F_r^2 - 2T_r' B_r^2 = 0\]

\[T_r' T_r F_r^2 = T_r' B_r^2\]

\[F_r^2 = (T_r' T_r)^{-1} (T_r' B_r^2) [1]\]

The new level of final demand for all 55 industries which minimizes the sum of the squares of the residuals between \(B_{55}^0\) and \(B_{55}^2\) is the sum of the final demands facing the other 55-\(r\) industries and the computed \(F_r^2\).

1The calculation of \(F_r^2\) is greatly simplified by the availability of standard regression packages. \(B_r^2 = T_r F_r^2\) is of the same general form as \(Y = X\beta\). In the least squares procedure, \(\beta\) is chosen so as to minimize the sum of the squares of the residuals of \((Y-X\beta)\).

It can be shown that \(\beta = (X'X)^{-1}(X'Y)\), and that \(\beta\) is the set of regression coefficients of \(X\). Therefore we can find the \(F_r^2\) that minimizes the sum of the squared deviations of \(B_{55}^0\) from \(B_{55}^2\) by regressing \(T_r\) on \(B_r^2\). The estimated coefficients of this regression are the optimal \(F_r^2\). See any statistics or econometric text on regression analysis; for example, Henri Theil, Principles of Econometrics (New York: John Wiley and Sons, 1971), pp. 35-6.
The new levels of employment can be calculated by the same method as before.

\[ F_{55}^2 = F_{55}^1 + F_r^2 \]

\[ T_{55}^2 F_{55}^2 = B_{55}^2 \]

The cost of using instruments

The procedure which we have explained will indeed achieve the goal of minimizing the change in employment in the various GED/SVP categories, but we have said nothing about the costs of using the instruments. Although the primary objective is to maintain the level, or minimize deviations from the original level of final demand needed to employ a certain number of workers with particular skill bundles, the policy-maker may wish to dispense these funds in such a way as to obtain some socially desirable set of goods and services. For instance, increased spending might be directed toward improving public transportation, or for use in building low cost housing. In these cases industries such as Transportation and Warehousing, and Construction would be included as policy instruments. If spending is to be reduced, it may be decided that cuts should not take place in the medical or education sectors, so the Medical and Educational Services Industry would not be an appropriate policy tool. In any case, social or political considerations might dictate those industries in which changes in final demand would represent the greatest or least cost to society, and which should, or should not, be included on the list of policy instruments.
Our equations only require that we minimize the sum of the squares of the errors in the employment vector, and there are no additional objectives to be fulfilled. Under more realistic conditions there would probably be a number of objectives that we would want to meet simultaneously with achieving the employment objective. For instance, the solution to our system of equations might call for incredibly large changes in final demand (or even negative levels) in some of the instrument industries. This could mean high costs in terms of structural problems in the affected industries when demand increases, or idle capacity when demand falls. Therefore, another desirable objective might be to require that the changes in final demand in each sector be as small as possible.

This objective can be handled in much the same manner as the minimization of the changes in employment. We would like the final demand facing the r industries which we are using as instruments to be as close as possible to their levels prior to effecting any changes in final demand. The expression which we would like to minimize is: \( (F_r^2 - F_r^0) \). This can also be written in the form \( (I_r F_r^2 - F_r^0 = 0) \). If we square this expression and take the derivative with respect to \( F_r^2 \), we will obtain the set of \( F_r^2 \) which minimizes this difference, which is, of course, \( F_r^2 = F_r^0 \). But we want to minimize this simultaneously with the minimization of the sum of the square of the differences in the employment vector.

These conditions take on the same general form with \( F_r^2 \) acting as the coefficient matrix of both the matrices of independent variables.
These two equations can be written as one system of equations.

Let the \( r \) instrument industries range from \( \alpha \) to \( \gamma \), and let \( b^2_{g,r} \) be the sum of the demands for workers over the \( r \) industries in GED/SVP category \( g \) after all compensating changes in final demand have taken place.

Figure 5-1. Notational Form of the Minimization Equations

\[
\begin{pmatrix}
  b^2_{1,r} \\
  \vdots \\
  \vdots \\
  b^2_{27,r} \\
  f^0_\alpha \\
  \vdots \\
  f^0_\gamma \\
\end{pmatrix}_{27+r} =
\begin{pmatrix}
  t_{1,\alpha} & \ldots & t_{1,\gamma} \\
  \vdots & \ddots & \vdots \\
  \vdots & \ddots & \vdots \\
  t_{27,\alpha} & \ldots & t_{27,\gamma} \\
  1 & \ddots & \varnothing \\
  \vdots & \ddots & 1 \\
  \varnothing & \ddots & 1 \\
\end{pmatrix}_{r}
\begin{pmatrix}
  f^2_\alpha \\
  \vdots \\
  \vdots \\
  f^2_\gamma \\
\end{pmatrix}_{r}
\]

\[
Z^2_r = Y_r F^2_r
\]

The minimization of the sum of the squared errors of this system is the same as on page 130, with \( Y \) substituted for \( T \) and \( Z \) substituted for \( B \). Therefore,
The level of final demand for all 55 industries which minimizes both the changes in employment by category and in the individual final demand entries, is found by calculating $F^2_r$ and adding it to the levels of final demand facing the other 55-$r$ industries.

$$F^2_{55} = F^1_{55-r} + F^2_r$$

**Other variations in the objective function**

There are a number of other possible statements of the objective function which might be specified by the policy-maker. We have been assuming that the initial level of employment by GED/SVP category was optimal and we have been attempting to return employment to that same level. This may not be the goal of the policy-maker. For instance, as part of a general economic plan to curb inflation, it may be determined that an increase in the unemployment rate is preferable to an increase in prices. In that case the vector of employment levels, $B^2_r$ in equation (5-2) or $Z^2_r$ in equation (5-3), would be expressed as the lower target level of employment. The same procedure could be used even if the government had not originally changed its level of final demand, but only wanted to change the level of employment. The processing of any set of employment levels through the equations will yield the level of final demand necessary to achieve that employment goal.

Another possibility is that the policy-maker might be more interested in re-employing all of the workers in one or more
categories than in returning employment in the other categories to their original levels. Therefore, he might place different weights on missing the target in different occupational classifications. This can be accomplished by multiplying both sides of equations (5-2) or (5-3) by a constant or a set of weights of value greater than one across the row which pertains to the GED/SVP categories which are to have the greater importance. In the minimization of the sum of squared differences procedure, the sum of the squared differences between $z_r^2$ and $y_r f_r^2$ will be greater, which means that they will have an increased effect upon the solution set.\textsuperscript{1} The choice of weights to be used would be determined by the relative importance that the policy-maker places upon each of the categories.

A similar situation could also arise in terms of the policy instruments. If it is possible to attach social or monetary costs to missing the instrument targets, relative weights can be placed upon the equations to take this into account. Both sides of the lower portion of equation (5-3) could be multiplied by constants across the rows pertaining to the industries to be affected. The larger the weights, the greater the cost, and the closer the result will come to hitting the target.

It would not be difficult to imagine a number of other statements of the objective function. The point is that as long as the targets can be expressed in terms of employment levels or

\textsuperscript{1}This is analagous to the solution to the problem of heteroscedasticity by weighted least squares. The multiplication of the equation by a weighting factor changes the size of the difference between the fitted and observed values, and thus the effect of the observation on the final solution.
the levels of final demand, this model can be used to determine what amounts of final demand would have to be generated in each industry in order to achieve the objective.

Demonstration of a Specific Example

The example which is given below is intended for expository purposes only and the statement of the objective function is only one of many possible variations that could be used in solving the problem.

Problem and objective function

We begin with the economy as it is represented in the 1967 input-output table. The interindustry relationships are those which are contained in the table, and the levels of final demand are the ones which are published along with the input-output study. These are shown in Table 5-1, column (1) in millions of 1967 dollars expressed in producers' prices. The levels of employment by GED/SVP category are found through the operation of the model on the given levels of final demand.

\[ W(I-A)^{-1}F_{55}^{0} = B_{55}^{0} \]

These results are shown in column (1) of Table 5-2.

For the purposes of example, assume that the federal government decides to make a 10% across-the-board cut in defense spending. The effect that this has on each particular industry depends upon the industry's level of final demand which originated in the defense sector. The first step is to reduce the final
<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>BEFORE</th>
<th>AFTER</th>
<th>CHANGE</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LIVESTOCK, OTHER AGRICUL PROD, AGRICUL SERV</td>
<td>9052</td>
<td>9050</td>
<td>-2</td>
<td>-0.02</td>
</tr>
<tr>
<td>2. FORESTRY &amp; FISHERY PRODUCTS</td>
<td>249</td>
<td>249</td>
<td>0</td>
<td>0.0</td>
</tr>
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<td>3. IRON, FERROALLOY AND NON FERGOS ORES MINING</td>
<td>255</td>
<td>255</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>4. COAL MINING</td>
<td>618</td>
<td>614</td>
<td>-4</td>
<td>-0.65</td>
</tr>
<tr>
<td>5. CRUDE PETROLEUM AND NATURAL GAS</td>
<td>339</td>
<td>339</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>6. STONE, CLAY, CHEMICAL AND FERTIL MINERAL MINING</td>
<td>240</td>
<td>240</td>
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<td>0.0</td>
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<td>7. CONSTRUCTION - NEW AND MAINTENANCE</td>
<td>85584</td>
<td>85389</td>
<td>-195</td>
<td>-0.23</td>
</tr>
<tr>
<td>8. FOOD AND KINDRED PRODUCTS</td>
<td>64911</td>
<td>64890</td>
<td>-21</td>
<td>-0.33</td>
</tr>
<tr>
<td>9. TOBACCO MANUFACTURES</td>
<td>60597</td>
<td>6059</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>10. BROAD &amp; NARROW FABRICS, YARN AND THREAD MILLS</td>
<td>1058</td>
<td>1050</td>
<td>-8</td>
<td>-0.76</td>
</tr>
<tr>
<td>11. MISC TEXTILE GOODS &amp; FLOOR COVERINGS</td>
<td>1710</td>
<td>1709</td>
<td>-1</td>
<td>-0.06</td>
</tr>
<tr>
<td>12. AEROSPACE</td>
<td>16827</td>
<td>16857</td>
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<td>-0.06</td>
</tr>
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<td>13. MISC FABRICATED TEXTILE PRODUCTS</td>
<td>2459</td>
<td>2427</td>
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</tr>
<tr>
<td>14. LUMBER &amp; WOOD PRODUCTS, EXCEPT CONTAINERS</td>
<td>787</td>
<td>785</td>
<td>-2</td>
<td>-0.25</td>
</tr>
<tr>
<td>15. WOODEN CONTAINERS</td>
<td>30</td>
<td>28</td>
<td>-2</td>
<td>-6.77</td>
</tr>
<tr>
<td>16. HOUSEHOLD FURNITURE, OTHER FURNITURE AND FIXT</td>
<td>6434</td>
<td>6427</td>
<td>-7</td>
<td>-0.11</td>
</tr>
<tr>
<td>17. PAPER &amp; ALLIED PROD, EXCEPT CONTAINERS AND BOXES</td>
<td>2673</td>
<td>2667</td>
<td>-6</td>
<td>-0.22</td>
</tr>
<tr>
<td>18. PAPERBOARD CONTAINERS AND BOXES</td>
<td>191</td>
<td>189</td>
<td>-3</td>
<td>-1.57</td>
</tr>
<tr>
<td>19. PRINTING AND PUBLISHING</td>
<td>5760</td>
<td>5742</td>
<td>-18</td>
<td>-0.31</td>
</tr>
<tr>
<td>20. CHEM AND SELECTED CHEM PROD, PLASTICS, SYNTHETICS</td>
<td>5164</td>
<td>5029</td>
<td>-135</td>
<td>-2.61</td>
</tr>
<tr>
<td>21. GLASS, CLEANSING TOILET PREPARATIONS</td>
<td>8669</td>
<td>8657</td>
<td>-12</td>
<td>-0.14</td>
</tr>
<tr>
<td>22. GLASS AND GLASS PRODUCTS</td>
<td>787</td>
<td>785</td>
<td>-2</td>
<td>-0.25</td>
</tr>
<tr>
<td>23. PRIMARY IRON &amp; STEEL MANUFACTURES</td>
<td>1328</td>
<td>1299</td>
<td>-29</td>
<td>-2.18</td>
</tr>
<tr>
<td>24. PRIMARY NONFERROUS METALS MANUFACTURING</td>
<td>1115</td>
<td>1115</td>
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<td>0.0</td>
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<td>25. PRIMARY NONMETALS MANUFACTURING</td>
<td>1633</td>
<td>1615</td>
<td>-18</td>
<td>-1.10</td>
</tr>
<tr>
<td>26. ORGANIC, METAL CONT, SCREW MACHINE PROD, OTHER FAB</td>
<td>12101</td>
<td>11423</td>
<td>-678</td>
<td>-5.60</td>
</tr>
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<td>27. FICTION MACHINES</td>
<td>3040</td>
<td>3065</td>
<td>3</td>
<td>-1.03</td>
</tr>
<tr>
<td>28. HEAVY MACHINERY AND ENGINES</td>
<td>21928</td>
<td>21795</td>
<td>-133</td>
<td>-0.61</td>
</tr>
<tr>
<td>29. OFFICE, COMPUTER AND ACCOUNTING MACHINES</td>
<td>5023</td>
<td>4998</td>
<td>-25</td>
<td>-0.50</td>
</tr>
<tr>
<td>30. ELECTRICAL AND ELECTRONIC MACHINES</td>
<td>25813</td>
<td>25616</td>
<td>-672</td>
<td>-2.60</td>
</tr>
<tr>
<td>31. MOTOR VEHICLES AND EQUIPMENT</td>
<td>28276</td>
<td>28192</td>
<td>-84</td>
<td>-0.30</td>
</tr>
<tr>
<td>32. AIRCRAFT AND PARTS</td>
<td>14794</td>
<td>14010</td>
<td>-784</td>
<td>-5.30</td>
</tr>
<tr>
<td>33. OTHER TRANSPORTATION EQUIPMENT</td>
<td>6475</td>
<td>6342</td>
<td>-133</td>
<td>-2.05</td>
</tr>
<tr>
<td>34. SCIENTIFIC, OPTICAL, PHOTOGRAPHIC EQUIPMENT</td>
<td>6208</td>
<td>6184</td>
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<td>35. MISCELLANEOUS MANUFACTURING</td>
<td>5692</td>
<td>5686</td>
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<td>36. TRANSPORTATION AND WAREHOUSING</td>
<td>20653</td>
<td>20353</td>
<td>-300</td>
<td>-1.45</td>
</tr>
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<td>37. COMMUNICATIONS, EXCEPT RADIO &amp; TV</td>
<td>10691</td>
<td>10050</td>
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<td>-6.01</td>
</tr>
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<td>38. RADIO AND TV BROADCASTING</td>
<td>7</td>
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<td>0.0</td>
</tr>
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<td>39. ELECTRIC, GAS, WATER AND SANITARY SERVICES</td>
<td>15952</td>
<td>15922</td>
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<td>120815</td>
<td>120701</td>
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<tr>
<td>41. FINANCE AND INSURANCE</td>
<td>25818</td>
<td>25816</td>
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<td>-0.01</td>
</tr>
<tr>
<td>42. REAL ESTATE AND RENTAL</td>
<td>74456</td>
<td>74443</td>
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<td>-0.02</td>
</tr>
<tr>
<td>43. HOTELS, PERSONAL AND REPAIR SERVICES</td>
<td>16151</td>
<td>16151</td>
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<td>0.0</td>
</tr>
<tr>
<td>44. BUSINESS SERVICES</td>
<td>9299</td>
<td>9102</td>
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<td>-2.01</td>
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<tr>
<td>45. AUTOMOBILE REPAIR AND SERVICES</td>
<td>8285</td>
<td>8279</td>
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<td>46. AMUSEMENTS</td>
<td>6057</td>
<td>6037</td>
<td>-20</td>
<td>-0.33</td>
</tr>
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<td>47. MEDICAL, EDUCATIONAL SERVICES, NONPROF ORG</td>
<td>45819</td>
<td>45710</td>
<td>-109</td>
<td>-0.24</td>
</tr>
<tr>
<td>48. FEDERAL GOVERNMENT ENTERPRISES (POST OFFICE)</td>
<td>1841</td>
<td>1818</td>
<td>-23</td>
<td>-1.25</td>
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<td>49. STATE AND LOCAL GOVERNMENT ENTERPRISES</td>
<td>1233</td>
<td>1233</td>
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<td>0.0</td>
</tr>
</tbody>
</table>

| TOTALS                                                                 | 731149 | 726998 | -4151  | -0.57  |
TABLE 5-2
EMPLOYMENT BY GED/SVP CATEGORY
BEFORE AND AFTER A 10% DEFENSE CUT

<table>
<thead>
<tr>
<th>GED/SVP CATEGORY</th>
<th>BEFORE</th>
<th>AFTER</th>
<th>CHANGE</th>
<th>PCT CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GED 1 SVP 1</td>
<td>16166</td>
<td>16084</td>
<td>-82</td>
<td>-0.51</td>
</tr>
<tr>
<td>2 GED 1 SVP 2</td>
<td>514212</td>
<td>513251</td>
<td>-961</td>
<td>-0.19</td>
</tr>
<tr>
<td>3 GED 1 SVP 3</td>
<td>7139142</td>
<td>7088125</td>
<td>-51017</td>
<td>-0.71</td>
</tr>
<tr>
<td>4 GED 2 SVP 3</td>
<td>3585987</td>
<td>3569681</td>
<td>-16306</td>
<td>-0.45</td>
</tr>
<tr>
<td>5 GED 2 SVP 4</td>
<td>329648</td>
<td>327705</td>
<td>-1943</td>
<td>-0.59</td>
</tr>
<tr>
<td>6 GED 2 SVP 5</td>
<td>217780</td>
<td>215688</td>
<td>-2092</td>
<td>-0.96</td>
</tr>
<tr>
<td>7 GED 2 SVP 6</td>
<td>335915</td>
<td>334414</td>
<td>-1501</td>
<td>-0.45</td>
</tr>
<tr>
<td>8 GED 3 SVP 2</td>
<td>3979831</td>
<td>3968733</td>
<td>-11098</td>
<td>-0.28</td>
</tr>
<tr>
<td>9 GED 3 SVP 3</td>
<td>7848863</td>
<td>7807147</td>
<td>-41716</td>
<td>-0.53</td>
</tr>
<tr>
<td>10 GED 3 SVP 4</td>
<td>2991825</td>
<td>2975446</td>
<td>-16379</td>
<td>-0.55</td>
</tr>
<tr>
<td>11 GED 3 SVP 5</td>
<td>1842631</td>
<td>1831504</td>
<td>-11127</td>
<td>-0.60</td>
</tr>
<tr>
<td>12 GED 3 SVP 6</td>
<td>1168193</td>
<td>1154645</td>
<td>-13548</td>
<td>-1.16</td>
</tr>
<tr>
<td>13 GED 3 SVP 7</td>
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TOTALS | 60917504| 60574272| -343174| -0.56      |
demand facing each of the industries by 10% of its pre-cut level of defense purchases. These figures are published in the final demand breakdown of the 1967 input-output table, and they are consistent with the interindustry transactions entries in terms of the price index and they are expressed in producers' prices. An examination of the breakdown of final demand by source indicates that the total level of Department of Defense expenditures from private industry in 1967 was around $41.5 billion, with the largest amounts going to ordnance, electric machinery, and aircraft production. The total final demand of each industry was reduced by 10% of the amount reported as federal government defense spending in that industry. In Table 5-1 this is shown in column (2) as the levels of final demand after the 10% cut in defense spending, and column (3) indicates the actual size of that cut in final demand. In column (4) the percentage relationship between the change and the original level of final demand is given.

The effect of this change on employment by GED/SVP category is again found by operation of the model.

\[ W(I-A)^{-1}F_{55}^1 = B_{55}^1 \]

In Table 5-2 the levels of employment after the 10% defense cut are found in column (2), the actual change in employment by category in column (3), and the percentage change in column (4). It appears that the largest number of defense workers are concentrated in categories 3,9,19,20. In percentage terms, however,
categories 12, 21, 22, and 27 seem to be affected the most. This reflects the fact that defense industries require a larger number of highly skilled, highly paid workers per dollar of output than do most other industries. The total at the bottom of column (3) indicates that as a result of a 10% cut in defense spending 343,174 workers have lost their jobs. These 343,174 workers form the crux of the problem. We want to define a loss function that will increase final demand in such a way that as many of these workers as possible will be re-employed.

Our loss function will be specified in terms of three kinds of targets. One set of targets is the pre-defense spending cut employment levels in the 27 GED/SVP categories.

The second set of targets is the pre-defense spending cut levels of final demand. This second set of targets reflects the fact that changing government spending involves costs. Therefore, our objective will be to minimize the sum of the squared deviations in final demand from their target levels in each of the instrument industries. In addition, we assume that the government can only change its spending in the ten industries with the largest non-military federal government spending, but not to include the ordnance industry. These figures can also be obtained from the input-output report.

The final target is the pre-defense spending cut level of total final demand. In effect this is tantamount to the objective

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\(^1\)Since we intend to return final demand to its original level through an increase in spending by the government, we will assume that any multiplier effects which this initial decrease in final demand might produce will be unimportant.
of maintaining pre and post-cut government final demands at the same level. This is necessary because any increase or decrease in total final demand will have a multiplier effect upon output and employment. In addition, an increase or decrease in government spending would require changes in the government's taxing or borrowing patterns which would also create a multiplier effect. While this specific problem may not be specified as a policymaker would specify it, we feel it illustrates the way our input-output analysis can be used in dealing with structural employment problems.

Procedure

First we must determine how much employment is being generated by the remaining 45 non-instrument industries. This can be done by setting the final demand for the 10 instrument industries equal to zero, and processing the vector of final demands through the model.

\[ T_{45} F^{1}_{45} = B_{45}^{1} \]

In Table 5-3 column (1) shows the levels of employment prior to the 10% defense cut, column (2) indicates the amount of employment generated by the 45 non-instrument industries, and column (3) gives the amount of employment by GED/SVP category which must be generated by the 10 instrument industries if we are to offset entirely the effects of the original government action.
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**TOTALS** 60917504 36007424 -24909968 -40.89
The solution to the problem requires that we make the proper substitutions into equation (5-3).

\[ Z_{10}^2 = Y_{10}^2 F_{10}^2 \]  

(5-3)

\( Z_{10} \) is a column vector with dimensions (1X38). The first 27 elements are the target levels of employment by GED/SVP category which we would like the 10 instrument industries to generate. They are obtained from column (3) of Table 5-3. The next ten elements of \( Z_{10} \) are the original levels of final demand in the instrument industries. They are indicated by an asterisk in column (1) of Table 5-4. The final entry in \( Z_{10} \) is the amount of final demand which we want the 10 instrument industries to generate. This is the sum of the final demands of the instrument industries, which is the difference between the original level of total final demand and the amount generated by the 45 non-instrument industries after the 10\% defense spending cut.

\[ \Sigma F_{10}^2 = \Sigma F_{55}^0 - \Sigma F_{45}^1 \]

\( Y_{10} \) is a (38X10) matrix. The upper (27X10) is the set of 10 column vectors for the 10 instrument industries of T elements, the set of requirements for workers by GED/SVP category per dollar of final demand. The lower (10X10) portion of \( Y_{10} \) is the identity matrix. The bottom row of \( Y_{10} \) has a one in each of the 10 entries, so that when this row is multiplied by \( F_{10}^2 \) it will give the sum of the final demands for the 10 instrument industries. The left hand side of this equation is the target level of the sum of final
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<th>(3) CHANGE</th>
<th>(4) PCT CHANGE</th>
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<td>1504</td>
<td>21.88</td>
</tr>
<tr>
<td>55</td>
<td>STATE AND LOCAL GOVERNMENT ENTERPRISES</td>
<td>1841</td>
<td>1818</td>
<td>-1.25</td>
</tr>
</tbody>
</table>

TOTALS | 731149 | 731216 | 67 | 0.01 |
demands for the 10 instrument industries, therefore this equation is of the same form as the employment and final demand equations.

\[ f_{10}^2 = U_{10} f_{10}^2 \]

where \( U_{10} \) is a row vector of one's with length 10.

The simultaneous solution of all of the equations in the system will yield the levels of final demand in the 10 instrument industries which will minimize the sum of the squared changes in employment in each GED/SVP category, plus the sum of the squared changes in final demand in each of the instrument industries, plus the sum of the squared changes in the total level of final demand facing all industries.

Prior to actually working through the equations, one adjustment was made. Our objective function has 38 targets, and if each target is given equal weight, the minimization of the change in one GED/SVP category or in one final demand category would carry the same importance as the minimization of the change in the sum of final demands. Since we wanted the target of the sum of final demands to be at least as important as the 10 individual final demands, we arbitrarily placed a weight of 10 on the achievement of the total final demand target. Therefore, the last entry in \( Z_{10}^2 \) and the entries in the bottom row of \( Y_{10} \) were multiplied by 10 before solving the system of equations. The design of the actual set of equations is shown in Table 5-5.

The solution to \( f_{10}^2 \) is found through the use of a standard regression package, and the results are reported as the figures
<table>
<thead>
<tr>
<th>[ t_{1,7} \cdots t_{1,55} ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,964</td>
</tr>
<tr>
<td>277,161</td>
</tr>
<tr>
<td>2,738,715</td>
</tr>
<tr>
<td>1,729,140</td>
</tr>
<tr>
<td>139,396</td>
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<tr>
<td>151,122</td>
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<td>128,260</td>
</tr>
<tr>
<td>648,960</td>
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<tr>
<td>2,969,288</td>
</tr>
<tr>
<td>925,282</td>
</tr>
<tr>
<td>643,597</td>
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<tr>
<td>602,589</td>
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<tr>
<td>686,617</td>
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<tr>
<td>161,832</td>
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<td>429,341</td>
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<td>449,661</td>
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<td>2,378,098</td>
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<tr>
<td>5,193,866</td>
</tr>
<tr>
<td>260,143</td>
</tr>
<tr>
<td>35,124</td>
</tr>
<tr>
<td>896,119</td>
</tr>
<tr>
<td>1,424,503</td>
</tr>
<tr>
<td>868,633</td>
</tr>
<tr>
<td>12,428</td>
</tr>
<tr>
<td>1,025,654</td>
</tr>
<tr>
<td>[ f_{7}^2 ]</td>
</tr>
<tr>
<td>[ f_{8}^2 ]</td>
</tr>
<tr>
<td>[ f_{20}^2 ]</td>
</tr>
<tr>
<td>[ f_{35}^2 ]</td>
</tr>
<tr>
<td>[ f_{36}^2 ]</td>
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<tr>
<td>[ f_{38}^2 ]</td>
</tr>
<tr>
<td>[ f_{42}^2 ]</td>
</tr>
<tr>
<td>[ f_{50}^2 ]</td>
</tr>
<tr>
<td>[ f_{53}^2 ]</td>
</tr>
<tr>
<td>[ f_{55}^2 ]</td>
</tr>
<tr>
<td>[ t_{27,7} \cdots t_{27,55} ]</td>
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<td>85,584</td>
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<tr>
<td>64,911</td>
</tr>
<tr>
<td>5,164</td>
</tr>
<tr>
<td>5,023</td>
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<tr>
<td>25,833</td>
</tr>
<tr>
<td>14,794</td>
</tr>
<tr>
<td>20,653</td>
</tr>
<tr>
<td>9,289</td>
</tr>
<tr>
<td>45,819</td>
</tr>
<tr>
<td>1,233</td>
</tr>
<tr>
<td>[ 10 \cdots 10 ]</td>
</tr>
</tbody>
</table>
followed by asterisks in column (2) of Table 5-4. Column (2) is $F^{2}_{55}$ which is equal to $F^{1}_{45} + F^{2}_{10}$. An examination of the changes in final demand in column (3) reveals that two industries experience substantial changes in final demand. The computer industry has a 16.72% increase, while purchases from state and local government enterprises is up 21.98%. In absolute terms the computer industry has the largest increase. Half of the 10 instrument industries still exhibit a decrease in final demand over their pre-defense spending cut levels even after the program's increases in government spending in those industries. The sum of all of the changes in final demand is only .01%, and the amount of final demand which must be generated by the government is $67$ million more than the defense cut of $4,151$ million.\footnote{Again we assume away any multiplier effects.}

The employment effect of this new final demand vector can be found through another simulation of the model.

$$W(I-A)^{-1}F^{2}_{55} = B^{2}_{55}$$

The employment generated by $F^{2}_{55}$ is shown in column (2) of Table 5-6. Column (3) shows how much employment has changed between the level of final demand before the 10% defense cut, and after we made the compensating changes. All of the changes are small, with the largest percentage change in category 21 where the decrease in employment is .35%. The total loss in employment is only 7,501 workers, which is less than 2.2% of the 343,174
TABLE 5-6

EMPLOYMENT BY GED/SVP CATEGORY
BEFORE A 10% DEFENSE CUT AND AFTER THE CUT AND COMPENSATING CHANGES

<table>
<thead>
<tr>
<th>GED/SVP CATEGORY</th>
<th>BEFORE</th>
<th>AFTER</th>
<th>CHANGE</th>
<th>PCT CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GED 1 SVP 1</td>
<td>16166</td>
<td>16134</td>
<td>-31</td>
<td>-0.19</td>
</tr>
<tr>
<td>2 GED 1 SVP 2</td>
<td>514212</td>
<td>514079</td>
<td>-133</td>
<td>-0.03</td>
</tr>
<tr>
<td>3 GED 2 SVP 2</td>
<td>7139142</td>
<td>7138239</td>
<td>-903</td>
<td>-0.01</td>
</tr>
<tr>
<td>4 GED 2 SVP 3</td>
<td>3585987</td>
<td>3584698</td>
<td>-1289</td>
<td>-0.04</td>
</tr>
<tr>
<td>5 GED 2 SVP 4</td>
<td>329648</td>
<td>329415</td>
<td>-233</td>
<td>-0.07</td>
</tr>
<tr>
<td>6 GED 2 SVP 5</td>
<td>217780</td>
<td>217234</td>
<td>-545</td>
<td>-0.25</td>
</tr>
<tr>
<td>7 GED 2 SVP 6</td>
<td>335915</td>
<td>336286</td>
<td>370</td>
<td>0.11</td>
</tr>
<tr>
<td>8 GED 3 SVP 2</td>
<td>3979831</td>
<td>3977925</td>
<td>-1906</td>
<td>-0.05</td>
</tr>
<tr>
<td>9 GED 3 SVP 3</td>
<td>7848863</td>
<td>7848733</td>
<td>-130</td>
<td>-0.00</td>
</tr>
<tr>
<td>10 GED 3 SVP 4</td>
<td>2991825</td>
<td>2987720</td>
<td>-4105</td>
<td>-0.14</td>
</tr>
<tr>
<td>11 GED 3 SVP 5</td>
<td>1842631</td>
<td>1841319</td>
<td>-1312</td>
<td>-0.07</td>
</tr>
<tr>
<td>12 GED 3 SVP 6</td>
<td>1168193</td>
<td>1168302</td>
<td>109</td>
<td>0.01</td>
</tr>
<tr>
<td>13 GED 3 SVP 7</td>
<td>1908708</td>
<td>1909510</td>
<td>802</td>
<td>0.04</td>
</tr>
<tr>
<td>14 GED 3 SVP 8</td>
<td>249944</td>
<td>250601</td>
<td>657</td>
<td>0.26</td>
</tr>
<tr>
<td>15 GED 4 SVP 2</td>
<td>570</td>
<td>571</td>
<td>1</td>
<td>0.21</td>
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<tr>
<td>16 GED 4 SVP 3</td>
<td>1525233</td>
<td>1524637</td>
<td>-596</td>
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<td>17 GED 4 SVP 4</td>
<td>398069</td>
<td>397682</td>
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</tr>
<tr>
<td>19 GED 4 SVP 6</td>
<td>6695552</td>
<td>6695739</td>
<td>187</td>
<td>0.00</td>
</tr>
<tr>
<td>20 GED 4 SVP 7</td>
<td>11294999</td>
<td>11296278</td>
<td>1279</td>
<td>0.01</td>
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<tr>
<td>21 GED 4 SVP 8</td>
<td>579209</td>
<td>577201</td>
<td>-2008</td>
<td>-0.35</td>
</tr>
<tr>
<td>22 GED 5 SVP 5</td>
<td>87523</td>
<td>87403</td>
<td>-121</td>
<td>-0.14</td>
</tr>
<tr>
<td>23 GED 5 SVP 6</td>
<td>1296252</td>
<td>1297308</td>
<td>1056</td>
<td>0.08</td>
</tr>
<tr>
<td>24 GED 5 SVP 7</td>
<td>2325975</td>
<td>2325850</td>
<td>-125</td>
<td>-0.01</td>
</tr>
<tr>
<td>25 GED 5 SVP 8</td>
<td>2076788</td>
<td>2077126</td>
<td>338</td>
<td>0.02</td>
</tr>
<tr>
<td>26 GED 6 SVP 7</td>
<td>56914</td>
<td>56858</td>
<td>-56</td>
<td>-0.10</td>
</tr>
<tr>
<td>27 GED 6 SVP 8</td>
<td>1445195</td>
<td>1446067</td>
<td>872</td>
<td>0.06</td>
</tr>
</tbody>
</table>

TOTALS 60917504 60909952 -7501 -0.01
that originally lost their jobs. Although this figure is of interest, its actual value is not tied to the model since we have placed no restrictions on the total change in employment, only on the changes in the individual GED/SVP categories.

The implication of this simulation is that if the government should cut defense expenditures by 10% across-the-board, it can offset the employment effects of the action through a redirection of the Department of Defense funds plus net additional expenditures of only $67 million. The resulting changes in industry final demand and employment by GED/SVP category will be quite small if the additions to final demand are made in the right proportions among policy industries.

Variations on the same problem

Since the final demands of the industries used as instruments must bear the weight of adjusting the level of employment and final demand to the target levels, the fewer the instruments in general the more will be the change in the final demands of a given instrument industry; the larger the number of instruments, the smaller the change in final demand for any instrument industry. In addition, the closer the number of instruments to the number of targets, the closer we should come to achieving our goal. Therefore, we ran two variations on the same example we used above.

In the first we eliminate half of the ten instrument industries and retain only the 5 with the highest level of non-military federal government expenditures. These are the construction, electronic, aircraft, business services, and medical
and educational services industries. We carry out the same procedures of finding the employment generated by the remaining 50 industries, define \( Z_5 = YSF_5 \), solve for \( F_5 \), and process the \( F_5 \) through our model. The results are what we had expected. The actual change in the final demand of each industry is larger than before. Construction shows a large increase of $1.757 billion, while electrical and electronic machinery is up $449 million. The increase in the construction industry is more than twice as large as any change we obtained in the previous case. The model tells us that the government would have to increase its expenditures by $78 million above the $4,151 million saved by the military cuts in order to minimize the changes in employment. This is $11 million more than the amount required in the previous case.

In terms of employment the results are still very good. The largest percentage change is .75% in category 15, but this represents a change of only 4 workers out of a total of 570. In absolute terms, the changes range from a loss of 45 in category 1 to a gain of 7,033 in category 19. More than half of the categories (14) have changes in employment of over 1,000 workers. This only occurs in 7 categories in the 10 instrument case. The total change in employment is a very small loss of 420 jobs. Again, this is purely accidental since this is not one of the targets of the model. Although the total change in employment is smaller, the individual changes which we are trying to minimize are much larger with fewer instruments. Thus the necessity for movement among categories and structural employment problems are more severe.
In another variation of the objective function, we add five more industries to the original ten, so that we have 15 instruments in the model. In this case we are working with very large levels of final demand and employment since these fifteen industries account for 70% of all final demand and employ 69% of the workers in the economy. We expected that changes in final demand and employment would be closer to the target levels than in either of the previous cases, and we were not disappointed.

The largest single change in final demand is in the scientific equipment industry where there is an increase of $1.2 billion or 19.35% of the industry's final demand. Another industry with a large change in final demand is computers where output is increased 9.78% and $491 million. In this case the construction industry shows one of the smaller increases of only $118 million, as opposed to its dominant position when only 5 instruments are included. The total change in final demand for all industries between the original pre-defense spending cut and after compensating changes have been made is only $22 million. This is only one-third the amount required when 10 instruments are used.

The resulting changes in employment are even closer to the target levels than are the changes in final demand. The largest change in any category is -1,803 workers in GED/SVP 21, which represents .31% of the original level of employment in that category. This is the only category in which the change in employment is over 1,000 workers. In percentage terms the largest individual change is .5% in GED/SVP 26. The total loss in employment for all 27 categories is 3,000 workers, which is a negligible
percentage of total employment, and only .87% of the 343,174 jobs that were lost by the defense cut. Again, this total is purely accidental since it is not one of the targets of the model. With respect to employment, this is a better performance than in either of the previous examples.

The relationship between the results obtained by using 10 as opposed to 15 instruments provides an indication of some of the costs which must be considered by the policy-maker. When 10 industries are used as instruments, the cost to the government in terms of increased final demand is $67 million. When 15 instruments are used, the government needs to pay out only $22 million in additional final demand. Besides, with 15 instruments we come much closer to achieving our employment targets. Therefore, there will be less of a need to move workers from one skill category to another, fewer structural bottlenecks, and lower re-training costs in terms of time and money.

In general, the larger the number of instruments the lower the cost in terms of final demand, and the better the fit between the targets and the achieved levels. This is assuming that the government can operate on the final demands of all of the additional industries and that there are no hidden, or non-monetary costs involved.

The number of different policy problems that can be solved with this model is virtually unlimited. All that is necessary is that the objective function be stated in a form that allows its specification in terms of target levels of employment and final demand. Once a particular policy is formulated, its impact
on employment can be estimated and the steps that must be taken to counteract the employment effects under a given set of constraints can be outlined. The availability of this information would help to reduce the structural impact of many government programs, and provide a rational basis for the implementation of corrective action.
CHAPTER VI

CONCLUSION

In the preceding chapters we have demonstrated a method for estimating the demand for workers in the U.S. economy on the basis of joint general educational development and specific vocational preparation classifications. Most of the theoretical basis for our model is derived from other sources, and we do not offer any new theory on the demand for labor. What we have done is to develop a technique which has far-reaching applications and implications. The need for such a technique is evident from a review of the literature. Estimates of the demand for workers according to individual skills are essential for manpower planning. Yet most models of employment demand yield figures on total employment only. Even the studies by Bezdek and Rutzick¹ which consider the workers' occupations, are too limited in scope to remedy the problem.

Our use of the set-theoretic approach to the labor market is appropriate in dealing with the non-homogeneity of workers and job slots. Each job requires the performance of a particular set of tasks, which in turn requires a number of different types

and levels of ability traits. In order to determine whether a worker fits a particular job slot, a comparison must be made between the type and level of the worker's ability traits and those required in the performance of the tasks of the job. Set theory provides a framework which allows this type of comparison to be made.

One of the basic assumptions of this study is that the level of employment is dependent upon the level of industrial production, and also that the actual relationship between the level of output and the level of total employment, and employment by skill category, varies by industry. Input-output analysis is particularly well-suited to our purposes in this respect. Our model includes separate matrices for each industry of the demand for workers in 27 skill categories per dollar of output. The input-output table is designed to estimate the level of industrial production based upon a given set of final demands. By combining the input-output production estimates with the matrices of the demand for worker skills, the demand for workers by skill category can be determined under various conditions of final demand.

Another key portion of our study pertains to offsetting the employment effects of changes in final demand through the use of a quadratic loss function. Various statements of the objective function are considered which include such goals as minimizing the difference between the actual and target levels of industrial final demands, total final demand, and employment by GED/SVP category. This procedure and the statement of the objective function are only suggested as possible applications of the model.
of the demand for workers. Other methods might prove equally well suited to the task, depending on the goals of the policy-maker.

The availability of the required data placed the greatest limitations on this study, and also provides some areas for future research. As our model is structured, we can estimate the demand for workers by joint GED/SVP classifications. However, we cannot complete the analysis by comparing our demand estimates with the existing supply of workers in the same classifications because comparable supply data does not exist. In Chapter IV we made some specific suggestions on how this shortcoming in the supply data can be corrected.

Another drawback caused by data limitations is that although we have disaggregated the demand for workers according to specific worker skills, our figures for each skill category are aggregates over the entire economy. We have made the implicit assumption that there are no obstacles to the geographic mobility of workers. This is a doubtful assumption. One way to get around this would be to develop separate regional models which are tied to one national model to provide consistency as is done by Leontief and his associates. Even Leontief's 17 regional models for the U.S. may include too large a geographical area. Some of the other studies which have been or are being done for the individual states may prove useful in this regard. In addition to regional


input-output studies, census data on employment by industry in each of the regions would be needed to construct the matrix of demand for worker skills per dollar of output. Any future studies which consider geographical mobility would depend on this data, but it is not published at the present time.

The use of SVP categories as indicators of skill levels provides another area for future study. Its name notwithstanding, SVP does not provide information on "job specific" skills. Instead it indicates the length of training time required to hold a particular job. Therefore, it provides a common unit of measurement for the skill level requirements of different jobs, but not for the different types of skills which those jobs might require. This makes it very difficult to assess the possibility of inter-occupational mobility. An expanded study which divided the demand for workers into skill levels and types of skills would be very useful.

Another data limitation involves the GED and SVP levels given in the Supplement. In many cases separate entries are made for the same occupation in different industries since requirements for the same job title may vary by industry. More often than not, however, only one set of classifications for a particular occupation

Review of Economics and Statistics (November 1963), pp. 409-18. One of Leontief's associates, Karen Polenske, is conducting a study for the state of Massachusetts, and a firm in Hartford, Connecticut is engaged in similar research for the state of Connecticut. There are probably a number of other such studies under way at the present time.

is listed "for all industries". Until and unless this source of information is improved, it seems unlikely that this problem can be corrected.

When this study was begun, the most recent figures on occupation by industry were those found in the 1960 census. At the present time the data from the 1970 census have become available, and the matrices can be up-dated to include the more recent structure of industry employment. In addition, the Bureau of Economic Analysis plans to use primary sources in compiling the national input-output tables in the future so that the tables will be available within a year or two of the period which they cover. Our model depends on linear employment and input-output coefficients, and the more recent the data, the more reliable the estimates. Therefore, in the future it may become possible to increase the reliability of the employment estimates.

Finally, the number of worker characteristics which are included in our model is limited to two, due to the time and funding constraints placed on our study. The demand for workers is based upon a number of different worker traits; we have merely scratched the surface here. Future studies might include such characteristics as race, sex, age, etc. What we have provided is a general framework which can be expanded to include a number of different characteristics.

The main conclusion of this dissertation is that it is within the capability of the government to implement a manpower plan which has as its objective the achievement of particular levels of employment for different types of worker skills. It
makes no difference if the imbalance in the labor market is caused by economic conditions, government policy, or the actions of private industry. In addition, such a plan can be carried out while minimizing the monetary cost to the government. The efficacy of the plan is subject to the limitations of the model which are outlined above, and the assumptions of linearity in the production and employment coefficients. We feel that these assumptions are realistic in the short-run and under relatively small variations in output, and that with future research to overcome some of the limitations, this model could become a useful tool in implementing national and regional manpower policies.
## APPENDIX A

### GENERAL EDUCATIONAL DEVELOPMENT

<table>
<thead>
<tr>
<th>Level</th>
<th>Reasoning Development</th>
<th>Mathematical Development</th>
<th>Language Development</th>
</tr>
</thead>
</table>
| 6     | Apply principles of logical or scientific thinking to a wide range of intellectual and practical problems. Deal with numerical symbolism (formulas, scientific equations, graphs, musical notes, etc.) in its most difficult phases. Deal with a variety of abstract and concrete variables. Appreciate the most ambiguous classes of concepts. | Apply knowledge of advanced mathematical and statistical techniques such as differential and integral calculus, factor analysis, and probability determination, or work with a wide variety of theoretical mathematical concepts and make original applications of mathematical procedures, as in empirical and differential equations. | Comprehension and expression of a level to—
  - Report, write, or edit articles for such publications as newspapers, magazines, and technical or scientific journals. Prepare and draw up deeds, leases, wills, mortgages, and contracts.  
  - Prepare and deliver lectures on politics, economics, education, or science.  
  - Interview, counsel, or advise such people as students, clients, or patients, in such matters as welfare eligibility, vocational rehabilitation, mental hygiene, or marital relations.  
  - Evaluate technical manuals as well as drawings and specifications, such as layouts, blueprints, and schematics. |}
| 5     | Apply principles of logical or scientific thinking to define problems, collect data, establish facts, and draw valid conclusions. Interpret an extensive variety of technical instructions, in books, manuals, and mathematical or diagrammatic form. Deal with several abstract and concrete variables. | Perform ordinary arithmetic, algebraic, and geometric procedures in standard, practical applications. | Comprehension and expression of a level to—
  - Transcribe dictation, make appointments for executive and handle his personal mail, interview and screen people wishing to speak to him, and write routine correspondence on own initiative.  
  - Interview job applicants to determine work best suited for their abilities and experience, and contact employers to interest them in services of agency.  
  - Interpret technical manuals as well as drawings and specifications, such as layouts, blueprints, and schematics. |}
| 4     | Apply principles of rational systems to solve practical problems and deal with a variety of concrete variables in situations where only limited standardization exists. Interpret a variety of instructions furnished in written, oral, diagrammatic, or schedule form. | Make arithmetic calculations involving fractions, decimals, and percentages. | Comprehension and expression of a level to—
  - File, post, and mail such material as forms, checks, receipts, and bills.  
  - Copy data from one record to another, fill in report forms, and type all work from rough draft or corrected copy.  
  - Interview members of household to obtain such information as age, occupation, and number of children, to be used as data for surveys or economic studies.  
  - Guide people on tours through historical or public buildings, describing such features as size, value, and points of interest. |}
| 3     | Apply common sense understanding to carry out instructions furnished in written, oral, or diagrammatic form. Deal with problems involving several concrete variables in or from standardized situations. | Use arithmetic to add, subtract, multiply, and divide whole numbers. | Comprehension and expression of a level to—
  - Learn job duties from oral instructions or demonstration.  
  - Write identifying information, such as name and address of customer, weight, number, or type of product, on tags or slips.  
  - Request orally, or in writing, such supplies as linen, soap, or work materials. |}
| 2     | Apply common sense understanding to carry out detailed but uninolved written or oral instructions. Deal with problems involving a few concrete variables in or from standardized situations. | Perform simple addition and subtraction, reading and copying of figures, or counting and recording. | Comprehension and expression of a level to—
  - Learn job duties from oral instructions or demonstration.  
  - Write identifying information, such as name and address of customer, weight, number, or type of product, on tags or slips.  
  - Request orally, or in writing, such supplies as linen, soap, or work materials. |}
| 1     | Apply common sense understanding to carry out simple one- or two-step instructions. Deal with standardized situations with occasional or no variables in or from these situations encountered on the job. | | Comprehension and expression of a level to—
  - Learn job duties from oral instructions or demonstration.  
  - Write identifying information, such as name and address of customer, weight, number, or type of product, on tags or slips.  
  - Request orally, or in writing, such supplies as linen, soap, or work materials. |}

---

1 Examples of "principles of rational systems" are: bookkeeping, internal combustion engines, electric wiring systems, house building, nursing, farm management, ship sailing.

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