PRODUCTION FUNCTIONS IN CONTRACT CONSTRUCTION FOR THE UNITED STATES, 1972

Dissertation for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY
JOHN SEWELL McCONNAUGHEY, JR.

1976

This is to certify that the

thesis entitled

PRODUCTION FUNCTIONS IN CONTRACT CONSTRUCTION
FOR THE UNITED STATES, 1972

presented by

John Sewell McConnaughey, Jr.

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Economics

W Paul Strassmann

Major professor

Date Dec 11 1975

O-7639

ABSTRACT

PRODUCTION FUNCTIONS IN CONTRACT CONSTRUCTION
FOR THE UNITED STATES, 1972

By

John Sewell McConnaughey, Jr.

Construction is a large and important sector of the U.S. Economy. Gross construction expenditures have generally averaged about 13-14 percent of Gross National product. The sector directly employs between 5 to 6 percent of the labor force. But over half the jobs created by construction expenditures are indirect, occurring in those mining, manufacturing, trade and transportation industries which provide construction materials to the sector.

It is generally agreed that cyclical and seasonal fluctuations within the sector, regional shifts in demand of output, sensitivity to monetary policy, and institutional constraints (such as the separation of design from production, restrictive building codes, contractural disputes, union bargaining strength) strongly affect performance and productivity growth in the sector. Economists and policy makers have been especially concerned about the performance of the construction sector regarding unemployment and inflation. Much employment is seasonal, and even in years of high demand unemployment among construction workers is high relative to other sectors. Construction costs have risen rapidly in recent years

while productivity growth in construction appears somewhat lower than for other sectors. Moreover, the complexity of the sector, the heterogeneity of the output, and poor construction statistics have greatly hindered economic investigation.

The purpose of this study is to examine the Contract Construction Industries using new data which has recently become available in the 1972 Census of Construction Industries. This census is the second since World War II, but is the first to contain data on capital inputs. No previous production function study of this type has been undertaken for the Contract Construction Industries because of the lack of appropriate statistical data.

We estimate single equation Cobb-Douglas and Constant Elasticity of Substitution (CES) functions for twenty-four 4 digit Contract Construction Industries. Our models are similar to those used in production function studies in manufacturing. In Contract Construction the 4 digit industries are separated into three major groups by type of specialization. They are: SIC 15, General Building Contractors; SIC 16, Heavy Construction General Contractors; and SIC 17, Special Trade Contractors.

Our major empirical findings are: (1) The elasticity of substitution between capital and labor is less than one for nearly half of the special trade contractor industries, but for most of the general building contractors and heavy construction general contractors a value of unity seems reasonable; (2) There is evidence of increasing returns to scale for about one third of the special trade contractor industries. However these industries employ nearly two-thirds of the workers in the special trade contractor group (SIC 17); (3) There is great diversity among the 4 digit industries. Many factors, especially geographic factors, influence the construction process differences in a complex way. Examples are skill composition, design, size of establishment, size of construction project, degree of urbanization, and degree of unionization. Our empirical results suggest that no single policy action for the sector as a whole is likely to have the same impact in each of the separate industries.

Traditional production function models generally use value added as output, and ignore the possibility of substitution between materials, other inputs. We provide evidence that substitution of materials for labor and capital occurs in construction, and that this substitution may be an important source of productivity growth in the sector. In a separate chapter we develop models which allows us to explore in a tentative way substitution between materials and other inputs, especially onsite labor. We find that most evidence suggests an elasticity of substitution between materials and labor of about one. But these findings are not conclusive since our efforts are hindered both by statistical problems and by limitations in the functional forms which we use to examine the multiple input production functions.

PRODUCTION FUNCTIONS IN CONTRACT CONSTRUCTION FOR THE UNITED STATES, 1972

By

John Sewell McConnaughey, Jr.

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Economics

1976

FOR MARGARETTA, GRETA,
KATHERINE, AND REBECCA

ACKNOWLEDGEMENTS

I wish to thank all my friends and colleagues at Michigan State University who have been a source of support and encouragement during this project. I am especially grateful to Professor W. Paul Strassmann for his constant guidance and support. He instilled in me an interest in the economics of the construction sector, and gave freely of his time and ideas. His help was invaluable.

My thanks go also to Professor Robert H. Rasche for his time, his problem solving, and his constructive criticism; to Professor Byron W. Brown whose guidance on production theory was particularly appreciated; and to Professor Paul B. Ginsburg who combined expeditious reading of the thesis with sound advice for improvement.

I would also like to thank my fellow graduate students, especially Robert Pierre Henry for his friendship and moral support. Technical advice on computer applications by Jan Palmer is also much appreciated.

I also wish to thank my parents for their continuous support of all my academic undertakings.

This thesis is dedicated to Margaretta, Greta, Katherine, and Rebecca, who have sacrificed much during the writing of this thesis. They make everything worthwhile.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

The main purpose of this thesis is to present cross section estimates of Cobb-Douglas and Constant Elasticity of Substitution (CES) Production Functions for twenty-four 4 digit Contract Construction Industries in the United States. No previous production function study of this type has been undertaken for the Contract Construction Industries because of the lack of appropriate statistical data. We use the 1972 Census of Construction Industries as our primary source of information. It is the second such census since World War II, but the first census to contain data on capital inputs.

Construction is a large and important sector of the U.S. economy. Gross construction expenditures have generally averaged about 13-14 percent of Gross National Product. The sector directly employs between 5 to 6 percent of the labor force. But more than half the jobs created by construction expenditures are indirect, occurring in those mining, manufacturing, trade, and transportation industries which provide construction materials to the sector. Changes in construction expenditure or its composition can have a large impact (often regional) upon the important supplying industries.

Construction output is a large component of new capital investment. A major factor in meeting national housing and social goals is the ability of the construction sector to produce low cost housing.

Inefficient production of capital goods or housing can lead to a "cost-push" type of inflation if the price of the factors of production in construction increase more rapidly than their productivity.

Economists and policy makers have been especially concerned about the performance of the construction sector regarding unemployment and inflation. This concern was clearly expressed by the Cabinet Committee on Price Stability in 1969.[1]

> Construction prices and the costs of labor and nonhuman inputs are generally believed to have been rising faster than the average in recent years, and productivity increases have been reported as being unusually low although data on these points are scarce. Unemployment among construction workers has been high relative to other sectors, even in years with high demand... Thus the construction sector contributes in several ways to the unemployment-inflation dilemma.

It is generally agreed that cyclical and seasonal fluctuations within the sector, regional shifts in demand and in the composition of output, sensitivity to monetary policy, and institutional constraints (such as the separation of design from production, restrictive building codes, union bargaining strength) strongly affect performance, and productivity growth in the sector. Moreover the complexity of the sector, the heterogeneity of the output, and poor construction statistics have greatly hindered economic investigation.

Early investigations such as Colean and Newcombs' Stabilizing Construction; The Record and Potential (1952) or Haber and Levinsons' Labor Relations and Productivity in the Building Trades (1956) concluded that productivity growth in the construction sector was practically non-existent.[2] However more recent studies using improved price indexes to deflate construction output - Dacy (1965), Gordon (1968), Sims (1968), and Cassimates (1969) - have all found that since about 1947 output per man hour has increased at an annual rate of roughly 3 percent per year.[3] This rate remains below that of the other major sectors and of the economy as a whole.[4]

The source of productivity growth in construction is not unlike the source of productivity growth in other sectors. Dacy presents a useful list of factors which have probably affected productivity growth in construction. These are: (1) An increase in the amount of capital per worker. This is especially true where new technology has been introduced such as earthmoving and excavating equipment, power cranes, ready-mix concrete trucks, or small power tools; (2) A shift in construction product mix toward output which is less labor intensive or which has more rapid productivity growth; (3) A shift in the geographic distribution of output to the West where productivity is thought to be higher; (4) An increase in the corporate share of contract construction output. Since corporate firms are generally larger than single proprietorships or partnerships economies of scale may have occurred; (5) A decline in the average age of construction workers following World War II; and (6) New techniques of building, and the substitution of labor saving building materials for on site labor.

Our census data provides new information on the Contract Construction Industries, and the production function framework is well suited for examining a number of the factors which affect productivity growth. In Chapter II we develop our major Cobb-Douglas and CES models. These are single equation models in which value added is the output measure, and labor and capital are the inputs. Our basic Cobb-Douglas model allows us to examine the relative importance of each input, and returns to scale in each of the 4 digit industries. We modify this

model so that we can also (partially) examine the influence of technological change and differences in the quality of labor.

The CES models are used to estimate the elasticity of substitution between capital and labor (σ). The elasticity of substitution measures the ease with which capital can be substituted for labor. In addition, knowledge of the value of σ provides information on how the factor shares of capital and labor change with a change in their relative factor prices. An important application of σ is in evaluating the impact of changes in payroll taxes or subsidies, and in investment tax credits or capital depreciation tax policies. We end Chapter II with a brief discussion of this application as it applies to employment in construction.

We might expect that production function analysis using time series data is more appropriate than cross section analysis for investigating the influence of technological change, changes in labor quality, and substitution between capital and labor. However there are several major drawbacks to time series data in construction. We outline these drawbacks briefly in Chapter III. Our main purpose in this chapter is to define the variables used in the study and to provide a general description of the 1972 Census of Construction Industries. Using the census data we describe in some detail the major characteristics of the sector and of the separate 4 digit industries.

The models developed in Chapter II are basically similar to those used in production function studies of manufacturing industries. This similarity allows us to compare our empirical results in the construction industries with results from similar types of studies in manufacturing. We present our main empirical results and make these manufacturing industry comparisons in Chapter IV.

Our results are not fully comparable with those in manufacturing for several reasons. One reason is that manufacturing industries are often concentrated in a few states, while the construction industries are located in every state. We discover that geographic location is an important variable in our production functions for most of the construction industries, but are unable to identify specifically which geographic characteristics (such as regional differences in size of firm, wage rates, output composition, skill composition, degree of unionization, differences in work rules) are most important.

The level of aggregation used may also have an important bearing upon our results. Our construction industries are classified in the narrower 4-digit classification while the majority of manufacturing studies are based on the broader 2-digit classification. Despite this narrower classification, we have a larger number of observations in most of our industries than the number of observations used in similar 2-digit manufacutring studies. To examine such problems of aggregation (in a limited way) we also present estimates for Cobb-Douglas and CES models for the construction sector as a whole. This also allows us to compare these aggregate estimates with time series estimates of the sector by Cassimates.[5]

Traditional models of production, which use value added as output ignore the possibility of substitution between materials and other inputs since the value of materials used is subtracted from both sides of the production function equation. This practice has lead Evsey Domar to remark[6] evelopa

ressure.

ruction

ant.

ed by

he mul

Perhaps

ubstit

alf th

nd mos

The

third o

Distric

ontrac

structi

Region.

ach of

studie

> ... it seems to me that a production function is supposed to explain a productive process, such as making potato chips from potatoes (and other ingredients), labor and capital. It must take some ingenuity to make potato chips without potatoes. I do not mean that the omission of material inputs is necessarily wrong. Rather that it is not at all obvious that it is the preferred method.

In Chapter V we examine the role of materials. Models are developed and results presented in which gross output is the output measure. These models allow us to explore in a tentative way substitution between materials and our other inputs, especially on-site labor. However our efforts are hindered by both statistical problems and by limitations in the functional forms which we use to examine the multiple input production functions.

Our findings and conclusions are reviewed in Chapter VI. Perhaps the most important of these are: (1) That the elasticity of substitution between capital and labor is less than one for nearly half the special trade contractors, but for general building contractors and most heavy construction contractors a value of one seems reasonable; (2) There is evidence of increasing returns to scale for about one third of the special trade contractor industries. However these industries employ nearly two-thirds of all employees in the special trade contractor group (SIC 17); (3) There is great diversity in the construction process between the 4-digit industries, and by geographic region. No single policy action is likely to have the same impact in each of the separate industries. Another implication is that aggregate studies of the sector as a whole must be interpreted with caution.

Notes to Chapter 1

1. Studies by the Staff of the Cabinet Committee on Price Stability, U.S. Government Printing Office, Washington, D.C., 1969, p. 103.

2. Colean, M. and Newcomb, R., Stabilizing Construction: The Record and the Potential, McGraw-Hill, New York, 1952; and Haber, W. and Levinson, H., Labor Relations and Productivity in the Building Trades, Bureau of Industrial Relations, University of Michigan, Ann Arbor, 1956.

3. Cassimates, Peter, Economics of the Construction Industry, The National Industrial Conference Board, Studies in Business Economics, No. 111, New York, 1969; Dacy, Douglas, "Productivity and Price Trends in Construction since 1947", Review of Economics and Statistics, November, 1965, pp. 406-411; Gordon, R.J., " A New View of Real Investment in Structures, 1919-1966," Review of Economics and Statistics, November 1968, pp. 417-428; and Sims, Christopher, "Efficiency in the Construction Industry", in the President's Committee on Urban Housing, Technical Studies: Housing Costs, Production Efficiency, Finance, Manpower, Land, Vol. II, U.S. Government Printing Office, Washington, D.C., 1968, pp. 145-176.

4. Cassimates, ibid., pp. 88-89.

5. Cassimates, ibid., Chapter 5.

6. Domar, Evsey, Comment in The Theory and Empirical Analysis of Production, Murry Brown, ed., NBER Studies in Income and Wealth, Vol. 31, Columbia University Press, New York 1967, pp. 471-472.

CHAPTER II

THEORETICAL BACKGROUND

Before discussing the particular theoretical models and estimating methods in detail, we will begin this chapter with a brief description of those characteristics of contract construction which distinguish this sector from others. Section 2 contains a general theoretical background, summarizes the properties of production functions, and discussed the assumptions required in order to estimate these functions. As a part of this section various problems and weaknesses in our approach will be considered. The particular Cobb-Douglas and Constant Elasticity of Substitution (CES) models to be estimated are presented in sections 3 and 4.

1. General Characteristics of the Contract Construction Industries

Most economic research concerning the construction sector has been in labor and industrial relations.[1] These studies have stressed the many characteristics of construction which distinguish the sector from others in the economy. The intent here is to list and to discuss briefly these characteristics for an overall picture of the sector. Specific information concerning the 1972 Census of Construction Industries, is presented in Chapter III.

Construction differs from manufacturing (and other industries) in a number of ways. The product is generally custom designed, durable, large, expensive, immobile, assembled at a particular site, and has a long gestation period from initial design to final completion. Since much of the work is outdoors, production is dependent upon weather conditions, and in most parts of the country construction is seasonal in nature. Construction is geographically dispersed throughout the country rather than concentrated in a few geographic areas. With the exception of heavy construction it is labor and material intensive relative to capital. There is a wide variability of demand -- between regions, over the business cycle, and among private residential, private non-residential, public building, and maintenance/repair work. The firms, labor markets, and institutions which have developed are highly flexible and specialized to meet the unique requirements of the sector. Long term financing is usually involved.

Construction has numerous and highly specialized firms. There are twenty-seven types of construction firms listed in the 1972 edition of the Standard Industrial Classification Manual. They are classified in three broad categories -- general building contractors (SIC 15), general heavy construction contractors (SIC 16), and special trade contractors (SIC 17). The firms are generally small but usually the general contractors are larger than the special trade contractors. One - two man firms outnumber larger firms, but their share in total construction receipts is small. With the partial exceptions of operative builders, subdividers and developers (who engage in residential construction for sale on their own account) the firms operate under a set of complex contractural and subcontractural relationships.

The main advantage of the subcontracting system is that it allows a high degree of flexibility in production. Construction projects differ in design, size, location, and skill requirements. General contractors do not have the volume of demand to continuously employ skilled workers or highly specialized equipment. In most cases they retain only some of the fixed capital investment and skilled workers needed, instead relying on subcontractors and rental equipment. Contractor specialization allows the flexibility to expand rapidly, to respond to changing product markets, and yet to use skilled workers and specialized equipment economically.

A major disadvantage of the subcontracting system is that management may be loose with wide divisions in responsibility. Disputes can arise between the general contractor and the subcontractor about contractural obligations. Jurisdictional disputes occur between unions. Such disputes can lead to work stoppages and reduce effective scheduling and coordination of the job. Disputes add uncertainty to already risky and uncertain undertakings. Many contractors fail. There is a large amount of entry and exit into the industry, particularly by smaller firms which have relatively low capital requirements.

The product and factor markets in which contractors operate are local in nature. There is a high degree of competition in the product market between contractors since construction work is most commonly obtained through competitive bidding. For public construction, competitive bidding is almost universal, since it is generally required by law. In private construction bidding is the most common method to award construction contracts, although contracts may often be negotiated.[2] In residential construction some builders (operative builders) construct residences on their own account. They act as the general contractor, but subcontract the major share of the work. Competition is not perfect however, since the size, reputation, and union/non union status of contractors are often considered by clients and lenders in determining the ability of the contractor to handle the job. The local nature of the market may also foster political relationships which affect the awarding of contracts. Building codes and regulations reinforce the local nature of the market. Contractors usually face fixed factor prices in their local market although larger firms often obtain quantity discounts in purchasing materials. Union wage agreements fix wages for two or three years. There is generally a prevailing wage for non union workers as well, but there can be a substantial differential between the union and non union wages which may differ from one local market to another. Factor prices vary substantially between regions. For material inputs this probably reflects transportation costs, the size of markets, and regional preferences or climatic differences in design. Labor markets are linked somewhat so that wage increases in one region will have impacts in other areas. However substantial differentials between regions exist. Wages may differ due to differences in the degree of unionization, the cost of living, regional variation in the composition of construction demand, or regional variation in demand for similarly skilled workers in industries other than construction.[3]

2. General Production Theory

The microeconomic theory of production, cost, and input demand is basic to understanding the neoclassical theory of distribution. The production function provides the framework for appraising these issues.

Let the general production function

$$Q = F(x_1, x_2, \ldots, x_n) \quad (2.1)$$

define the technical relationship between a flow of output (Q) and a flow of inputs (X_i) for a firm, where F is assumed to be a continuous twice differentiable function. The output and inputs are measured in physical terms. However this study, like the vast majority of empirical studies of production, is based upon aggregate rather than firm data. Output is aggregated using prices and is measured in value terms. While the labor input is measured in physical terms all other inputs are measured in value terms. To apply the production function concept to aggregate data, and to specify a particular form of the production function for estimation requires a number of strong simplifying assumptions.

This study involves a cross section of the 4 digit contract construction industries. The industries are the general and special trade contractors defined in the 1972 edition of the Standard Industrial Classification Manual. Observations are by state. Output and input data is divided by the number of establishments in each state. Each observation is assumed to be from a "representative establishment" in that state.[4] We also assume that representative establishments in the same industry have the same production function, and that each establishment is producing efficiently. The production function is assumed to have the property of homotheticity. This means that the observations can be thought of as being observed on a single isoquant, since this property requires that the slope of the isoquant (or marginal rate of substitution) is independent of scale and depends only on input proportions. Industry output is assumed to be homogeneous in each 4 digit industry. Each representative establishment is assumed to face a perfectly competitive local factor market. Different relative factor prices between local markets lead establishments to choose different factor proportions which allows identification of the production function.

Although such assumptions are typical of aggregate production studies they introduce a number of weaknesses to the study.[5] Some assumptions do not correspond to the actual conditions (such as the assumption of constant output prices cross-sectionally) but cannot be avoided because of data limitation. The best that can be done in this case is to examine the possible direction of bias. The assumption that there is a homogeneous output may be particularly open to criticism in a study of the construction sector. Buildings and other structures are not homogeneous. They may differ from each other in design, materials used, quality, size and by many other characteristics. However this problem is minimized by the classification system which defines the industries. General contractors usually specialize in one or a few building types. The workers which they directly employ usually work on the structure. The rest of the work is subcontracted. The other function which general contractors usually perform is that of general supervisor and coordinator at the site. Although the design and characteristics of two construction projects may be dissimilar the work performed by subcontractors may be relatively homogeneous.

Thus the relatively narrow classification system reduces criticism of the homogeneous output assumption. In fact, our data is probably superior in this regard to many studies in manufacturing. The level of aggregation used in most manufacturing studies is a broad 2 digit classification which leaves much greater leeway for errors due to changes in the composition of output. For example, in the food processing industry (SIC 20) observations in Michigan may largely represent breakfast food production, in Florida orange juice processing, in Iowa meat packing, and in California frozen vegetable processing.

There are several assumptions which can be made about the ways in which the output and inputs are defined. Aggregate studies in manufacturing use a value added measure of output. In this chapter we will also follow this practice. Value added is obtained for the construction industries studied by subtracting the value of materials and subcontracting services purchased from the value of gross output $(V = Q - M - S)$. This value added assumption allows comparison of our results with those from similar types of studies in manufacturing. It focuses attention on the role of capital and labor. Since the value of materials and subcontracting services is subtracted from both sides of the production function problems of estimation are reduced.

For the economy as a whole it is legitimate to use value added as output since the material inputs are intermediate goods and cancel out (except imports). Similarly, for the construction sector as a whole subcontracting services may also be excluded. But for the separate general contracting and special trade contracting industries analyzed in this study both materials and subcontracting services are purchased outside the 4 digit industry. They do not cancel out. Both can be substituted for labor or capital used in the industry. The level of capital and labor services used in the industry depends not only on the relative price of capital and labor, but also on the relative prices of materials and subcontracting services. In Chapter V we introduce materials as an input and develop models using a gross measure of output for this purpose.

This study will use single equation production function models. To estimate a single equation model using ordinary least squares (OLS) a multiplicative disturbance, or random error is introduced. For example, a simple Cobb-Douglas model is specified as

$$V_i = A\, K_i^{\alpha} L_i^{\beta} e^{u_i} \qquad (2.2)$$

Traditionally, the rationalization for introducing the error term (u_i) is to account for differences in entrepreneurial ability between establishments.

The basic assumptions necessary to use OLS require that: (1) u_i is normally distributed; (2) $E(u_i) = 0$; $E(u_i^2) = \sigma^2$; (3) The u_i's are independent of each other, that is $E(u_i u_j) = 0$; (4) That u_i is independent of the level of L and K used. That is, $E(u_i \log L_i) = E(u_i \log K_i) = 0$. These assumptions imply that the level of output is a function only of the level of inputs chosen, and by theform of the production function. Marschack and Andrews first criticized the single equation approach and presented a more comprehensive simultaneous equation system model of the firm derived from the profit maximizing assumption.[6] In their model output and input levels are jointly determined from the production function and from the input demand equations. Product and factor market conditions other than perfect competition are allowed. They show that random disturbances in the input demand equations are transmitted to the production function so that assumption (4) above no longer holds, and if OLS is used to estimate the single equation (2.2) the estimates of α and β will be biased and inconsistent.[7]

Our rationale for using the single equation OLS approach stems from a model developed by Zellner, Kmenta and Dreze (ZKD).[8] Although it is also a simultaneous equation model it differs from the Marschack-Andrews model by assuming: (1) that the production process is not instantaneous or deterministic; and (2) that production is viewed as a stochastic process with respect to profit maximization by the firm. Now, the random disturbance (u_i in equation 2.2) represents the influence of factors such as weather or other unpredictable circumstances which affect production. Production is not instantaneous and profit is uncertain. ZKD assume that establishments maximize expected profits. Output and input prices are assumed to be known with certainty; or if input prices are not known exactly decisions are based upon anticipated prices randomly distributed around the actual price. With the added assumption that u_i is normally distributed ZKD are able to show that random disturbances in their input demand equations are not transmitted to the production function. This vindicates the single equation OLS approach to estimating the Cobb-Douglas function from cross section data, and the estimates from this model are asymptotically unbiased and consistent.

Since conditions in the construction industries approximate the assumptions of the ZKD model the use of OLS seems appropriate.

In preparing bids contractors use existing or anticipated input prices. Except for "cost plus" types of contracts and cuildings build for speculation the "price" for the output which contractors receive is set in advance except for later adjustments made for specification changes which entail extra work. Profits are uncertain for many projects due to the long gestation period in which unanticipated jurisdictional disputes, weather problems, soil conditions, etc. can occur. Of course we cannot push this interpretation too far, and the small sample characteristics of the OLS estimators remain unknown.

Whatever the interpretation given to the data a likely and serious source of bias will be simultaneity and bias introduced due to errors in the measurement of the data - particularly capital data. While we cannot do a great deal about errors in the data specific attempts to investigate various sources of bias in both the Cobb-Douglas and CES models reported later.

3. The Cobb-Douglas Form

The main parameters of the Cobb-Douglas form which we will be concerned with are: (1) The output elasticities which indicate the relative importance of each input in the production of the output; (2) returns to scale, which tell how output responds to changes in the scale of the establishment; (3) How these properties vary by industry and by census region.

The non stochastic Cobb-Douglas form is

$$V = AK^{\alpha}L^{\beta} \tag{2.3}$$

where α and β are the output elasticities for capital and labor defined as

$$\alpha = \frac{\frac{\partial V}{\partial K}}{V/K} \quad , \qquad \beta = \frac{\frac{\partial V}{\partial L}}{V/L} \quad .$$

They provide a normalized measure of how much output changes due to a proportional change in the input. If there is perfect competition and constant returns to scale these elasticities also measure the relative factor shares of capital and labor. The sum of the output elasticities indicate returns to scale ($\alpha + \beta \lesseqgtr 1$ imply decreasing, constant, increasing returns to scale). The parameter A can be considered an efficiency parameter since functions with identical output elasticities may have different outputs if A differs. The elasticity of substitution σ, which measures the relative ease with which capital may be substituted for labor, is restricted to one.

Equation 2.3, which we will call the basic Cobb-Douglas model assumes that both capital and labor inputs are homogeneous. We will modify this assumption to allow for differences in input quality. The first modification is to separate labor into construction (L_c) and nonconstruction (L_A) workers. The function to be estimated is

$$V = AK^{\alpha}L_C^{\beta_1}L_A^{\beta_2} \qquad (2.4)$$

The basic model assumes that L_C and L_A are perfect substitutes, i.e., $\sigma_{L_C L_A} = \infty$ while this model assumes that $\sigma_{L_C L_A} = 1$. A preferable method for incorporating differences in the quality of labor would be to construct an index of labor quality for each industry by state. Griliches has done this in his studies of the 2 digit manufacturing industries.[9] On the basis of his findings he concludes that his results "...underscore the importance of labor-quality differences in accounting for differences in productivity."[10] However, adequate data on the occupational distribution of the labor force in construction by state, which is needed for such an index of labor quality are not available.

A second modification to the basic model, developed by Solow and others, attempts to adjust for the different ages - or vintages - of capital.[11] Liu and Hildebrand have proposed the ratio of net to gross value of capital stock (R) as a proxy for capital vintage.[12] The higher R the newer the capital. Their hypothesis is that technological change is embodied in new capital goods so that new capital is also more capital. We introduce R into the Cobb-Douglas model, augmenting capital as follows

$$V = A(R \cdot K)^{\alpha} L^{\beta} \qquad (2.5)$$

This assumes that R and K have the same exponent which allows equation (2.5) to be rewritten as

$$V = A\, R^{\alpha} K^{\alpha} L^{\beta} \qquad (2.5a)$$

Estimating equation (2.5a) will test the common exponent assumption and allows the effect of R to be estimated separately.

A final modification to the basic [illegible] to introduce regional dummy variables. Many factors which affect construction -- such as building design, size of establishment, skill composition of labor, degree of unionization and of urbanization, climate, building materials prices, output prices, to only name a few -- vary by geographic region. If these factors have an important effect upon production in our industries but are not incorporated in our models then our models are misspecified. The use of regional dummies will reduce this specification error, but unfortunately will not identify the influence of any particular geographic factor.

4. The CES Form

A major problem associated with the Cobb-Douglas form is that the elasticity of substitution is restricted to one. In the CES form

$$V = \gamma[\delta K^{-\rho} + (1 - \delta)L^{-\rho}]^{-v/\rho} \tag{2.6}$$

ρ is the substitution parameter where $\sigma = \frac{1}{1+\rho}$, γ is the efficiency parameter, δ is the distribution parameter, and v is the scale parameter. If $\rho = 0$ then $\sigma = 1$ and the function reduces to the Cobb-Douglas form. Direct estimate of the CES form is difficult since it is non-linear in the parameters. However Kmenta has developed a linear approximation of the CES by taking logarithms and expanding a Taylor series around $\rho = 0$.[12] The approximation is

$$\text{Log } V = \text{Log } \gamma + \delta \text{Log} K + v(1 - \delta)\text{Log } L - \frac{1}{2}\rho\, v\delta(1 - \delta)[\log K - \log L]^2 \tag{2.7}$$

In addition to providing an estimate of σ, estimation of this equation provides a test of the Cobb-Douglas form. If $\rho = 0$ then $\sigma = 1$ and the coefficient of the last term will not be significantly different from zero. Such a test is weak since the value of the coefficient also depends on the value of δ. Since 1/2 and the $\delta(1 - \delta)$ terms are fractions the value of the coefficient is likely to be low. Additionally σ is estimated as a second order parameter since its value is derived from the value of ρ. To illustrate if $V = 1$, $\delta = .3$, $(1 - \delta) = .7$, and $\rho = 1$ ($\sigma = .5$) then the coefficient is quite small (equal to -.105). With a small sample size or with data containing measurement error it is likely that the standard error will be large. Another problem associated with using this approximation is that the estimate of σ becomes worse as ρ departs from a value near zero.

The original method of estimating the elasticity of substitution introduced by Arrow, Chenery, Minhas and Solow (ACMS) provides another means of testing the Cobb-Douglas assumption. The ACMS method, which assumes constant returns to scale, is based on the marginal productivity condition derived from profit maximization. The estimating equation is

$$\text{Log } V/L = a + b \text{ Log } w/p \qquad (2.9)$$

where b is the elasticity of substitution and w/p is the real wage. This method is also weak since it has been shown that for cross section data b may often be biased toward one.[13] This is true for example, if labor quality, output price, or the efficiency parameter vary over observations. We will again use regional dummies to examine this problem. Since these sources of bias may be geographic we would expect the estimate of b to be lower when regional dummies are included.

ACMS derived the CES function by first observing the strong empirical relationship between V/L and the real wage. Liu and Hildebrand have criticized this approach by arguing that V/L is ot only

apital p

for 17 t

ndustri

rm lea

is beyon

owever

erived

of capi

of subs

has to

labor h

capital

upon th

that u

with o

repres

demand

elasti

increa

wage e

study

scope

elasti

not only a function of the real wage but also of the amount of capital per worker. They estimated

$$\text{Log } V/L = a + b \text{ Log}(w/p) + c \text{ Log } (K/L) \qquad (2.11)$$

for 17 two digit manufacturing industries and for the majority of the industries obtained significant coefficients for c.[14] This equation leads to a variable elasticity of substitution (VES) form. It is beyond the scope of this study to fully develop a VES model. However a rough estimate of the elasticity of substitution can be derived from the coefficients of equation 2.11 and data on the share of capital.[15]

One of the major reasons for interest in the elasticity of substitution between capital and labor is the relationship σ has to the demand for labor. The wage elasticity of demand for labor has two components, the substitution effect which occurs as capitol is substituted for labor and the output effect which depends upon the output price elasticity of demand.[16] Minasian has shown that under the ACMS assumptions σ is the wage elasticity of demand with output held constant. When output is allowed to vary σ represents the substitution component of the wage elasticity of demand for labor, and represents a lower bound estimate of this elasticity.[17] Thus a $\sigma < 1$ not only implies that a relative wage increase will increase the labor share of output, but also that the wage elasticity of demand for labor may be inelastic. A complete study of the demand for labor in construction is again beyond the scope of this study. However, to supplement our estimates of the elasticity of substitution we will estimate a simple demand for labor function. From the marginal productivity conditions on labor the demand for labor is a function of the wage rate, output, and the price of capital. Our estimating equation modifies this by excluding the price of capital. Thus we will estimate

$$\text{Log } L = a + b \text{ Log } W + c \text{ Log } V \qquad (2.12)$$

where b is the wage elasticity of demand for labor with output held constant.

Notes to Chapter II

1. Two excellent early studies are Colean, M., and Newcomb, R., Stabilizing Construction: The Record and Potential, McGraw-Hill, New York, 1952; and Haber, W., and Levinson, H., Labor Relations and Productivity in the Building Trades, Bureau of Industrial Relations, University of Michigan, Ann Arbor, 1956. More recent general studies are: Cassimates, Peter, Economics of the Construction Industry, The National Industrial Conference Board, Studies in Business Economics, No 111, New York, 1969; Dietz, Alfred, The Building Industry, prepared for the Commission on Urban Problems, Department of Architecutre, M.I.T., Cambridge, 1968; and Rossow, Janet, and Moavenzadah, Fred, The Construction Industry, Department of Civil Engineering, M.I.T., Cambridge, 1974. The most recent comprehensive work on industrial relations is Mills, D. Quinn, Industrial Relations and Manpower in Construction, M.I.T. Press, Cambridge, 1972.

2. For a more complete discussion of the types of contracts see Rossow and Moavenzadan, ibid., pp. 202-216.

3. For more information on wage determination in construction see Mills, op. cit., Chapter 6.

4. A similar assumption is made in Liu, Ta-Chung, and Hildebrand, George, Manufacturing Production Functions in the United States, 1957, New York State School of Industrial and Labor Relations, Cornell University, Ithaca, 1965.

5. See Liu and Hildebrand, ibid., Chapter II for a critical review of the general assumptions which are common to most aggregate production function studies. Liu and Hildebrand present their own model in Chapter III which relaxes many of these assumptions.

6. Marschak, J. and Andrews, W., "Random Simultaneous Equations and the Theory of Production", Econometrica, July-October, 1944, pp. 143-205. For an excellent review of the Marschack-Andrews approach as it has developed in the literature see Bridge, J.L., Applied Econometrics, North-Holland Publishing Co., Amsterdam, 1971.

7. For proof see Zellner, A., Kmenta, J., and Dreze, J., "Specification and Estimation of Cobb-Douglas Production Function Models", Econometrica, October 1966, pp. 784-786. See also Griliches, Zvi, and Ringstad, V., Economics of Scale and the Form of the Production Function, North Holland Publishing Co., Amsterdam, 1971, pp. 13-14.

8. Zellner, Kmenta, and Dreze, ibid.

9. See Griliches, Z., "Production Functions in Manufacturing: Some Preliminary Results" in M. Brown, ed., The Theory and Empirical Analysis of Production, NBER, Studies in Income and Wealth, Vol. 31, New York, 1967, pp. 275-322, for results using 1958 data. See Griliches, Z., "Production Functions in Manufacturing: Some Additional Results", The Southern Economic Journal, October 1968, pp. 151-156, for results using 1954, 1957, and 1963 data.

10. Griliches, Z., "Production Functions in Manufacturing: Some Additional Results", ibid., p. 168.

11. Solow, R.M., "A Contribution to the Theory of Economic Growth", Quarterly Journal of Economics, February, 1956, pp. 65-94.

12. Liu and Hildebrand, op. cit., pp. 49-50.

13. See Kmenta, Jan, Elements of Econometrics, The Macmillan Co., New York, 1971, pp. 462-465.

14. See Lucas, Robert E., "Substitution Between Labor and Capital in U.S. Manufacturing", unpublished doctoral dissertation, Univ. of Chicago, 1964, pp. 26-31. Also see Mayor, Thomas, "Some Theoretical Difficulties in the Estimation of the Elasticity of Substitution from Cross-Section Data", Western Economic Journal, June 1969, pp. 153-163.

15. Liu and Hildebrand, op. cit., pp. 33-40.

16. $\sigma = \frac{1}{1+\rho - \rho m/S_K}$ where $\rho = \frac{1-b}{b}$, $m = \frac{c}{1-b}$, and S_K is the share of capital. See Nerlove, Marc, "Recent Empirical Studies of the CES and RElated Production Functions" in M. Brown, ed., The Theory and Empirical Analysis of Production, NBER, Studies in Income and Wealth, Vol. 31, New York, 1967, pp. 74-82. Also see Nadiri, M.Ishaq, "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey", Journal of Economic Literature, December 1970, pp. 1156-1157.

17. For a more complete discussion see Ferguson, C.E., The Neoclassical Theory of Production and Distribution, Cambridge University Press, Cambridge, England, 1969, pp. 235-239.

18. Minasian, Jora, "Elasticities of Substitution and Constant Output Demand Curves for Labor", Journal of Political Economy, June 1961, pp. 261-270.

CHAPTER III

THE DATA AND THE VARIABLES

In this chapter our main purpose is to define the variables and to describe the characteristics of the Contract Construction Industries in greater detail. We begin with a general description of the 1972 Census of Construction Industries (Census) and briefly compare the type of information which it provides to data from other sources. Next, in section 2 we define the variables which will be used in the study. We conclude, in section 3, with a description of how these variables differ between industries, regions, by size, and by degree of urbanization.

1. The 1972 Census of Construction Industries

The 1972 Census of Construction Industries is the second such census since the end of World War II. It is superior to the previous 1967 Census because it is the first census to contain data on the gross and net book value of capital assets. It also uses the new 1972 SIC industry definitions. The main advantage of these definitions over the previous 1967 SIC definitions is that the general contracting industries are now split up into a larger number of industries which correspond more closely to the type of construction which they perform. The Census also furnishes data on total construction receipts, value added, payrolls, employment, the number of establishments, equipment rental, and material and subcontracting payments. The Census is based upon information provided by all construction establishments with ten or more employees, and from a sample of smaller construction establishments with payroll. Other federal records were used to compile information on the very small "non-employer" establishments with no payroll. We have already briefly discussed in Chapter II how the 1972 SIC classification is based upon specialization within the sector. Table 3.1 lists the industries included in the Census and presents U.S. summary statistics for construction establishments with payroll.[1]

From Table 3.1 we see that in 1972 there were approximately 437,941 construction industry establishments with payroll compared with 368,771 such establishments in 1967. Approximately 30 percent of the establishments are general building contractors, 6 percent general heavy construction contractors, 61 percent special trade contractors, and 2 percent subdividers and developers.[2] Net construction amounted to over $11.2 billion, 30 percent of which went to general building contractors (including subdividers and developers), 23 percent to general heavy construction contractors, 47 percent to special trade contractors. Value added was nearly $68.2 billion and total payroll slightly over $40 billion. The census reported a total average employment of over 4.1 million workers. Special trade contractors employed the most workers (nearly 51 percent), followed by general building contractors (28 percent), general heavy construction contractors (20 percent) and subdividers and developers (1.5 percent).

The year 1972 had a boom in residential construction with approximately 1.3 million single family and 1 million multiple unit

TABLE 3.1

U.S. SUMMARY STATISTICS FOR THE
CONTRACT CONSTRUCTION INDUSTRIES, 1972

1972 SIC code	Industry group and industry	1972							
		Total number of establishments	Number of employees		Payroll		Receipts during year		Net construction receipts
			All employees (average)	Construction workers (average)	Total payroll	Construction workers	Total receipts	Total construction receipts	(G-J)
		A	B	C	D	E	F	G	H
	CONSTRUCTION INDUSTRIES AND SUBDIVIDERS AND DEVELOPERS, TOTAL	437 941	4 145 779	3 486 592	40 004 782	32 187 130	155 849 652	149 429 496	111 232 179
15,16, 17	CONSTRUCTION INDUSTRIES, TOTAL	430 027	4 083 465	3 464 203	39 528 036	32 035 697	152 721 579	148 110 817	110 715 923
15	GENERAL BUILDING CONTRACTORS AND OPERATIVE BUILDERS	133 054	1 149 520	937 771	10 159 240	7 739 797	64 349 923	61 865 294	33 245 313
1521 1531	GENERAL CONTRACTORS--SINGLE-FAMILY HOUSES OPERATIVE BUILDERS	[1] 90 207	469 152	365 778	3 460 727	2 464 262	25 122 681	23 161 742	14 264 267
1522	GENERAL CONTRACTORS--RESIDENTIAL BUILDINGS, OTHER THAN SINGLE-FAMILY	7 651	112 215	94 627	977 707	771 876	6 525 533	6 407 131	3 033 312
154	GENERAL CONTRACTORS--NONRESIDENTIAL BUILDINGS:								
1541	INDUSTRIAL BUILDINGS AND WAREHOUSES	9 538	173 094	144 625	1 729 634	1 356 140	8 666 746	8 507 370	4 805 838
1542	NONRESIDENTIAL BUILDINGS, N.E.C	25 658	395 059	332 741	3 991 172	3 147 519	24 034 963	23 789 051	11 141 896
16	HEAVY CONSTRUCTION GENERAL CONTRACTORS	27 991	827 346	709 306	9 255 253	7 537 355	31 460 896	30 514 009	25 357 103
1611	HIGHWAY AND STREET CONSTRUCTION	9 232	278 107	244 292	2 846 063	2 364 818	11 325 982	11 005 402	8 986 451
162	HEAVY CONSTRUCTION, EXCEPT HIGHWAY:								
1622	BRIDGE, TUNNEL, AND ELEVATED HIGHWAY CONSTRUCTION	1 294	53 710	47 366	589 670	498 749	2 282 232	2 233 369	1 780 057
1623	WATER, SEWER, AND UTILITY LINES	9 355	209 318	184 199	2 154 000	1 798 102	6 369 576	6 227 482	5 628 010
1629	HEAVY CONSTRUCTION, N.E.C	8 110	286 211	233 449	3 665 520	2 875 686	11 483 106	11 047 756	8 962 585
17	SPECIAL TRADE CONTRACTORS	268 982	2 106 599	1 817 126	20 113 543	16 758 545	56 910 760	55 731 514	52 113 507
1711	PLUMBING, HEATING, AND AIR CONDITIONING	53 301	456 100	371 113	4 787 958	3 809 878	15 615 468	15 321 135	13 594 125
1721	PAINTING, PAPER HANGING, AND DECORATING	29 011	136 575	125 807	1 080 729	961 201	2 405 714	2 382 301	2 290 258
1731	ELECTRICAL WORK	32 455	323 748	271 441	3 792 682	3 151 047	9 608 035	9 448 881	9 229 369
174	MASONRY, PLASTERING, AND TILE SETTING:								
1741	MASONRY, STONE SETTING, AND OTHER STONEWORK	23 896	165 580	156 395	1 310 777	1 199 012	3 104 947	3 085 759	2 978 087
1742	PLASTERING, DRYWALL, AND INSULATION WORK	13 415	170 364	151 825	1 684 875	1 445 728	4 195 295	4 084 687	3 839 335
1743	TERRAZZO, TILE, MARBLE, AND MOSAIC WORK	4 270	30 874	26 600	260 053	213 439	716 892	703 114	684 738
175	CARPENTERING AND FLOORING:								
1751	CARPENTERING	23 524	123 910	115 464	925 144	842 225	2 355 521	2 329 145	2 128 203
1752	FLOOR LAYING AND OTHER FLOORWORK	9 052	44 262	36 402	367 077	291 384	1 209 945	1 175 846	1 132 194
1761	ROOFING AND SHEET METAL WORK	18 535	158 051	134 189	1 405 756	1 137 273	3 999 967	3 940 243	3 752 108
1771	CONCRETE WORK	17 772	147 924	135 041	1 197 014	1 045 342	3 699 141	3 650 338	3 452 348
1781	WATER WELL DRILLING	4 159	17 136	14 598	125 147	101 967	556 965	534 171	523 128
179	MISCELLANEOUS SPECIAL TRADE CONTRACTORS:								
1791	STRUCTURAL STEEL ERECTION	2 760	58 137	49 983	637 949	534 094	1 496 417	1 457 836	1 385 610
1793	GLASS AND GLAZING WORK	2 459	20 023	14 175	190 447	133 487	657 352	593 658	584 642
1794	EXCAVATING AND FOUNDATION WORK	15 981	104 598	92 592	923 468	786 583	3 054 467	2 956 531	2 722 914
1795	WRECKING AND DEMOLITION WORK	1 027	9 067	7 544	80 173	64 081	236 678	219 412	202 581
1796	INSTALLING BUILDING EQUIPMENT, N.E.C	1 945	38 956	31 058	517 966	406 046	1 457 818	1 408 192	1 349 214
1799	SPECIAL TRADE CONTRACTORS, N.E.C	15 420	101 294	82 899	826 328	635 758	2 540 138	2 440 265	2 264 658
6552	SUBDIVIDERS AND DEVELOPERS, N.E.C	7 914	62 314	22 389	476 746	151 433	3 128 073	1 318 679	516 256

Note: Some of the 1972 industry definitions are different from those used in 1967. Where applicable, the 1967 data shown in this table were developed by retabulating the original information to approximate the new definitions.

[1]Combined because of misclassification problems within these two industries. See Industry Series Report C72-1-2, "General Contractors, Single-Family Houses and Operative Builders (SIC 1521/1531)."

TABLE 3.1 (Continued

1972–Continued							1967			
Selected payments		Value added	Total capital expenditures other than land	Depreciable assets		Rental payments for machinery and equipment	All employees	Total construction receipts	Value added	1972 SIC code
Materials, components, and supplies	Construction work subcontracted to others	(F-I-J)		Gross book value at end of year	Net value at end of year		(average)			
I	J	K	L	M	N	O	P	Q	R	
46 426 441	38 197 317	68 197 327	3 871 388	23 238 226	12 054 282	1 972 054	3 436 265	92 588 002	42 322 697	
46 084 702	37 394 894	67 809 926	3 653 222	22 331 682	11 405 576	1 945 271	3 413 757	92 113 437	42 165 324	15,16 17
16 414 029	28 619 981	17 883 856	895 325	4 998 988	3 149 327	339 619	938 043	36 925 654	10 891 353	15
7 723 579	8 897 475	[3]7 069 570	511 579	2 419 962	1 711 637	60 536	306 385	12 025 240	[3]3 910 677	1521 1531
1 589 863	3 373 819	1 561 851	63 220	400 441	270 036	40 597	61 442	2 708 839	686 370	1522
										154
2 213 309	3 701 532	2 751 905	97 248	699 057	386 673	92 513	184 960	6 700 474	2 120 302	1541
4 887 278	12 647 155	6 500 530	223 278	1 479 528	780 981	165 973	385 256	15 491 101	4 174 004	1542
10 103 694	5 156 906	16 200 296	1 429 874	9 399 199	3 995 227	1 091 666	792 926	21 562 953	11 439 684	16
3 468 714	2 018 951	5 838 317	688 463	4 649 351	1 822 418	523 288	255 777	7 711 858	3 929 002	1611
										162
858 892	453 312	970 028	81 002	568 005	223 723	57 868	56 718	1 606 558	747 446	1622
1 900 404	599 472	3 869 700	351 136	2 028 677	941 274	260 159	187 484	4 229 522	2 604 465	1623
3 875 684	2 085 171	5 522 251	309 273	2 153 166	1 007 812	250 351	292 945	8 015 015	4 158 771	1629
19 566 979	3 618 007	33 725 774	1 328 023	7 933 495	4 261 022	513 986	1 682 767	33 624 701	19 834 248	17
6 093 928	1 727 010	7 794 530	222 285	1 498 811	807 105	59 520	369 131	9 932 963	4 758 236	1711
474 514	92 043	1 839 157	35 810	254 102	151 049	12 917	139 196	1 766 017	1 363 309	1721
3 591 892	219 512	5 796 631	126 739	860 171	455 230	38 028	264 960	5 891 241	3 449 512	1731
										174
940 345	107 677	2 056 925	66 275	357 335	209 340	24 705	144 935	1 953 216	1 308 714	1741
1 365 138	245 352	2 584 805	56 848	410 874	248 221	19 513	116 753	2 028 651	1 254 132	1742
279 118	18 376	419 398	8 823	70 409	36 544	1 419	32 167	555 714	324 769	1743
										175
649 595	200 942	1 504 984	34 391	170 392	104 354	11 232	82 354	1 207 693	796 928	1751
516 918	43 652	649 375	14 441	90 013	51 099	1 735	38 459	762 005	433 246	1752
1 463 849	188 135	2 347 983	68 317	488 912	258 326	14 164	133 147	2 384 266	1 414 565	1761
1 359 862	197 990	2 141 289	132 804	707 394	363 977	63 501	114 879	2 126 761	1 243 873	1771
220 075	11 043	325 847	47 238	261 987	138 313	4 042	14 196	318 690	190 033	1781
										179
411 301	72 226	1 012 890	45 797	273 928	143 352	34 134	[4]41 515	[4]731 914	[4]551 110	1791
307 561	9 016	340 775	9 508	68 591	39 255	1 172	12 280	274 191	161 672	1793
632 601	233 617	2 188 249	359 344	1 814 402	936 612	173 188	77 920	1 652 031	1 218 909	1794
24 489	16 831	195 358	17 409	88 842	45 332	18 858	10 218	161 457	144 711	1795
420 621	58 978	978 219	17 638	140 443	64 290	11 883	25 176	644 758	434 642	1796
815 172	175 607	1 549 359	64 356	376 889	208 623	23 975	65 481	1 233 133	785 867	1799
341 739	802 423	[2]387 401	218 166	906 544	648 706	26 783	22 508	474 565	157 373	6552

[2]"Value added" equals "total receipts" less "land receipts" less "total selected payments." "Land receipts" for SIC 1521 and SIC 1531 combined were $1,432,057(000) and for SIC 6552 were $1,596,510(000).

[3]Not comparable to the SIC 1521 and SIC 1531 industry report because land receipts were not taken into consideration when calculating value added for each state. In 1967 land receipts amounted to $620,935(000).

[4]Identifying code number, 1971, for this industry is the same for 1972 as 1967, but the data are not exactly comparable. Special trade contractors primarily engaged in nonbuilding construction and classified in major group 16 in 1967 are now included in the appropriate industry in major group 17.

housing starts. But most categories of non-residential construction declined in real terms from 1971.[3] We may also see a changing composition of demand in Table 3.2 which compares the distribution of total construction receipts by type of construction for both 1967 and 1972.

Table 3.2. Distribution of Total Construction Receipts by Type of Construction, 1967 and 1972[1]

Type of Construction	Percentage of Total Construction Receipts 1967	1972
Residential building	27.5	33.1
Non-residential building	41.4	38.8
Heavy Construction	25.9	24.5
Not Classified	5.2	3.7

[1]Source: Same as Table 3.1. 1967 data uses 1972 SIC classification.

The 1972 Census is particularly useful as a source of information about the construction sector because it provides the first complete set of disaggregated output and input data. Prior construction statistics on output are not comparable with input statistics. The Bureau of the Census collects and reports statistics on construction activity, but this measure -- value of construction put in place -- includes forced account construction, which is performed by owners who hire their own labor rather than hire firms classified in the contract construction industries. Employment information collected by the Bureau of Labor Statistics measures employment in contract construction only. When output is disaggregated it is classified by type of construction (residential, commercial, highways, etc.) or by type of ownership (private residential, private nonresidential, public). Employment information is disaggregated by skill or trade (carpenters, electricians, masons, etc.). Information on capital assets (for construction corporations only) are available from the Internal Renevue Service, which also measures output as business receipts in contract construction.[4] Separate output and employment data are also published by the Bureau of the Census in County Business Patterns, based primarily upon Social Security Administration information.

These statistical problems have hindered economic analysis of production in the construction sector. The only previous study of U.S. construction using the production function approach is a time series study by Cassimates.[5] It is an aggregate study. Due to the data limitations Cassimates was only able to estimate production functions for the contract construction as a whole. Time series data are strongly influenced by cyclical phenomenona.[6] Construction activity is strongly cyclical. Until recently private residential construction has generally been countercyclical, rising during recessions and falling during booms. Private nonresidential construction generally moves with the business cycle. Although these two types of cycle tend to cancel out the composition of construction output is constantly changing. This changing composition of output as well as the changing physical characteristics of the various types of construction over time have hindered the development of appropriate price indexes to deflate the aggregate construction output, although some progress has been made in this area by Gordon.[7] Thus the information provided by the Census is particularly useful since it lessens some of these statistical problems and allows production function analysis at a disaggregate level. Of course, numerous statistical problems associated with using the Census remain.

2. The Variables

The basic variables in this study are defined on a per establishment basis for the 4 digit industries listed in Table 3.1. Observations are by state, but for many industries data is not available for each state. Two 4 digit industries were excluded from the study: Industry 1799, Special Trade Contractors, not elsewhere classified, was excluded since it is a miscellaneous "catch all", Industry 6552, Subdividers and Developers was excluded after obtaining poor results in preliminary calculations. One problem was the relatively small number of observations in this industry. More serious however, was the manner in which the census obtained value added. Value added was obtained by subtracting land receipts as well as materials and subcontracting payments from total receipts. However after this subtraction, value added is smaller than total payroll! One possible explanation for this result is that establishments in this industry inflated land receipts which qualify as capital gains. In addition, data for Industry 1521, General Contractors for Single Family Housing and Industry 1531, Operative Builders are combined. During its review of the final industry reports, the Census Bureau discovered that approximately 30% of the establishments classified in industry 1521 should have been classified as Operative Builders, but no reclassification was made. Both industries predominantly build single family houses including rowhouses and townhouses. Operative Builders are classified separately since they engage in construction for sale on their own account rather than as contractors. Speculative builders and condominium developers are also included in this industry.

The variables and derived variables which we will use are:

N = Total number of establishments. The Census defines construction establishment as "a relatively permanent office or other place of business at which ... usual business activities related to construction are conducted". State observations are divided by N to give a per establishment average.

LT = Average number of all employees. This is the average number of all paid employees (permanent and temporary, full-time and part-time) on the establishment payroll on the 12th of March, May, August, and November. Excluded are all salaried officers and executives of corporations, and if unincorporated the proprietors or partners.

LC = Average number of construction workers. This is the average of all paid construction workers including supervisors through working foremen on the establishment payroll on the 12th of March, May, August, and November.

LA = Average number of non-construction workers. Defined as LT - LC.

L = Adjusted Labor input. This is defined as the total payroll divided by the construction worker payroll times LC. This adjustment converts non-construction workers into construction worker equivalents in order to partially allow for quality differences due to differences in the mix of construction/non-construction workers between states.[8]

PW = Total payroll.

WC = Average construction worker wage. The ratio of the total construction worker payroll to LC.

WA = Average non-construction worker wage. Defined as the ratio of the difference between the total payroll and the total construction worker payroll to LA.

Q = Total establishment receipts. Includes receipts from non-construction activities such as land sales, rental of equipment, engineering and architecturer's fees.

C = Total construction receipts. Includes receipts from new construction and from maintenance and repair. Also includes receipts from the sale of buildings less the value of land.

M = Materials payments. Payments for the purchase of all materials, components, supplies, and fuel by the establishment.

S = Subcontracting payments. Payments for construction work subcontracted to other establishments. This includes payment for all materials, supplies, and components used by the subcontractor.

V = Value added. Defined as (Q - M - S).

Y = Gross output. Defined as (V + M).

GK = Gross book value of capital assets (at acquisition cost).

NK = Net book value of capital assets. Defined as GK less accumulated depreciation.

FK = Capital services. A proxy derived by assuming a 15% rate of depreciation on GK and a 6% rate of return to GK. Thus capital services from owned capital is 21% times GK. Rental payments for equipment and machinery is added to this amount to obtain FK.

R = The ratio of net to gross value of capital stock. A proxy for capital "vintage".

E,C,S,W = Regional dummy variables where E is the Northeastern, C the North Central, S the Southern, and W the Western Census regions.[9]

U = Degree of urbanization. This is the proportion of the state population living in Standard Metropolitan Statistical Areas (SMSA) according to the 1970 Census of Population. For those states with no SMSA (Vermont, Wyoming, Alaska) U was set to .01. For the District of Columbia U as assigned the value 1.

3. Detailed Characteristics of the Construction Industries

In this section we describe in greater detail some of the important characteristics of the 4 digit construction industries. We find that specific characteristics such as size, or the relative importance of the different inputs vary a great deal both between industries and in the same industry for different geographic regions.

a. Local Nature of Construction

One characteristic which was stressed in Chapter II was the local nature of construction. In 1972 only 12.7 percent of the total construction receipts for all of construction were received for work performed by establishments outside their home state, and much of that in border areas. A more detailed breakdown, by 4 digit industry, is listed in Table 3.3. The percentage of receipts obtained outside of the home state for the special trade contractors and single family contractors is much less than for other general building/heavy construction contractors. Receipts from outside the home state are higher for heavy contractors, and to a lesser extent the general building contractors (other than single family residences) due primarily to the size and complexity of the work being performed. The market for suppliers of the larger, more complex projects which require special skills (such as dams, utility plants, refineries, hospitals, etc.) may often encompass more than one state and for some types of construction (i.e. nuclear power plants) may be very large.

b. Size of establishment

One way to measure size of firm is to look at total receipts, while another is to look at the number of employees per establishment. Although we have already noted in Chapter II that the size of the majority of the firms in construction is small, there is a wide diversity in size for each industry. Small firms are more numerous but larger firms account for the majority of total receipts. According to the 1972 Census there were 920,806 establishments in 1972, but the majority (482,865) were "non-employers" with no pay-

TABLE 3.3

CONSTRUCTION ACTIVITY OUTSIDE OF HOME STATE

	Percent of construction receipts earned outside home state
1521/1531 Single Family Houses/Operative Builders	4.0
1522 Other Residential Buildings	12.6
1541 Industrial Buildings	17.1
1542 Other Non-residential Buildings	13.4
1611 Highways and Streets	12.0
1622 Bridge/Tunnel/Elevated Highway	24.4
1623 Water/Sewer/ Utility Lines	15.9
1629 Other Heavy Construction	52.9
1711 Plumbing/Heating/ Air Conditioning	6.1
1721 Painting/Pater Hanging	7.2
1731 Electrical Work	6.8
1741 Masonry/Stonework	6.6
1742 Plastering/Drywall/Insulation	8.9
1743 Tile/Marble/Mosaic Work	6.8
1751 Carpentering	4.1
1752 Floorwork	5.2
1761 Roofing/Sheet Metal	7.4
1771 Concrete Work	5.1
1781 Water Well Drilling	5.9
1791 Structural Steel[2]	18.7
1973 Glass & Glazing	4.6
1794 Excavation/ Foundations	5.1
1795 Wrecking/ Demolition	8.7
1796 Equipment Installation	11.6

[1]In dollars; [2]Based upon preliminary Census Report.

roll. They accounted for only 5 percent of total receipts. Although less than 2 percent of the establishments reported receipts over $2,500,000 in 1972 they accounted for 44 percent of receipts of all construction establishments. Various measures of establishment size by 4 digit industry are presented in Table 3.4, primarily using the number of employees and total construction receipts as proxies. Table 3.4 also presents the average construction wage for each industry. Not unexpectedly, we find that the heavy contractors are largest using either size measure. General building contractors, except single family residence contractors, are next while the special trade contractors (with a few exceptions) are smallest. Construction wages roughly follow the same pattern, being relatively high for heavy contractors and somewhat lower for general building contractors. Wages for workers employed by the single family residence contractors are especially low. This probably reflects both lower skill requirements and a smaller amount of unionization in this industry. There is a wide range in the construction wage for the special trade contractors with the lesser skilled trades such as carpenters or painters at the low end, and the more highly skilled trade such as equipment installers or electricians at the high end.

In comparing size neither number of employees nor total construction receipts per establishment are perfect measures. This is especially true for employment by the general building contractors. A particularly high proportion of their total construction receipts is paid out to subcontractors, thus lowering their average number of employees.

TABLE 3.4

SIZE CHARACTERISTICS BY INDUSTRY, INCLUDING AVERAGE NUMBER OF WORKERS, TOTAL CONSTRUCTION RECEIPTS, AND CONSTRUCTION WAGE PER ESTABLISHMENT

	Percent of establishments with 10 or more employees	Percent of Industry receipts for establishments with 10 or more employees	LT	C^1	W_{C1}
1521/1531 Single Family Houses/Operative Builders	11	54	5.201	256,762	6,737
1522 Other Residential Buildings	31	85	14.667	837,424	8,157
1541 Industrial Buildings	37	87	18.148	891,945	9,377
1542 Other Non-residential Buildings	30	89	15.397	927,159	9,459
1611 Highways and Streets	46	95	30.124	1,192,093	9,680
1622 Bridge/Tunnel/Elevated Highway	55	96	41.507	1,725,942	10,530
1623 Water/Sewer/Utility Lines	42	91	22.375	665,684	9,762
1629 Other Heavy Construction	27	96	35.291	1,362,239	12,318
1711 Plumbing/Heating/Air Conditioning	21	75	8.557	287,446	10,266
1721 Painting/Pater Hanging	10	54	4.708	82,117	7,640
1731 Electrical Work	23	78	9.975	291,138	11,609
1741 Masonry/Stonework	16	66	6.929	129,133	7,667

TABLE 3.4 (continued)

1742 Plastering/Drywall/Insulation	30	82	12.700	304,487	9,522
1743 Tile/Marble/Mosaic Work	19	65	7.230	164,664	8,024
1751 Carpentering	11	56	5.267	99,011	7,294
1752 Floorwork	13	59	4.890	129,899	8,005
1761 Roofing/Sheet Metal	23	73	8.527	212,584	8,475
1771 Concrete Work	20	70	8.323	205,398	7,741
1781 Water Well Drilling	9	42	4.120	128,437	6,985
1791 Structural Steel[2]	48	91	19.872	490,877	10,748
1973 Glass & Glazing	26	66	8.143	241,423	9,417
1794 Excavation/ Foundations	16	65	6.545	185,002	8,495
1795 Wrecking/ Demolition	27	72	8.829	213,643	8,494
1796 Equipment Installation	41	90	20.029	724,006	13,074

[1]In dollars; [2]Based upon preliminary Census Report.

When we compare both size measures by census region in Table 3.5, we also find that the two measures do not always agree. For example, the South has the highest number of employees per establishment in 11 of 24 industries and the lowest number in only 3 industries. When we look at total construction receipts per establishment, receipts are highest in only 2 industries (1611, General highway contractors and 1522 General Building contractors of multiresidential buildings) but lowest in 12. Although there are a number of factors which probably contribute to this difference, a major reason for the large number of workers in the South is due to the low wage for construction workers. In all 24 industries the construction wage (WC) is lowest in the South. Table 3.5 also separates the number of workers (LT) into construction (LC) and non-construction worker (LA) and additionally presents the non-construction worker wage (WA). Although WA is also lowest in the South for 20 of 24 industries LA is high in only 2 (1522, 1611) but low in 14 industries. The other regions do not display the divergence in employment between LA and LC. For the South at least LA appears to be more consistent with construction receipts as a measure of size than LC. Quite a few industries are large in the East by either measure (LT is largest in 11 industries while total construction receipts is largest in 12 industries).

c. Diversity of Operations

One particularly striking feature is the wide variance in these size statistics between regions. For example in Table 3.5 we see that bridge, tunnel, and elevated highway contractors (industry 1622) in the East employ nearly three times as many employees as they do in the West. We can attribute this difference in employment to a number

TABLE 3.5
NUMBER OF WORKERS, CONSTRUCTION WORKERS, AND NONCONSTRUCTION WORKERS, WAGES, AND TOTAL CONSTRUCTION RECEIPTS BY INDUSTRY AND CENSUS REGION

EAST

	LT	LC	LA	W_A[1]	W_C[1]	C[1]
1521/1531 Single Family Houses/Operative Builders	4.176	3.100	1.076	7,480	7,236	189,408
1522 Other Residential Buildings	11.159	9.237	1.922	13,090	9,382	784,420
1541 Industrial Buildings	13.658	11.012	2.646	13,782	10,098	749,093
1542 Other Non-residential Buildings	15.446	12.855	2.591	14,712	11,098	1,012,258
1611 Highways and Streets	22.916	19.889	3.027	14,146	11,304	908,881
1622 Bridge/Tunnel/Elevated Highway	73.801	66.350	7.451	15,552	9,993	3,283,650
1623 Water/Sewer/Utility Lines	29.271	25.991	3.280	16,543	11,021	891,130
1629 Other Heavy Construction	55.343	42.551	12.792	14,801	14,052	2,007,046
1711 Plumbing/Heating/Air Conditioning	8.157	6.566	1.591	12,023	11,283	291,566
1721 Painting/Pater Hanging	4.279	3.922	.357	11,477	7,635	74,487
1731 Electrical Work	9.964	8.352	1.612	13,352	13,037	313,160
1741 Masonry/Stonework	7.655	7.111	.544	12,803	8,819	164,245
1742 Plastering/Drywall/Insulation	14.943	13.131	1.812	14,543	10,956	391,304
1743 Tile/Marble/Mosaic Work	8.941	7.602	1.339	15,015	9,092	209,185
1751 Carpentering	4.544	4.159	.385	10,229	7,825	96,306
1752 Floorwork	4.805	3.991	.814	9,345	8,602	131,537
1761 Roofing/Sheet Metal	7.638	6.391	1.247	11,387	9,668	199,104
1771 Concrete Work	8.369	7.603	.766	12,743	9,264	225,735
1781 Water Well Drilling	4.494	3.775	.719	10,821	8,991	149,833
1791 Structural Steel[2]	22.175	19.000	3.175	14,128	11,875	688,279
1973 Glass & Glazing	8.733	6.313	2.421	10,074	9,848	261,822
1794 Excavation/Foundations	6.956	6.045	.910	11,575	9,584	205,686
1795 Wrecking/Demolition	10.237	8.535	1.702	11,598	10,043	253,282
1796 Equipment Installation	25.752	19.838	5.914	14,192	13,861	930,934

[1]In dollars; [2]Based upon preliminary Census Report.

TABLE 3.5 (Continued)

NORTH CENTRAL	LT	LC	LA	W_A	W_C	C
1521/1531 Single Family Houses/Operative Builders	4.470	3.474	.996	10,264	7,434	239,574
1522 Other Residential Buildings	12.283	9.815	2.468	12,185	10,107	808,131
1541 Industrial Buildings	17.666	14.182	3.484	14,097	10,984	979,580
1542 Other Non-residential Buildings	14.057	11,583	2.474	13,892	10,262	858,440
1611 Highways and Streets	28.826	24.949	3.877	15,279	11,306	1,240,557
1622 Bridge/Tunnel/Elevated Highway	32.025	27,578	4.447	15,103	11,650	1,354,088
1623 Water/Sewer/ Utility Lines	18.983	16.683	2.300	15,056	11,587	648,770
1629 Other Heavy Construction	24.011	20.484	3.527	15,105	13,005	906,655
1711 Plumbing/Heating/ Air Conditioning	8.215	6.532	1.683	11,477	11,891	293,361
1721 Painting/Pater Hanging	4.437	4.050	.387	11,657	8,801	83,140
1731 Electrical Work	9.800	8.071	1.729	12,591	12,979	299,778
1741 Masonry/Stonework	6.745	6.301	.444	12,324	9,017	148,085
1742 Plastering/Drywall/Insulation	11.028	9.727	1.301	13,603	10,504	280,216
1743 Tile/Marble/Mosaic Work	7.537	6.201	1.336	12,160	9,657	186,922
1751 Carpentering	5.490	5.071	.419	10,821	9,083	120,283
1752 Floorwork	4.778	3.825	.953	10,250	8,985	128,736
1761 Roofing/Sheet Metal	8.670	7.271	1.399	12,334	9,776	233,938
1771 Concrete Work	6.804	6.144	.660	12,028	8,576	184,679
1781 Water Well Drilling	3.962	3.353	.601	10,281	7,411	133,069
1791 Structural Steel[2]	18.506	16.052	2.454	11,488	11,620	415,325
1973 Glass & Glazing	8.093	5.459	2.634	10,391	9,919	227,619
1794 Excavation/ Foundations	5.738	5.061	.677	12,230	9,126	163,975
1795 Wrecking/ Demolition	8.109	6.578	1.531	10,527	8,203	214,404
1796 Equipment Installation	17.854	14.449	3.405	13,974	13,757	669,121

[1]In dollars; [2]Based upon preliminary Census Report.

TABLE 3.5 (Continued)

SOUTH	LT	LC	LA	W_A	WC	C
1521/1531 Single Family Houses/Operative Builders	6.058	4.762	1.296	8,929	5,653	259,568
1522 Other Residential Buildings	20.075	17.388	2.687	10,904	6,654	977,482
1541 Industrial Buildings	24.677	21.569	3.108	11,465	7,797	966,267
1542 Other Non-residential Buildings	17.630	15.191	2.439	12,404	7,618	910,867
1611 Highways and Streets	37.416	33.415	4.001	13,041	7,029	1,300,660
1622 Bridge/Tunnel/Elevated Highway	43.663	38.328	5.335	12,710	7,959	1,583,878
1623 Water/Sewer/Utility Lines	24.554	22.022	2.532	12,236	7,447	596,765
1629 Other Heavy Construction	31.601	26.972	4.629	14,685	10,328	1,135,979
1711 Plumbing/Heating/Air Conditioning	9.006	7.529	1.477	11,122	8,014	266,577
1721 Painting/Pater Hanging	5.234	4.902	.332	10,556	6.255	77,738
1731 Electrical Work	10.447	8.974	1.473	11,376	9,130	257,023
1741 Masonry/Stonework	6.688	6.429	.259	11,724	5,975	89,624
1742 Plastering/Drywall/Insulation	12.170	10.892	1.278	11,677	7,774	250,800
1743 Tile/Marble/Mosaic Work	6.729	5.960	.769	9,611	6,516	135,737
1751 Carpentering	4.857	4.599	.258	7,791	5,347	68,494
1752 Floorwork	4.664	3.911	.753	8,536	6,288	109,048
1761 Roofing/Sheet Metal	9.247	8.061	1.186	10,297	6,514	187,263
1771 Concrete Work	9.763	9.036	.727	10,528	5,737	192,166
1781 Water Well Drilling	4.113	3.560	.553	7,884	5,809	121,887
1791 Structural Steel[2]	18.830	16.414	2.416	12,167	9,032	347,614
1973 Glass & Glazing	8.494	6.274	2.220	9,406	8,223	241,320
1794 Excavation/Foundations	7.363	6.617	.746	10,087	6,537	179,885
1795 Wrecking/Demolition	8.025	6.895	1.130	8,268	5,803	145,343
1796 Equipment Installation	16.288	13.479	2.809	12,757	11,259	533,617

[1]In dollars; [2]Based upon preliminary Census Report.

TABLE 3.5 (Continued)

1521/1531 WEST	LT	LC	LA	WA	WC	C
Single Family Houses/Operative Builders	5.720	4.322	1.398	10,697	8,005	361,952
1522 Other Residential Buildings	12.444	10.496	1.948	11,437	9,026	715,223
1541 Industrial Buildings	11.842	9.467	2.375	14,135	10,625	786,788
1542 Other Non-residential Buildings	13.475	11.330	2.145	13,399	10,166	947,381
1611 Highways and Streets	27.680	24.181	3,499	14,955	11,955	1,251,112
1622 Bridge/Tunnel/Elevated Highway	25.605	22.817	2.788	15,471	12,926	1,270,384
1623 Water/Sewer/ Utility Lines	16.691	13.724	2.967	14,156	11,893	624,799
1629 Other Heavy Construction	43.798	33.789	10.009	15,383	13,559	2,019,871
1711 Plumbing/Heating/ Air Conditioning	8.812	7.107	1.705	11,526	11,411	316,656
1721 Painting/Pater Hanging	4.775	4.347	.428	11,176	9,107	101,602
1731 Electrical Work	9.377	7.676	1.701	11,755	12,694	310,150
1741 Masonry/Stonework	6.862	6.446	.416	11,323	8,564	164,732
1742 Plastering/Drywall/Insulation	13.652	12.345	1.307	12,296	10,002	351,100
1743 Tile/Marble/Mosaic Work	6.715	5.683	1.032	11,779	9,435	181,480
1751 Carpentering	7.561	7.065	.496	10,667	7,971	155,343
1752 Floorwork	5.490	4.471	1.019	10,553	8,962	164,505
1761 Roofing/Sheet Metal	8.442	7.068	1.374	14,936	8,791	251,970
1771 Concrete Work	8.652	7.870	.782	12,028	8,373	235,406
1781 Water Well Drilling	4.077	3.428	.649	8,236	7,107	116,197
1791 Structural Steel[2]	21.012	16.975	4.037	12,497	11,275	636,400
1973 Glass & Glazing	7.167	4.867	2.300	9,373	10,209	232,995
1794 Excavation/ Foundations	6.148	5.490	.658	11,878	9,391	202,609
1795 Wrecking/ Demolition	7.879	6.468	1.411	10,475	8,543	221,915
1796 Equipment Installation	23.078	18.055	5.023	16,352	13,371	910,784

[1]In dollars; [2]Based upon preliminary Census Report.

of factors. The demand for bridges, tunnels, and elevated highways is apparently larger in the East. Total construction receipts are over twice as large in the East as in the West. There is also a diversity of operation between the two regions. We can illustrate this in table 3.6.

Table 3.6. Factor Payments as a Share of Total Construction Receipts for Industry 1622

Region	V/C	PW/C	M/C	FK/C	S/C
East	.441	.277	.402	.051	.176
West	.523	.266	.272	.077	.257

We see that payrolls as a share of total construction receipts are nearly the same in the two regions. This helps to explain the difference in employment given the difference in total construction receipts between the two regions, although another factor is probably the higher construction wage in the West. There are a number of other differences between the two regions. More work is subcontracted in the West while materials payments are larger in the East. We may also illustrate these differences by looking at input ratios in table 3.7.

Table 3.7 Input Ratios for Industry 1622

Region	FK/LT	M/LT	M/FK	S/LT	S/M	S/FK
East	2.281	17.873	7.836	7.847	.439	3.440
West	3.823	13.475	3.524	12.745	.946	3.333

The West is more capital intensive relative to labor and materials while the East is more material intensive relative to labor, capital, and subcontracting.

We have illustrated differences in operation in one industry between regions. We will examine the reason for such regional differences later. There are even larger differences between our individual 4 digit industries.

Some rely heavily on subcontracting while for others capital is important. Table 3.8 gives us some idea of this diversity by showing value added, payroll capital services, materials, and subcontracting payments (as the share of total construction receipts). There is particularly wide range in the ratio of value added to total construction receipts with the smallest being for general building contractors and the largest for the special trade contractors. This difference is primarily due to subcontracting. The subcontracting share is around 40-50 percent for general building contractors while the material payments share is another 20-30 percent. The payroll share is particularly small, generally less than 20 percent. This pattern is reversed for heavy contractors where both the material and payroll share exceed subcontracting. The payroll share is generally high and the subcontracting share low for the special trade contractors. The share of capital services is especially low -- less than 3 percent for most industries -- but is important for heavy contractors and certain special trade contractors (Concrete Work, Water Well Drilling, Structural Steel Erection, Excavating and Foundation Work, and Wrecking and Demolition).

These differences between the general building and the heavy construction contractors, and between types of subcontractor stem in part from the construction process associated with each type of construction. For the heavy contractors and those special trade contractors

TABLE 3.8
VALUE ADDED, PAYROLL, MATERIALS, CAPITAL, AND SUBCONTRACTING PAYMENTS AS A SHARE OF TOTAL CONSTRUCTION RECEIPTS, BY INDUSTRY

	V/C	PW/C	M/C	FK/C	S/C
1521/1531 Single Family Houses/Operative Builders	.305	.149	.333	.025	.384
1522 Other Residential Buildings	.244	.153	.248	.020	.527
1541 Industrial Buildings	.324	.203	.260	.026	.435
1542 Other Non-residential Buildings	.273	.168	.205	.020	.532
1611 Highways and Streets	.530	.259	.315	.136	.183
1622 Bridge/Tunnel/Elevated Highway	.434	.264	.385	.079	.203
1623 Water/Sewer/Utility Lines	.621	.346	.305	.110	.096
1629 Other Heavy Construction	.500	.332	.351	.064	.189
1711 Plumbing/Heating/Air Conditioning	.509	.313	.398	.024	.113
1721 Painting/Pater Hanging	.772	.454	.199	.028	.039
1731 Electrical Work	.613	.401	.380	.023	.023
1741 Masonry/Stonework	.667	.425	.305	.032	.035
1742 Plastering/Drywall/Insulation	.633	.412	.334	.026	.060
1743 Tile/Marble/Mosaic Work	.596	.370	.397	.023	.026
1751 Carpentering	.646	.397	.279	.020	.086
1752 Floorwork	.552	.312	.440	.018	.037
1761 Roofing/Sheet Metal	.596	.357	.372	.030	.048
1771 Concrete Work	.587	.328	.373	.058	.054
1781 Water Well Drilling	.610	.234	.412	.111	.021
1791 Structural Steel[1]	.702	.446	.280	.062	.047
1973 Glass & Glazing	.574	.321	.518	.026	.015
1794 Excavation/Foundations	.740	.312	.214	.187	.079
1795 Wrecking/Demolition	.890	.365	.112	.171	.077
1796 Equipment Installation	.695	.368	.299	.029	.042

[1] Based upon preliminary Census Report.

in which capital is important, skilled workers operate expensive equipment to move earth or handle bulky material which is general is not highly fabricated. In many cases fuel costs are an important component of the total materials cost. In building construction highly skilled workers often work by hand, use small power tools, and deal with materials which are more highly fabrictaed. The larger diversity of skills in building construction account for the greater amount of subcontracting by general building contractors. Another factor is that skill requirements differ by types of construction. The Bureau of Labor Statistics (BLS) has estimated that about 60-70 percent of the total on site manhours in building construction is skilled, while about 40 percent of total on site manhours are skilled for heaving construction. Skill requirements for selected types of construction are given in table 3.9.[10]

Table 3.9 **Percent distribution of onsite man-hours for selected types of construction, by occupation, various years**

Occupation	Residential		Commercial		Federally aided highways, 1970	Heavy construction	
	Private single-family houses, 1969	Public housing, 1968	Elementary and secondary schools, 1964-65	Hospitals, 1965-66		Civil works, land projects, 1959-60	Sewer lines, 1962-63
All occupations	100	100	100	100	100	100	100
Supervisory, professional, technical, and clerical	3	4	4	3	6	10	10
Skilled trades[1]	69	64	64	70	47	41	27
Bricklayers	6	8	9	5	---	---	1
Carpenters	35	20	17	13	6	6	(2)
Electricians	3	6	7	10	1	---	2
Operating engineers	2	3	3	2	25	24	20
Plumbers	4	9	10	16	(2)	---	(2)
Semiskilled and unskilled workers[1]	28	32	32	26	47	49	63
Helpers and tenders	14	7	7	6	---	1	2
Laborers	14	23	24	19	34	22	43
Truckdrivers	1	2	1	1	11	14	4

[1] May include data for workers in occupations not shown separately.
[2] Less than 0.5 percent.

NOTE: Because of rounding, sums of individual items may not equal totals.

Regional differences in share payments are presented in Table 3.10. The subcontracting share is highest in the West, especially for the general building and heavy contractor industries where this share is highest in 7 of the 8 industries. The materials share is highest in the South and lowest in the East (both in 14 of the 24 industries). The payroll share is highest in the East and North Central regions and lowest in the South and West. Another way to look at this regional diversity is to examine input ratios for each census region, which we do in Table 3.11.

Perhaps the most striking feature of these statistics is something we have noticed before in our discussion on size. This is the high degree of labor intensity in the South. In comparison to the other regions in the South the capital/labor ratio is lowest in 17 industries, the material/labor ratio lowest in 12 industries, and the subcontracting/labor ratio lowest in 13 industries. In contrast the West is the least labor intensive. Compared to the other regions the capital/labor ratio is highest in 13 industries, the material labor ratio highest in 15 industries and the subcontracting/labor ratio highest in 14 industries. Other patterns which are apparent from the input ratios are that the South tends to be material intensive relative to subcontracting and capital and the West least material inten sive in comparison to the other regions.

Such diversity between industries and regions illustrates some of the complexity of the sector. On balance we may consider the differences in the various input ratios between regions to be good since this allows identification of the production function. But we have also learned that there are differences between regions

TABLE 3.10
VALUE ADDED, PAYROLL, MATERIALS, CAPITAL,
AND SUBCONTRACTING PAYMENTS AS A SHARE OF
TOTAL CONSTRUCTION RECEIPTS, BY INDUSTRY AND CENSUS REGION.

EAST	V/C	PW/C	M/C	FK/C	S/C
1521/1531 Single Family Houses/Operative Builders	.331	.168	.350	.029	.334
1522 Other Residential Buildings	.248	.143	.216	.019	.549
1541 Industrial Buildings	.350	.206	.204	.024	.463
1542 Other Non-residential Buildings	.290	.179	.180	.020	.538
1611 Highways and Streets	.568	.294	.309	.131	.160
1622 Bridge/Tunnel/Elevated Highway	.441	.277	.402	.051	.176
1623 Water/Sewer/ Utility Lines	.672	.382	.256	.100	.093
1629 Other Heavy Construction	.553	.392	.313	.047	.172
1711 Plumbing/Heating/ Air Conditioning	.523	.320	.351	.023	.143
1721 Painting/Pater Hanging	.794	.456	.183	.024	.034
1731 Electrical Work	.640	.416	.349	.018	.024
1741 Masonry/Stonework	.677	.424	.297	.030	.033
1742 Plastering/Drywall/Insulation	.664	.435	.309	.024	.062
1743 Tile/Marble/Mosaic Work	.632	.402	.361	.022	.024
1751 Carpentering	.650	.379	.253	.020	.104
1752 Floorwork	.578	.319	.407	.017	.037
1761 Roofing/Sheet Metal	.617	.382	.329	.027	.062
1771 Concrete Work	.621	.355	.345	.055	.043
1781 Water Well Drilling	.607	.278	.385	.131	.032
1791 Structural Steel[1]	.632	.393	.319	.057	.059
1973 Glass & Glazing	.595	.331	.480	.027	.013
1794 Excavation/ Foundations	.741	.333	.212	.180	.085
1795 Wrecking/ Demolition	.878	.415	.108	.174	.071
1796 Equipment Installation	.705	.295	.284	.033	.043

[1]Based upon preliminary Census Report.

TABLE 3.10 (Continued)

1521/1531 NORTH CENTRAL	V/C	PW/C	M/C	FK/C	S/C
Single Family Houses/Operative Builders	.288	.150	.365	.023	.371
1522 Other Residential Buildings	.236	.160	.225	.021	.559
1541 Industrial Buildings	.322	.209	.260	.026	.435
1542 Other Non-residential Buildings	.286	.178	.213	.020	.515
1611 Highways and Streets	.527	.275	.313	.143	.181
1622 Bridge/Tunnel/Elevated Highway	.438	.287	.404	.090	.176
1623 Water/Sewer/ Utility Lines	.613	.351	.310	.120	.089
1629 Other Heavy Construction	.558	.353	.291	.076	.174
1711 Plumbing/Heating/ Air Conditioning	.511	.331	.385	.025	.121
1721 Painting/Pater Hanging	.779	.483	.201	.027	.036
1731 Electrical Work	.632	.422	.370	.023	.020
1741 Masonry/Stonework	.650	.421	.304	.035	.027
1742 Plastering/Drywall/Insulation	.644	.428	.330	.019	.047
1743 Tile/Marble/Mosaic Work	.635	.407	.380	.021	.018
1751 Carpentering	.646	.421	.304	.018	.061
1752 Floorwork	.588	.343	.419	.019	.037
1761 Roofing/Sheet Metal	.614	.378	.357	.028	.049
1771 Concrete Work	.580	.328	.384	.054	.049
1781 Water Well Drilling	.622	.233	.405	.105	.017
1791 Structural Steel[1]	.779	.517	.197	.065	.052
1973 Glass & Glazing	.619	.358	.495	.029	.017
1794 Excavation/ Foundations	.744	.332	.228	.186	.058
1795 Wrecking/ Demolition	.933	.327	.089	.130	.055
1796 Equipment Installation	.754	.368	.241	.030	.049

[1]Based on Preliminary Census Report

TABLE 3.10 (Continued)

SOUTH	V/C	PW/C	M/C	FK/C	S/C
1521/1531 Single Family Houses/Operative Builders	.301	.148	.366	.025	.359
1522 Other Residential Buildings	.236	.148	.281	.016	.498
1541 Industrial Buildings	.326	.211	.305	.025	.384
1542 Other Non-residential Buildings	.258	.160	.236	.019	.515
1611 Highways and Streets	.488	.221	.349	.127	.188
1622 Bridge/Tunnel/Elevated Highway	.385	.235	.407	.089	.221
1623 Water/Sewer/ Utility Lines	.601	.327	.332	.105	.089
1629 Other Heavy Construction	.470	.305	.393	.074	.173
1711 Plumbing/Heating/ Air Conditioning	.477	.288	.447	.024	.096
1721 Painting/Pater Hanging	.751	.440	.213	.028	.043
1731 Electrical Work	.586	.404	.408	.026	.021
1741 Masonry/Stonework	.694	.462	.284	.032	.027
1742 Plastering/Drywall/Insulation	.608	.400	.368	.034	.056
1743 Tile/Marble/Mosaic Work	.564	.341	.415	.024	.034
1751 Carpentering	.651	.388	.254	.020	.106
1752 Floorwork	.508	.284	.469	.020	.045
1761 Roofing/Sheet Metal	.588	.346	.387	.030	.041
1771 Concrete Work	.570	.310	.382	.065	.065
1781 Water Well Drilling	.563	.205	.439	.097	.020
1791 Structural Steel[1]	.779	.511	.231	.079	.032
1973 Glass & Glazing	.530	.300	.558	.025	.013
1794 Excavation/ Foundations	.741	.282	.209	.191	.082
1795 Wrecking/ Demolition	.877	.340	.136	.120	.075
1796 Equipment Installation	.649	.352	.346	.023	.031

[1]Based on Preliminary Census Report.

TABLE 3.10 (Continued)

WEST	V/C	PW/C	M/C	FK/C	S/C
1521/1531 Single Family Houses/Operative Builders	.310	.137	.244	.022	.469
1522 Other Residential Buildings	.262	.164	.242	.024	.526
1541 Industrial Buildings	.289	.171	.220	.028	.523
1542 Other Non-residential Buildings	.260	.152	.180	.022	.571
1611 Highways and Streets	.578	.273	.265	.148	.197
1622 Bridge/Tunnel/Elevated Highway	.523	.266	.272	.077	.257
1623 Water/Sewer/Utility Lines	.607	.328	.309	.097	.123
1629 Other Heavy Construction	.456	.303	.366	.055	.233
1711 Plumbing/Heating/Air Conditioning	.543	.318	.396	.027	.085
1721 Painting/Pater Hanging	.768	.437	.197	.034	.041
1731 Electrical Work	.594	.378	.396	.026	.030
1741 Masonry/Stonework	.626	.364	.357	.031	.021
1742 Plastering/Drywall/Insulation	.624	.397	.321	.024	.074
1743 Tile/Marble/Mosaic Work	.591	.362	.414	.024	.021
1751 Carpentering	.635	.397	.307	.024	.076
1752 Floorwork	.547	.309	.454	.014	.033
1761 Roofing/Sheet Metal	.550	.306	.433	.035	.036
1771 Concrete Work	.577	.320	.377	.059	.060
1781 Water Well Drilling	.702	.256	.390	.132	.017
1791 Structural Steel[1]	.639	.380	.358	.050	.042
1973 Glass & Glazing	.566	.303	.528	.025	.019
1794 Excavation/Foundations	.732	.293	.202	.196	.098
1795 Wrecking/Demolition	.863	.316	.138	.164	.138
1796 Equipment Installation	.638	.355	.359	.030	.042

[1]Based on Preliminary Census Report.

TABLE 3.11

INPUT RATIOS BY INDUSTRY AND CENSUS REGION

1521/1531 EAST	FK/LT	M/LT	M/FK	S/LT	S/M	S/FK
Single Family Houses/Operative Builders	2.172	15.844	7.294	15.112	.954	6.957
1522 Other Residential Buildings	1.363	15.155	11.121	38.611	2.548	28.333
1541 Industrial Buildings	1.327	11.188	8.429	25.401	2.270	19.136
1542 Other Non-residential Buildings	1.278	11.807	9.237	35.283	2.988	27.603
1611 Highways and Streets	5.188	12.238	2.359	6.355	.519	1.225
1622 Bridge/Tunnel/Elevated Highway	2.281	17.873	7.836	7.847	.439	3.440
1623 Water/Sewer/Utility Lines	3.053	7.792	2.553	2.833	.364	.928
1629 Other Heavy Construction	1.697	11.358	6.691	6.228	.548	3.669
1711 Plumbing/Heating/Air Conditioning	.813	12.544	15.431	5.105	.407	6.280
1721 Painting/Paper Hanging	.410	3.182	7.758	.593	.186	1.446
1731 Electrical Work	.581	10.976	18.904	.754	.069	1.298
1741 Masonry/Stonework	.649	6.382	9.842	.712	.111	1.097
1742 Plastering/Drywall/Insulation	.617	8.079	13.086	1.635	.202	2.648
1743 Tile/Marble/Mosaic Work	.514	8.450	16.432	.563	.067	1.095
1751 Carpentering	.426	5.364	12.589	2.196	.409	5.154
1752 Floorwork	.460	11.146	24.234	1.016	.091	2.210
1761 Roofing/Sheet Metal	.692	8.571	12.385	1.627	.190	2.351
1771 Concrete Work	1.488	9.293	6.247	1.174	.126	.790
1781 Water Well Drilling	4.388	12.850	2.928	1.064	.083	.243
1791 Structural Steel[1]	1.760	9.896	5.624	1.832	.185	1.041
1973 Glass & Glazing	.820	14.389	17.548	.399	.028	.486
1794 Excavation/Foundations	5.314	6.266	1.179	2.500	.399	.471
1795 Wrecking/Demolition	4.325	2.688	.895	1.753	.652	.405
1796 Equipment Installation	1.195	10.281	8.606	1.578	.153	1.321

[1] **Based upon preliminary Census Report.**

TABLE 3.11 (Continued)

NORTH CENTRAL	FK/LT	M/LT	M/FK	S/LT	S/M	S/FK
1521/1531 Single Family Houses/Operative Builders	1.224	19.555	15.980	19.889	1.017	16.253
1522 Other Residential Buildings	1.374	14.792	10.763	36.774	2.486	26.759
1541 Industrial Buildings	1.458	14.414	9.887	24.125	1.674	16.547
1542 Other Non-residential Buildings	1.251	13.017	10.408	31.444	2.416	25.140
1611 Highways and Streets	6.144	13.490	2.196	7.784	.577	1.267
1622 Bridge/Tunnel/Elevated Highway	3.815	17.075	4.475	7.432	.435	1.948
1623 Water/Sewer/Utility Lines	4.115	10.608	2.578	3.051	.288	.741
1629 Other Heavy Construction	2.877	11.000	3.827	6.508	.597	2.283
1711 Plumbing/Heating/Air Conditioning	.880	13.753	15.630	4.325	.314	4.915
1721 Painting/Pater Hanging	.499	3.758	7.525	.678	.180	1.358
1731 Electrical Work	.707	11.314	16.002	.618	.055	.873
1741 Masonry/Stonework	.774	6.666	8.608	1.096	.164	1.415
1742 Plastering/Drywall/Insulation	.483	8.380	17.343	1.191	.142	2.466
1743 Tile/Marble/Mosaic Work	.518	9.423	18.201	.438	.046	.846
1751 Carpentering	.392	6.661	17.000	1.331	.200	3.397
1752 Floorwork	.510	11.278	11.278	.911	.081	1.781
1761 Roofing/Sheet Metal	.763	9.626	12.613	1.315	.137	1.723
1771 Concrete Work	1.469	10.416	7.116	1.331	.128	.909
1781 Water Well Drilling	3.962	13.615	3.877	.557	.041	.159
1791 Structural Steel[1]	1.461	4.427	3.030	1.177	.266	.806
1973 Glass & Glazing	.809	13.921	17.214	.473	.034	.584
1794 Excavation/Foundations	5.328	6.515	1.223	1.670	.256	.313
1795 Wrecking/Demolition	3.433	2.344	.683	1.443	.615	.420
1796 Equipment Installation	1.132	9.044	7.988	1.847	.204	1.631

[1]Based on Preliminary Census Report.

TABLE 3.11 (Continued)

SOUTH

	FK/LT	M/LT	M/FK	S/LT	S/M	S/FK
1521/1531 Single Family Houses/Operative Builders	1.072	15.663	14.609	15.388	.982	14.353
1522 Other Residential Buildings	.798	13.670	17.128	24.225	1.772	30.353
1541 Industrial Buildings	.980	11.947	12.196	15.045	1.259	15.359
1542 Other Non-residential Buildings	.967	12.182	12.602	26.630	2.186	27.548
1611 Highways and Streets	4.402	12.134	2.756	6.533	.538	1.484
1622 Bridge/Tunnel/Elevated Highway	3.214	14.779	4.599	8.032	.543	2.499
1623 Water/Sewer/Utility Lines	2.560	8.072	3.153	2.163	.268	.845
1629 Other Heavy Construction	2.667	14.143	5.303	6.207	.439	2.327
1711 Plumbing/Heating/Air Conditioning	.717	13.246	18.463	2.843	.215	3.963
1721 Painting/Pater Hanging	.421	3.158	7.500	.632	.200	1.500
1731 Electrical Work	.628	10.034	15.972	.518	.052	.824
1741 Masonry/Stonework	.431	3.809	8.834	.398	.105	.922
1742 Plastering/Drywall/Insulation	.703	7.578	10.780	1.155	.152	1.643
1743 Tile/Marble/Mosaic Work	.480	8.366	17.417	.678	.081	1.411
1751 Carpentering	.287	3.580	12.454	1.502	.420	5.225
1752 Floorwork	.471	10.956	23.240	1.057	.096	2.242
1761 Roofing/Sheet Metal	.613	7.829	12.765	.828	.106	1.350
1771 Concrete Work	1.272	7.526	5.917	1.287	.171	1.012
1781 Water Well Drilling	2.864	13.014	4.544	.597	.046	.209
1791 Structural Steel[1]	1.451	4.260	2.935	.594	.139	.409
1973 Glass & Glazing	.707	15.858	22.427	.367	.023	.521
1794 Excavation/Foundations	4.665	5.105	1.094	2.004	.392	.429
1795 Wrecking/Demolition	2.172	2.455	1.130	1.362	.555	.627
1796 Equipment Installation	.755	11.342	15.016	1.002	.088	1.326

[1]Based on Preliminary Census Report.

TABLE 3.11 (Continued)

1521/1531 WEST	FK/LT	M/LT	M/FK	S/LT	S/M	S/FK
Single Family Houses/Operative Builders	1.405	15.468	11.009	29.660	1.918	21.109
1522 Other Residential Buildings	.646	13.922	10.086	13.634	2.173	21.921
1541 Industrial Buildings	1.890	14.624	7.737	34.747	2.376	18.383
1542 Other Non-residential Buildings	1.569	12.628	8.047	40.119	3.177	25.565
1611 Highways and Streets	6.692	11.989	1.791	8.917	.744	1.332
1622 Bridge/Tunnel/Elevated Highway	3.823	13.475	3.524	12.745	.946	3.333
1623 Water/Sewer/ Utility Lines	3.642	11.585	3.181	4.603	.397	1.264
1629 Other Heavy Construction	2.551	16.869	6.612	10.757	.638	4.216
1711 Plumbing/Heating/ Air Conditioning	.969	14.218	14.667	3.052	.215	3.149
1721 Painting/Pater Hanging	.714	4.190	5.872	.876	.209	1.228
1731 Electrical Work	.866	13.108	15.139	.980	.075	1.132
1741 Masonry/Stonework	.743	8.569	11.539	.494	.058	.666
1742 Plastering/Drywall/Insulation	.627	8.263	13.178	1.909	.231	3.045
1743 Tile/Marble/Mosaic Work	.661	11.195	16.947	.557	.050	.843
1751 Carpentering	.484	6.305	13.021	1.567	.249	3.237
1752 Floorwork	.420	13.612	32.434	.934	.069	2.226
1761 Roofing/Sheet Metal	1.052	12.911	12.275	1.063	.082	1.011
1771 Concrete Work	1.654	9.293	5.618	1.662	.179	1.005
1781 Water Well Drilling	3.771	11.124	2.950	.485	.044	.129
1791 Structural Steel[1]	1.516	10.844	7.151	1.259	.116	.830
1973 Glass & Glazing	.797	17.154	21.531	.609	.035	.763
1794 Excavation/ Foundations	6.459	6.670	1.032	3.244	.486	.502
1795 Wrecking/ Demolition	4.633	3.883	.843	3.894	1.003	.845
1796 Equipment Installation	1.166	14.162	12.146	1.638	.116	1.405

[1]Based on Preliminary Census Report.

which may distort our later estimates. In this light netting out the value of materials and subcontracting payments from gross output to obtain value added becomes an even more heroic assumption, especially for the general building contractors.

d. Regional influences

These regional patterns largely reflect interrelated factors such as regional differences in design and availability of materials, the degree of unionization, the degree of urbanization, and size of project.

Types of design or materials popular in one region may be used less frequently in another because of climate, availability of materials, degree of urbanization or tradition. For example in table 3.12 we present BLS information on selected characteristics by region of apartments constructed in 1971.[11]

Table 3.12 Apartment Characteristics by Region, 1971

Characteristic	East	North Central	South	West
Number of Stories	4 +	2-3	2-3	2-3
Number of units per project	240	163	149	135
Most common framing	Reinforced Concrete	Wood	Wood	Wood
Most common exterior	Brick	Brick	Brick	Stucco

Similarly selected characteristics for single family houses constructed in 1971 are given in table 3.13.[12]

Table 3.13 Single Family House Characteristics, by Region, 1971

Percent of houses in Region having:	East	North Central	South	West
1 story	47	61	83	75
Full basement	82	74	16	14
Slab basement	11	12	47	63
Crawl space	7	14	37	23

We find that the number of stories and the number of units per apartment project are larger in the East, which in general is more urbanized and densely populated than the other regions. The number of stories also influences the choice of structural framing. Other comparisons are obvious from the tables.

The degree of unionization by region is an important variable in examining wage determination between regions, and job classifications such as the classification of skilled and unskilled worker. Complete information on the degree of unionization by industry and region is not available.[13] The Bureau of Labor Statistics estimates that nationally between 60-70 percent of workers were employed by unionized establishments during the sixties.[14] Least organized are workers in residential construction where possibly 65-80 percent of the workers are nonunion. The special trades and general contractors associated with nonresidential building appear to be most unionized. There is greater unionization in urban than in rural areas. Unionization is less in the South. The Bureau of Labor Statistics has recently published its first wage survey of contract construction in over 35 years. Table 3.14 gives the degree of unionization by industry group and contractor size for 21 urban areas.[15] Since urban areas

Table 3.14 Percent of nonsupervisory construction workers in firms operating under labor-management agreements, September 1972

Area	All firms[1]	Industry branch			Contractor size		
		General contractors		Selected special trades contractors	8 to 49 workers	50 to 249 workers	250 workers or more
		Building	Heavy construction				
21 areas, total	80-84	80-84	75-79	80-84	70-74	85-89	95+
Northeast:							
Boston	75-79	85-89	80-84	70-74	55-59	95+	95+
Buffalo	90-94	90-94	85-89	95+	85-89	90-94	95+
Hartford	70-74	80-84	65-69	65-69	55-59	90-94	95+
New York and Nassau-Suffolk	90-94	85-89	95+	90-94	80-84	95+	95+
Philadelphia	75-79	60-64	75-79	80-84	70-74	70-74	95+
South:							
Atlanta	50-54	40-44	20-24	65-69	35-39	65-69	95+
Biloxi-Gulfport and Pascagoula	40-44	35-39	10-14	55-59	45-49	25-29	--
Dallas	30-34	50-54	0-4	40-44	40-44	35-39	95+
Memphis	60-64	80-84	5-9	70-74	50-54	65-69	--
Miami	75-79	85-89	60-64	75-79	70-74	80-84	95+
Washington	40-44	45-49	20-24	55-59	30-34	45-49	70-74
North Central:							
Chicago	95+	95+	95+	95+	90-94	95+	95+
Des Moines	85-89	80-84	85-89	90-94	80-84	95+	--
Indianapolis	65-69	80-84	95+	45-49	45-49	85-89	--
Kansas City	95+	95+	95+	95+	95+	95+	95+
Minneapolis-St. Paul	95+	95+	95+	95+	95+	95+	95+
St. Louis	95+	95+	90-94	95+	95+	95+	95+
West:							
Denver	70-74	80-84	60-64	65-69	60-64	90-95	65-69
Los Angeles-Long Beach and Anaheim-Santa Ana-Garden Grove	95+	95+	95+	95+	95+	95+	95+
Portland	95+	95+	95+	95+	95+	95+	95+
San Francisco-Oakland	95+	95+	95+	95+	95+	95+	95+

[1] Includes data for workers employed by operative builders not shown separately.

NOTE: Dashes indicate no data reported.

only are surveyed these estimates are higher than average. Although the survey was conducted in 1972 the industry classification is based upon the 1967 SIC classification of the construction industries. By this industry grouping heavy contractors are somewhat less unionized than either the general building or special trade contractors. Larger contractors tend to be more unionized. Unionization appears highest in the East and West, and lowest in the South.

Lower unionization is probably one of the major reasons for the lower wages which we have observed in the South, but other factors such as the lower cost of living are probably as important. Another reason, which a number of Bureau of Labor Statistics studies have documented, is the lower percentage of skilled workers used in the South. An example is given in table 3.15, which presents BLS statistics on skilled worker hours as a percentage of total onsite manhours for public housing built in 1968.[16] Average hourly earnings are also given.

Table 3.15. Skilled Labor Requirements for Public Housing, 1968

Region	Percentage of Skilled Manhours	Average Hourly Earnings
West	74.5	4.80
East	69.1	5.14
Central	67.6	4.18
South	58.1	3.16

Although the West ranked first in the percentage of skilled manhours it ranked second to the East in average hourly earnings. The BLS attributed this change in ranking to the fact that a larger percentage of the public housing projects in the East were constructed in urban areas where wage rates are higher than nonurban areas.[17]

Can one verify the finding that wage rates are higher in urbanized areas from our data? Since a more metropolitan area represents a larger market does size of establishment or amount of subcontracting increase in states which are highly urbanized? One way to examine these questions is to look at the simple correlations between our state urbanization variable and our other basic variables. The simple correlation is positive between urbanization and size related variables such as V (23 industries), LC (20 industries), LA (24 industries and the ratio of LA/LC (24 industries). It is also positive for subcontracting (23 industries), the construction worker wage (22 industries), labor productivity, V/L (21 industries), and capitol productivity, V/FK (21 industries). There are fewer positive correlations of U with our input ratios FK/L (15 industries), M/L (13 industries) and M/FK (14 industries), and the degree of association is generally not as strong. One interesting result is that the correlation between U and the ratio of materials to gross output (M/Y) is negative in 19 of our industries. This may reflect a greater reliance on already finished materials in the more rural areas.

These correlations emphasize the importance of the degree of urbanization to the construction industries which we are studying. They also serve to emphasize the complex interrelations between urbanization, size, region, type of industry, and degree of unionization for the sector as a whole.

Notes to Chapter III

1. Table 1 and the summary statistics discussed below are from U.S. Bureau of the Census, 1972 Census of Construction Industries, U.S. Summary - Statistics for Construction Establishments With or Without Payroll, Government Printing Office, Washington, D.C., 1975.

2. The Subdividers and Developers Industry (SIC 6552) is comprised of firms which subdivide property into lots and develop it for resale on their own account. In 1972 51% of the total receipts from this industry were reported from the sale of land rather than from construction activity.

3. Goldblatt, Abraham, "Construction in 1972", Construction Review, U.S. Department of Commerce, April 1973, pp. 4-9.

4. A more complete description of these statistical problems are found in Chapter 2 of Cassimates, op. cit.

5. Ibid.

6. For discussion see Griliches, A., "Production Functions in Manufacturing: Some Preliminary Results", op. cit., pp. 285-292.

7. Due to the nature of construction (particularly heterogeneous output and changes in quality and composition over time) appropriate price indexes are not available for the sector as a whole. The Department of Commerce Component Cost index and the double deflation method are not appropriate to deflate output or measure productivity change. For discussion of this problem and efforts to correct it see Cassimates, ibid., Ch. 6; Dacy, D., "Productivity and Price Trends in Construction Since 1947", Review of Economics and Statistics, November 1965, pp. 406-411; and Gordon, R.J., "A New View of Real Investment in Structures, 1919-166", Review of Economics and Statistics, November 1968, pp. 417-428.

8. This definition is similar to that used by Griliches, Z., "Production Functions in Manufacturing: Some Preliminary Results", op. cit., p. 280.

9. The four census regions are composed of: Northeastern - Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania; North Central - Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas; Southern - Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas; West - Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California, Alaska, and Hawaii.

10. See Industry Wage Survey: Contract Construction, September, 1972. Bureau of Labor Statistics Bulletin 1853, 1975, p. 5.

11. Ball, Robert, "Labor and Material Requirements for Apartment Construction", Monthly Labor Review, U.S. Department of Labor, January 1975, pp. 70-73.

12. Goldblatt, Abraham, "Profile of New One-Family Homes", Construction Review, U.S. Department of Commerce, February 1973, pp. 4-8.

13. This discussion is based primarily upon a section on Unionization in Construction in D.Q. Mills work Industrial Relations and Manpower in Construction, op. cit., pp. 16-18.

14. Compensation in the Construction Industry, Bureau of Labor Statistics Bulletin 1656, 1970, pp. 9-10.

15. BLS Bulletin 1853, ibid., p. 4.

16. Labor and Material Requirements for Public Housing Construction 1968, Bureau of Labor Statistics Bulletin 1821, 1974, pp. 12-13.

17. Ibid.

CHAPTER IV

THE EMPIRICAL RESULTS

This chapter presents the main empirical results for the models outlined in Chapter II. We begin in section 1 the Cobb-Douglas findings, while section 2 contains the CES results. Section 2 also presents estimates for the simple labor demand equation. In these first two sections we concentrate upon presenting estimates for the twenty-four 4 digit industries. In section 3 we consider both our Cobb-Douglas and CES models for the construction sector as a whole. Two sets of estimates are presented. In one set our observations are by State. The variables in each State observation are the sum of all construction activity by the 4 digit industries, including subdividers and developers. The other set of observations is by industry, where the U.S. Summary for each 4 digit industry is one observation. We include industry 1799, Special Trade Contractors, not elsewhere classified, but exclude industry 6552, Subdividers and Developers.

1. The Cobb-Douglas Results

Table 4.1 contains the results from estimating equation 2.3, which is the basic two factor Cobb-Douglas model.[1] We have used capital services (FK) as our measure of the capital input. A capital services definition is theoretically superior to a capital stock definition since it measures the flow of capital used in production.

TABLE 4.1 TWO FACTOR COBB-DOUGLAS ESTIMATES[1]

	NR OBS	COEFFICIENTS OF FK	L	SCALE	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	48	.332 (3,162)	.674 (4.578)	1.006	.616
1522 Other Residential Buildings [2]	40	.225 (2.602)	.651 (7.073)	.876	.621
1542 Industrial Buildings [2]	42	.375 (3.902)	.609 (7.128)	.984	.849
1542 Other Non-residential Buildings [2]	51	.500 (5.526)	.472 (4.041)	.972	.744
1611 Highways & Streets [2]	50	.774 (10.196)	.258 (3.590)	1.032	.881
1622 Bridge/Tunnel/ Elevated Highway [2]	27	.731 (4.149)	.237 (1.318)	.968	.820
1623 Water/Sewer/ Utility lines	41	.751 (7.746)	.271 (3.020)	1.022	.869
1629 Other Heavy Construction [2]	40	.293 (3.262)	.798 (10.117)	1.091*	.945
1711 Plumbing/Heating/ Air Conditioning [2]	51	.397 (4.406)	.727 (7.110)	1.124	.777
1721 Painting/Paper Hanging	38	.414 (5.848)	.750 (5.245)	1.164	.738
1731 Electrical Work [2]	45	.264 (3.355)	.847 (8.484)	1.111	.800
1741 Masonry/Stonework [2]	38	.465 (6.148)	.656 (5.177)	1.120	.879
1742 Plastering/Drywall/Insulation [2]	40	.263 (2.675)	.874 (7.470)	1.137**	.837
1743 Tile/Marble/ Mosaic Work	14	.785 (2.900)	.251 (1.043)	1.036	.577
1751 Carpentering [2]	29	.315 (3.059)	.798 (5.402)	1.113	.880
1752 Floorwork [2]	27	.092 (1.903)	.890 (7.891)	.982	.784
1761 Roofing/Sheet Metal [2]	32	.418 (2.740)	.361 (2.014)	.779	.266
1771 Concrete [2] Work	38	.404 (4.397)	.766 (6.525)	1.170	.760
1781 Water Well Drilling	21	.267 (3.277)	.740 (5.282)	1.007	.733
1791 Structural Steel	28	.378 (2.500)	.669 (3.314)	1.047	.820
1793 Glass & Glazing	17	.180 (1.311)	.571 (2.828)	.751**	.663
1794 Excavation/ Foundations [2]	40	.714 (6.762)	.339 (3.250)	1.053	.849
1795 Wrecking/ Demolition [2]	17	.574 (5.150)	.715 (5.167)	1.289**	.831
1796 Equipment Installation [2]	20	.055 (.708)	1.174 (8.276)	1.229*	.906

[1] $\text{Log } V = \text{Const} + \alpha \text{ Log } FK + \beta \text{ Log } L$

[2] Data from preliminary census Reports. Remainder of data from final reports.

*Significantly different from 1 at .05 level.

**Significantly different from 1 at .10 level.

Because FK relies in part upon a somewhat arbitrary determination of the depreciation rate and the rate of return to capital, in our preliminary investigation we also used net capital stock, NK, as an alternative measure of capital. For the Cobb-Douglas models the fit using either definition was close, but with few exceptions the NK specification had slightly lower coefficients of determination. The labor coefficients were somewhat larger and the capital coefficients smaller (and often not significant) for the NK specification. We also used the NK specification for the other models discussed in Chapter II, with similar results. Since NK did no better, and was often worse than the capital services definition we will only report results using the FK specification.

Nearly all the coefficients of L and FK are significant (values are reported in the tables beneath the coefficient estimate). The output elasticity for labor is larger than that of capital for the majority of our industries. But there are important exceptions among the heavy contractors and for a few of the special trade contractors. Although the sum of the output elasticities exceed one in over two thirds of the industries, increasing returns to scale are statistically significant at the .05 percent level only in industries 1629 and 1796. The sum of the coefficients for the general building contractors appears slightly smaller than for the heavy or special trade contractor groups.

Our $\bar{R}^2$ is reasonably high, with majority of the industries about .75. However the fairly high $\bar{R}^2$ is in part due to our choice of Log v rather than Log(V/L) as our dependent variable. A transformation to a regression using Log(V/L) as the dependent variable

(Log(V/L) = const + α Log(FK/L) + (1 - α - β)Log L) give the same capital output (α) and labor output (β) elasticities, but the $\bar{R}^2$ is generally lower. Although the output elasticity for labor is not given directly, this transformation is especially useful since a labor coefficient in this model (1 - α - β) which is significantly different from zero provides a direct two tail test for significant returns to scale.

In table 4.2 we report the results of estimating the three factor Cobb-Douglas model (equation 2.4) which separates labor into construction and non-construction workers. Although the adjusted coefficients of determination are slightly larger than those in table 4.1 the fit has not noticeably improved. There are fewer significant coefficients, primarily due to the increased collinearity between the inputs. For most industries, excepting the heavy contractors, the capital coefficient is lower while the sum of the two labor coefficients is higher than similar coefficients in the basic model. Moreover, the coefficient for the nonconstruction workers relative to construction workers is larger than its share of the wage bill would suggest. Griliches also obtained this type of result in a study of the 2-digit manufacturing industries for 1963.[2] He suggests that errors in measurement may partially account for his result. Our data may be even more subject to such errors since the census uses number of workers rather than manhours as the basic unit of measure for labor. This choice means that part-time employees are counted with the same weight as full time employees. Varying degrees of part-time employment between LA and LC could possibly account for this result.

TABLE 4.2 THREE FACTOR COBB-DOUGLAS ESTIMATES[1,2]

	COEFFICIENTS OF FK	LA	LC	SCALE	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	.163 (1.640)	.405 (5.454)	.393 (2.760)	.961	.718
1522 Other Residential Buildings	.172 (2.064)	.251 (2.692)	.515 (5.778)	.938	.676
1542 Industrial Buildings	.220 (2.320)	.394 (4.192)	.395 (5.107)	1.008	.885
1542 Other Non-residential Buildings	.379 (4.195)	.410 (3.440)	.178 (1.289)	.967	.787
1611 Highways & Streets	.698 (9.734)	.342 (4.054)	.033 (.378)	1.073	.907
1622 Bridge/Tunnel/ Elevated Highway	.749 (.603)	-.140 (-1.837)	.334 (3.805)	.943	.825
1623 Water/Sewer/ Utility lines	.748 (7.197)	.016 (.112)	.266 (1.839)	1.030	.866
1629 Other Heavy Construction	.269 (3.204)	.223 (3.541)	.568 (5.846)	1.065	.953
1711 Plumbing/Heating/ Air Conditioning	.260 (3.093)	.344 (4.346)	.518 (4.880)	1.122	.834
1721 Painting/Paper Hanging	.334 (5.538)	.373 (28.281)	.388 (2.849)	1.095	.829
1731 Electrical Work	.188 (2.688)	.548 (4.891)	.453 (4.333)	1.189	.853
1741 Masonry/Stonework	.428 (5.327)	.100 (2.024)	.561 (4.271)	1.089	.879
1742 Plastering/Drywall/Insulation	.279 (3.088)	.312 (4.481)	.506 (3.676)	1.097	.878
1743 Tile/Marble/ Mosaic Work	.366 (1.560)	.576 (3.519)	.015 (.080)	.957	.783
1751 Carpentering	.315 (3.057)	.121 (1.811)	.645 (4.189)	1.081	.879
1752 Floorwork	.035 (.373)	.198 (1.716)	.773 (5.528)	1.006	.803
1761 Roofing/Sheet Metal	.076 (.587)	.749 (5.231)	.058 (.417)	.883	.605
1771 Concrete Work	.328 (3.600)	.204 (2.669)	.642 (5.959)	1.174	.801
1781 Water Well Drilling	.265 (2.524)	.060 (.844)	.722 (3.930)	1.047	.717
1791 Structural Steel	.460 (3.303)	.288 (3.323)	.243 (1.080)	.991	.857
1793 Glass & Glazing	-.025 (-.198)	.891 (3.211)	.176 (.886)	1.092	.788
1794 Excavation/ Foundations	.571 (4.789)	.145 (2.550)	.330 (3.360)	1.046	.863
1795 Wrecking/ Demolition	.620 (5.562)	-.118 (-.992)	.760 (5.519)	1.262	.845
1796 Equipment Installation	.367 (4.469)	.785 (12.422)	.054 (.710)	1.206	.909

[1]Number of observations and source of data same as Table 4.1.

[2] $\text{Log } V = \text{Const} + \alpha \text{ Log } FK + \beta \text{ Log } LA + \gamma \text{ Log } LC$.

We also estimated those models which use R, the ratio of net to gross value of capital as a proxy for capital vintage. Our results do not support Liu and Hildebrands' hypothesis that R is a good proxy for the vintage of technology. The coefficient of determination for the capitol augmenting model (equation 2.5, $V = R\cdot FK)^{\alpha}L^{\beta})$ was roughly similar to the basic model. For practically all industries the labor coefficient increased and the coefficient of $(R\cdot FK)$ decreased - in several cases so that it was no longer significant. In our alternative model (equation 2.5a) which allows the effect of R to be estimated separately ($\text{Log } V = \text{const} + \alpha \text{ Log } R + \alpha \text{ Log } FK + \beta \text{ Log } L$) there were significant coefficients for R in two industries, but they were negative - i.e. the wrong sign. In fact, for over two-thirds of our industries, the simple correlation between R and value added was negative. Griliches has also tested Liu and Hildebrands' hypothesis. He found no support in his study of the manufacturing industries in 1958 but in a later study found a "... trace of 'embodiment' in 1963, industries with "younger" capital stock having somewhat higher productivity levels..."[3] Griliches suggests two reasons why R may not be a good proxy for capital vintage. The first reason is that R may differ more due to different depreciation policies than due to different ages of capital stock. The other reason is thathistoric costs rather than current or constant prices are used to report capital data. Although newer capital may be "more" capital under the embodiment hypothesis, it may also be "less" capital due to changes in the price of capital goods. It is likely that these effects may cancel out.[4]

In the final set of Cobb-Douglas estimates which we will present regional dummy variables are introduced. Table 4.3 contains estimates for the basic model with the regional dummies, using the Eastern census region is the reference region. A comparison of these results to those of the basic model using the F test indicates that the addition of the regional dummies as explanatory variables is significant for over half of the industries estimated. For nearly all industries the output elasticity for capital has decreased while the output elasticity for labor has increased. Of special interest is that in this model we now have 7 industries in which increasing returns to scale are significant at the .05 percent level.

In table 4.4 we report similar results for our three factor Cobb-Douglas model. When we include regional dummies as explanatory variables, their addition is significant in 14 of the industries. Comparing these coefficient estimates to earlier estimates, we see that the coefficient for construction workers has increased and the coefficient for capital services decreased in practically all of the industries. The output elasticity for nonconstruction workers has not changed as systematically, although for the majority of industries this coefficient declined. We have significant increasing returns to scale in nearly one fourth of the industries.

Since the LA and LC coefficients with regional dummies in more closely correspond to their wage bill shares, the use of the regional dummies appears to have helped by reducing some of the specification error without seriously affecting the significance level of these coefficients. Even though the estimates with dummies in

TABLE 4.3 TWO FACTOR COBB-DOUGLAS ESTIMATES WITH REGIONAL DUMMIES[1,2]

	COEFFICIENTS OF FK	L	CENTRAL	SOUTH	WEST	$\bar{R}^2$	SCALE
1521/1531 Single Family Houses/Operative Builders	.222 (2.049)	.861 (4.838)	.080 (.808)	-.125 (-1.102)	.188 (1.885)	.696	1.083
1522 Other Residential Buildings[3]	.209 (2.582)	.834 (7.678)	-.019 (-.171)	-.308 -2.676)	-.126 -1.177)	.673	1.043
1542 Industrial Buildings	.257 (2.404)	.775 (7.161)	-.119 (-1.409)	-.240 (-2.446)	-.067 (-.724)	.862	1.032
1542 Other Non-residential Buildings	.440 (4.042)	.566 (3.730)	-.049 (-.514)	-.115 (-1.177)	-.029 (-.308)	.736	1.006
1611 Highways & Streets	.635 (6.475)	.436 (4.760)	.008 (.1099)	-.149 (-1.940)	.021 (.251)	.893	1.071
1622 Bridge/Tunnel/ Elevated Highway[3]	.627 (4.546)	.337 (2.202)	-.345 (-2.700)	-.474 (-4.038)	-.098 (-.578)	.897	.964
1623 Water/Sewer/[3] Utility lines	.610 (6.352)	.455 (4.669)	-.095 (-1.239)	-.234 (-3.179)	.012 (.151)	.903	1.065
1629 Other Heavy Construction[3]	.319 (4.055)	.780 (11.006)	.066 (.738)	-.166 (-1.929)	.078 (.857)	.960	1.098*
1711 Plumbing/Heating/[3] Air Conditioning	.235 (2.883)	.976 (10.322)	-.007 (-.107)	-.275 (-4.540)	-.028 (-.438)	.859	1.211*
1721 Painting/Paper[3] Hanging	.227 (2.968)	1.027 (8.083)	.041 (.506)	-.226 (-2.943)	.127 (1.236)	.837	1.254*
1731 Electrical[3] Work	.118 (1.854)	1.104 (13.311)	-.049 (-.780)	-.320 (-5.118)	-.003 (-.049)	.898	1.272*
1741 Masonry/Stone-[3] work	.222 (2.636)	.922 (7.645)	-.030 (-.471)	-.298 (-4.424)	-.084 (-1.275)	.923	1.145*
1742 Plastering/Dry-[3] wall/Insulation	.231 (2.272)	.900 (7.997)	-.024 (-.334)	-.229 (-3.550)	-.176 (-2.241)	.892	1.132**
1743 Tile/Marble/ Mosaic Work	.332 (1.366)	.513 (2.640)	.092 (.708)	-.328 (-2.838)	-.138 (-1.034)	.784	.646
1751 Carpentering	-.030 (-.294)	1.230 (8.748)	.005 (.064)	-.392 (-4.200)	-.161 (-1.736)	.936	1.200*
1752 Floorwork[3]	.089 (1.147)	.972 (10.889)	-.010 (-.116)	-.311 (-3.464)	-.047 (-.530)	.876	[illegible]
1761 Roofing/Sheet[3] Metal	.254 (1.339)	.732 (3.721)	-.070 (-.649)	-.300 (-2.968)	-.147 (-1.323)	.430	.557
1771 Concrete[3] Work	.333 (4.388)	1.064 (9.754)	-.032 (-.472)	-.358 (-4.589)	-.059 (-.724)	.861	1.387*
1781 Water Well[3] Drilling	.231 (3.253)	.856 (6.769)	.152 (2.112)	-.117 (-1.501)	.091 (1.223)	.854	1.087
1791 Structural[3] Steel	.405 (3.214)	.582 (3.551)	-.061 (-.708	-.264 (-3.499)	-.046 (-.444)	.888	[illegible]
1793 Glass & Glazing	.152 (1.178)	.761 (3.661)	-.164 (-1.54)	-.128 (-1.207)	.145 (1.127)	.742	.913
1794 Excavation/ Foundations	.628 (5.800)	.459 (4.039)	.010 (.175)	-.085 (-1.633)	.049 (.775)	.859	1.088
1795 Wrecking/ Demolition	.450 (4.393)	.984 (6.660)	.045 (.397)	-.277 (-2.361)	.198 (1.246)	.885	1.433*
1796 Equipment Installation	-.052 (-.617)	1.244 (9.962)	.087 (1.005)	-.142 (-1.243)	-.175 (-1.174)	.930	1.192**

[1]Number of observations and source of data same as Table 4.1.

[2]Log V = const + α Log FK + β Log L + a Log c + b Log S + c Log W.

[3]Significantly different at .05 level from estimate in Table 4.1.

*Significantly different from 1 at .05 level.

TABLE 4.4 THREE FACTOR COBB-DOUGLAS ESTIMATES WITH REGIONAL DUMMIES[1,2]

	COEFFICIENTS OF							
	FK	LA	LC	CENTRAL	SOUTH	WEST	$\bar{R}^2$	SCALE
1521/1531 Single Family Houses/Operative Builders	-.008	.504	.538	-.015	-.200	.163	.834	1.034
	(-.084)	(8.011)	(3.916)	(-.200)	(-2.381)	(2.175)		
1522 Other Residential Buildings	.166	.231	.661	-.010	-.251	-.099	.708	1.059
	(2.096)	(2.567)	(6.450)	(-.095)	-(2.313)	(-.894)		
1542 Industrial Buildings[3]	.078	.475	.529	-.146	-.252	.001	.914	1.082
	(.837)	(5.556)	(6.502)	(-2.176)	(-3.263)	(.019)		
1542 Other Non-residential Buildings	.320	.422	.254	-.077	-.104	-.019	.781	.996
	(2.989)	(3.384)	(1.482)	(-.880)	(-1.160)	(-.215)		
1611 Highways & Streets	.567	.332	.165	.024	-.065	.078	.921	1.064
	(6.092)	(3.821)	(1.504)	(.374)	(-.897)	(1.001)		
1622 Bridge/Tunnel/ Elevated Highway[3]	.651	-.060	.344	-.339	-.457	-.122	.695	.936
	(4.184)	(-.409)	(2.279)	(-2.624)	(-3.850)	(-.698)		
1623 Water/Sewer/ Utility lines[3]	.634	.008	.429	-.097	-.219	.007	.896	1.072
	(6.154)	(.065)	(3.123)	(-1.215)	(-2.907)	(.087)		
1629 Other Heavy Construction	[illegible]	.164	.625	.070	-.138	.084	.964	1.084*
	(3.886)	(2.741)	(7.114)	(.815)	(-1.632)	(.964)		
1711 Plumbing/Heating/ Air Conditioning[3]	.161	.234	.788	-.024	-.218	-.020	.875	1.204*
	(2.278)	(3.120)	(6.961)	(-.402)	(-3.571)	(-.336)		
1721 Painting/Paper Hanging	.218	.269	.688	.057	-.124	.114	.852	1.175
	(2.913)	(3.490)	(4.027)	(.731)	(-1.480)	(1.158)		
1731 Electrical[3] Work	.101	.324	.836	-.049	-.265	-.019	.911	1.261*
	(1.692)	(3.822)	(8.078)	(-.834)	(-4.424)	(-.324)		
1741 Masonry/Stone-[3] work	.252	.041	.849	-.038	-.281	-.106	.910	1.143**
	(2.834)	(.906)	(6.011)	(-.559)	(-3.625)	(-1.506)		
1742 Plastering/Dry-wall/Insulation[3]	.150	.270	.669	-.043	-.223	-.083	.918	1.089
	(1.616)	(3.515)	(5.264)	(-.697)	(-3.926)	(-1.058)		
1743 Tile/Marble/ Mosaic Work	.211	.360	.307	.077	-.219	-.074	.826	.878
	(.903)	(2.059)	(1.416)	(.653)	(-1.861)	(-.593)		
1751 Carpentering[3]	-.034	.118	1.108	-.058	-.432	-.223	.936	1.192*
	(-.325)	(2.236)	(7.606)	(-.714)	(-4.466)	(-2.318)		
1752 Floorwork[3]	.034	.211	.824	-.024	-.295	-.032	.888	1.068
	(.414)	(2.380)	(7.427)	(-.286)	(-3.470)	(-.376)		
1761 Roofing/Sheet Metal	.102	.648	.200	-.044	-.103	-.073	.578	.950
	(.600)	(3.641)	(.982)	(-.478)	(-1.057)	(-.734)		
1771 Concrete[3] Work	.309	.139	.904	-.027	-.305	-.039	.874	1.351*
	(4.192)	(2.229)	(8.561)	(-.423)	(-4.036)	(-.496)		
1781 Water Well[3] Drilling	.205	.046	.857	.158	-.112	.084	.642	1.108
	(2.149)	(.806)	(5.169)	(2.025)	(-1.273)	(1.057)		
1791 Structural[3] Steel	.450	.180	.340	-.061	-.224	-.055	.893	.969
	(3.295)	(2.119)	(1.603)	(-.679)	(-2.791)	(-.546)		
1793 Glass &[3] Glazing	-.060	1.059	.089	-.251	-.113	-.077	.661	1.088
	(-.524)	(3.763)	(.378)	(-2.897)	(-1.441)	(-.680)		
1794 Excavation/ Foundations[3]	.343	.226	.532	.020	-.137	.066	.904	1.101
	(3.009)	(4.399)	(5.494)	(.425)	(-3.067)	(1.250)		
1795 Wrecking/ Demolition	.497	-.019	.954	.102	-.196	.207	.873	1.432*
	(4.318)	(-.158)	(6.319)	(.831)	(-1.603)	(1.157)		
1796 Equipment Installation	-.031	.390	.807	.100	-.103	-.107	.925	1.166
	(-.334)	(2.256)	(3.752)	(1.056)	(-.809)	(-.691)		

[1]Number of observations and source of data same as Table 4.1.

[2]$\text{Log } V = \text{const} + \alpha \text{ Log } FK + \beta \text{ Log } LA + \gamma \text{ Log } LC + \text{Regional Dummies}$.

[3]Significantly different at .05 level from estimates in Table 4.2.

*Significantly different from 1 at .05 level.

more closely correspond to our a priori expectations we must be cautious in interpreting these results since we cannot separate specific characteristics which vary by region.

A particularly interesting result is the finding of increasing returns to scale for a number of our industries - especially the special trade contractors. Previous studies have found that there are economies of scale for certain building types. Increasing returns to scale and economies of scale are related, but somewhat different concepts. Returns to scale is a production function concept which indicates how much output responds to changes in the scale of the establishment. Economies of scale is a cost function concept which indicates how unit costs respond to changes in the scale of the establishment.

Sherman Maisel, in Housebuilding in Transition found in the 1950's that medium-sized builders sold houses (excluding land) at a price 3 percent below the price for similar houses built by small builders. Large builders (over 100 houses per year) sold houses 6 percent lower than similar houses built by small builders.[5] Cassimates obtained similar results in the 1960's but also found some evidence of diseconomies of scale for builders with a volume of more than 500 houses per year.[6] Fleming found somewhat different results in Northern Ireland where medium sized firms (79-120 workers) priced houses 11.5 percent less than similar houses build by either larger or smaller firms.[7] Fleming makes a useful distinction by pointing out that for homebuilding economies of scale may be associated both with the size of the builder and with the number of units built in one project. This distinction was also made recently in a study of multiple family housing construction by Barbara Stevens. She found evidence of economies of scale in single site construction of multiple family projects.[8] Over her entire sample (which consisted of projects in Massachusetts and New Jersey having between 12 and 600 units per project) unit costs declined about 10 percent when the number of units in the project doubled.[9] The Bureau of Labor Statistics has also showed that economies of scale are associated with larger public housing projects.[10]

Although the sum of the output elasticities generally exceeds one in tables 4.1 to 4.4 for the general residential building contractor industries 1521/31, and 1522, increasing returns to scale are not statistically significant. Combining operative builders with single family residence contractors may have affected these results. Operative builders, who build on their own accounts, employ a larger number of nonconstruction workers (such as salesmen) than the general building contractors. Land receipts are important for operative builders, and we suspect that like Subdividers and Developers (Industry 6552) they may be inflated for tax purposes. Since land receipts are also subtracted from gross receipts to obtain value added, value added may be somewhat smaller than it otherwise would be. But our findings of increasing returns to scale for many of the special trade contractors complements findings of economies of scale in the literature. Such a result is not surprising since theory suggests that economies of scale stem from both specialization of labor and technological factors. Special trade contractors may achieve economies of scale by performing the same specialized type of job on different projects. There is probably greater opportunity in the building trades for such economies in the more urbanized areas. It is also likely that the larger subcontractors work on the larger building projects. We provided some evidence in Chapter III that project size varies regionally. The major technological factor is that the subcontracting system allows the special trade contractors to use more specialized construction equipment at a high rate of utilization.

2. The CES Results

Our results for estimating the Kmenta linear approximation of the CES function are given in table 4.5. Compared to our basic Cobb-Douglas results in table 4.1, our fit has not appreciably improved nor are there as many significant labor or capital coefficients.[11] Recall that this model provides a test of the Cobb-Douglas form, by examining the significance of the coefficient of the squared term . In only one industry (1796 - Building Equipment Installers) is this coefficient significantly different from zero. Even this result is questionable since $\rho < -1$ and the elasticity of substitution implies is infinite. The other estimates of the elasticity of substitution differ from one in both directions but are not statistically significant. Thus this test provides no evidence to reject the Cobb-Douglas hypothesis that $\sigma = 1$. As we see in table 4.6 the addition of regional dummies to the Kmenta model does not change our conclusions concerning the value of σ. However the Kmenta model is a weak test of the Cobb-Douglas hypothesis,

TABLE 4.5 KMENTA APPROXIMATION OF THE CES FUNCTION[1,2]

	COEFFICIENTS OF FK	L	$(FK/L)^2$	SCALE	σ^3	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	.383 (3.444)	.671 (4.591)	-.251 (-1.312)	1.054	.327	.622
1522 Other Residential Buildings	.332 (3.053)	.583 (5.830)	-.160 (-1.570)	.915	.398	.635
1542 Industrial Buildings	.326 (.315)	.489 (3.553)	-.235 (-1.106)	1.016	.350	.850
1542 Other Non-residential Buildings	.700 (4.225)	.352 (2.472)	-.280 (-1.439)	1.052	.295	.750
1611 Highways & Streets	.317 (.593)	.688 (1.368)	.130 (.864)	1.005	∞	.880
1622 Bridge/Tunnel/ Elevated Highway	-1.423 (-1.196)	2.319 (2.014)	.902 (1.828)	.896	.671	.836
1623 Water/Sewer/ Utility lines	.554 (.783)	.461 (.678)	.089 (.282)	1.080	4.049	.866
1629 Other Heavy Construction	-.268 (-.899)	1.349 (4.656)	.235 (1.967)	1.080**	.416	.949
1711 Plumbing/Heating/ Air Conditioning	.381 (4.079)	.744 (7.036)	-.181 (-.700)	1.125	.410	.775
1721 Painting/Paper Hanging	.433 (4.066)	.714 (3.789)	.027 (.299)	1.152	1.249	.732
1731 Electrical Work	.174 (1.621)	.972 (6.808)	-.181 (-1.221)	1.146	.290	.802
1741 Masonry/Stonework	.256 (1.218)	.856 (3.787)	-.179 (-1.068)	1.112	.355	.879
1742 Plastering/Drywall/Insulation	.068 (.146)	1.075 (2.207)	-.132 (-.427)	1.144**	.195	.833
1743 Tile/Marble/ Mosaic Work	1.164 (1.281)	-.168 (-.170)	.306 (.439)	.996	.893	.543
1751 Carpentering	.882 (1.478)	.243 (.408)	.215 (.965)	1.125	∞	.880
1752 Floorwork	.319 (1.349)	.679 (2.976)	.196 (1.064)	.998	∞	.786
1761 Roofing/Sheet Metal	.009 (.024)	.782 (2.078)	-.564 (-1.268)	.791	.008	.281
1771 Concrete Work	.325 (2.236)	.844 (5.218)	.113 (.705)	1.169	27.142	.756
1781 Water Well Drilling	.260 (.632)	.759 (1.631)	.007 (.042)	1.019	1.078	.717
1791 Structural Steel	.947 (1.853)	.103 (.196)	-.716 (-1.164)	1.050	.061	.822
1793 Glass & Glazing	.244 (1.594)	.513 (2.423)	.275 (.955)	.757**	∞	.661
1794 Excavation/ Foundations	1.603 (1.529)	-.550 (-.525)	-.284 (-.852)	1.053	3.109	.848
1795 Wrecking/ Demolition	.844 (2.063)	.465 (1.190)	-.104 (-.687)	1.309**	.590	.825
1796 Equipment Installation	.185 (1.999)	1.043 (7.336)	.282 (2.157)	1.228*	∞	.923

[1] Number of observations and source of data same as Table 4.1.

[2] $\text{Log } V = \text{const} + \alpha \text{ Log } FK + \beta \text{ Log } L + \gamma(\text{Log } FK/L)^2$.

[3] σ set to ∞ where $\rho < -1$.

* Significantly different from 1 at .05 level.

** Significantly different from 1 at .10 level.

TABLE 4.6 KMENTA APPROXIMATION OF THE CES FUNCTION WITH REGIONAL DUMMIES[1,2]

	COEFFICIENTS OF								
	L	FK	$(FK/L)^2$	CENTRAL	SOUTH	WEST	SCALE	$\hat{\sigma}$ [3]	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	.855	.266	-.218	.062	-.129	.182	1.121	.380	.701
	(4.836)	(2.355)	(-1.267)	(.623)	(-1.145)	(1.834)			
1522 Other Residential Buildings	.776	.264	-.079	-.044	-.291	-.139	1.040	.555	.668
	(5.690)	(2.351)	(-.713)	(-.384)	(-2.464)	(-1.728)			
1542 Industrial Buildings	.655	.402	-.210	-.134	-.236	-.210	1.057	.307	.862
	(4.054)	(2.224)	(-.994)	(-1.559)	(-2.394)	(-.994)			
1542 Other Non-residential Buildings	.446	.628	-.252	-.045	-.085	-.004	1.072	2.929	.738
	(2.443)	(3.288)	(-1.195)	(-.474)	(-.844)	(-.045)			
1611 Highways & Streets	1.168	-.147	.215	.029	-.148	.039	1.021	3.557	.896
	(2.341)	(-.275)	(1.491)	(.411)	(-1.953)	(.469)			
1622 Bridge/Tunnel/Elevated Highway	.702	.251	.159	-.328	-.452	-.083	.953	∞	.892
	(.669)	(.231)	(.352)	(-2.361)	(-3.335)	(-.466)			
1623 Water/Sewer/Utility lines	.378	.690	-.036	-.095	-.235	.011	1.068	.772	.900
	(.641)	(1.127)	(-.132)	(-1.223)	(-3.121)	(.139)			
1629 Other Heavy Construction	1.119	-.027	.142	.085	-.136	.084	1.092*	.089	.961
	(4.096)	(-.096)	(1.289)	(.943)	(-1.533)	(.929)			
1711 Plumbing/Heating/Air Conditioning	.970	.243	.134	-.006	-.284	-.031	1.231*	∞	.857
	(10.155)	(2.924)	(.623)	(-.087)	(-4.533)	(-.473)			
1721 Painting/Paper Hanging	.911	.304	.099	.066	-.226	.142	1.215**	7.614	.841
	(6.015)	(3.220)	(1.357)	(.809)	(-2.981)	(1.395)			
1731 Electrical Work	1.220	.033	-.171	-.062	-.323	-.005	1.253*	.086	.903
	(11.289)	(.408)	(-1.624)	(.408)	(-.994)	(-5.266)			
1741 Masonry/Stonework	.951	.193	-.027	-.027	-.294	-.081	1.143*	.748	.919
	(4.885)	(1.069)	(-.189)	(-4.16)	(-4.118)	(-1.202)			
1742 Plastering/Drywall/Insulation	.727	.400	.110	-.023	-.231	-.185	1.127**	6.785	.889
	(1.667)	(.947)	(4.12)	(-.325)	(-3.526)	(-2.245)			
1743 Tile/Marble/Mosaic Work	-.037	.842	.407	.117	-.319	-.115	1.212	.031	.775
	(-.051)	(1.235)	(.803)	(.857)	(-2.677)	(-.828)			
1751 Carpentering	.497	.722	.287	.012	-.397	-.172	1.219*	∞	.942
	(1.189)	(1.725)	(1.849)	(.164)	(-4.473)	(-1.943)			
1752 Floorwork	.846	.228	.120	.006	-.297	-.062	1.120	∞	.873
	(4.278)	(1.035)	(.713)	(.069)	(-3.204)	(-.664)			
1761 Roofing/Sheet Metal	.730	.257	.004	.070	.300	-.147	.987	1.044	.408
	(2.090)	(.703)	(.009)	(.703)	(-.634)	(-2.696)			
1771 Concrete Work	1.357	.074	.350	.006	-.398	-.070	1.431	∞	.888
	(9.766)	(.698)	(2.969)	(.098)	(-5.592)	(-.948)			
1781 Water Well Drilling	1.035	.066	.063	.147	-.128	.084	1.102	∞	.847
	(2.840)	(.206)	(.526)	(1.972)	(-1.550)	(1.083)			
1791 Structural Steel	-.482	1.467	-1.321	-.051	-.292	-.031	.986	∞	.917
	(-1.276)	(4.008)	(3.037)	(-.688)	(-4.474)	(-.357)			
1793 Glass & Glazing	.717	.210	.233	-.127	-.108	.177	.927	∞	.735
	(3.301)	(1.421)	(.840)	(-1.072)	(-.977)	(1.307)			
1794 Excavation/Foundations	-.420	1.508	-.280	.014	-.076	.063	1.087	25.704	.858
	(-.400)	(1.436)	(-.842)	(.244)	(-1.435)	(.950)			
1795 Wrecking/Demolition	.636	.849	-.155	.113	-.253	.227	1.484*	.504	.888
	(1.837)	(2.272)	(-1.110)	(.886)	(-2.135)	(1.423)			
1796 Equipment Installation	1.140	.064	.208	.086	-.107	-.152	1.204*	∞	.939
	(8.679)	(.612)	(1.733)	(1.066)	(-.987)	(-1.033)			

[1]Number of observations and source of data same as Table 4.1.

[2]$\text{Log } V = \text{const} + \beta \text{ Log } FK + \alpha \text{ Log } L + \gamma(\text{Log } FK/L)^2 + \text{Dummies}$.

[3]$\hat{\sigma}$ set to ∞ for $\rho < -1$.

*Significantly different from 1 at .05 level.

as we have already mentioned. Our poor results in estimating σ using the Kmenta method are similar to Griliches and Ringstad's findings in their study of Norwegian manufacturing. In that study they showed that the estimate of the coefficient for the squared term had only about 1/7th of the precision of the estimate for the capital coefficient.[12] In this light our results are not surprising.

Our findings on returns to scale using the Kmenta model agree with the Cobb-Douglas models. And, the addition of regional dummies as explanatory variables in the Kmenta model has almost the same effect upon the scale parameter. This is an encouraging result since Maddala and Kadone, in a Monte Carlo study of Kmenta type equations have shown that the Kmenta method provides a reliable estimate of returns to scale even though the estimate for σ is poor.[13]

Two alternative sets of estimates for σ are given in tables 4.7 and 4.8. The first set is the traditional ACMS (Arrow, Chenery, Minhas, Solow) method while the second adds our regional dummies to the ACMS equation. We use W_C as our wage variable.

None of our sample ACMS estimates are significantly above unity while there are seven industries with an estimate significantly below unity at the .05 percent level. This is an unusual result in comparison with cross sectional studies of the manufacturing industries. Griliches, who surveyed a number of studies of the manufacturing industries, points out that generally σ clusters around 1 in cross section studies but time series estimates are significantly below 1.[14]

It is well known that is biased towards 1 for the ACMS model using cross section data if labor quality, output price, or the efficiency parameter vary over observations.[15]

TABLE 4.7 ACMS ESTIMATES

	[illegible]	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	1.085 (10.289)	.686
1522 Other Residential Buildings	.917 (7.393)	.579
1542 Industrial Buildings	.825** (8.144)	.614
1542 Other Non-residential Buildings	1.043 (12.026)	.742
1611 Highways & Streets	.870* (13.397)	.785
1622 Bridge/Tunnel/ Elevated Highway	1.043 (8.095)	.713
1623 Water/Sewer/ Utility lines	1.013 (18.176)	.889
1629 Other Heavy Construction	.569* (5.603)	.438
1711 Plumbing/Heating/ Air Conditioning	.902** (16.492)	.844
1721 Painting/Paper Hanging	.954 (20.284)	.917
1731 Electrical Work	.914 (15.227)	.840
1741 Masonry/Stonework	.942 (16.363)	.878
1742 Plastering/Drywall/Insulation	.845* (16.109)	.869
1743 Tile/Marble/ Mosaic Work	.961 (10.399)	.892
1751 Carpentering	.765* (11.341)	.820
1752 Floorwork	.668* (6.909)	.643
1761 Roofing/Sheet Metal	.885** (14.997)	.878
1771 Concrete Work	.890** (14.761)	.854
1781 Water Well Drilling	.514* (2.583)	.221
1791 Structural Steel	.887 (11.947)	.835
1793 Glass & Glazing	1.229 (5.231)	.622
1794 Excavation/ Foundations	.711* (10.697)	.744
1795 Wrecking/ Demolition	.852 (8.152)	.804
1796 Equipment Installation	.760 (3.621)	.389

[1] Number of observations and source of data same as Table 4.1.

[2] $\text{Log } V/L = \text{Const} + \alpha \text{ Log } WC$.

*Significantly different from 1 at .05 level.

**Significantly different from 1 at .10 level.

TABLE 4.8 ACMS ESTIMATES WITH REGIONAL DUMMIES

	β[1]	CENTRAL	SOUTH	WEST	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	1.050	.015	.044	.143	.715
	(8.386)	(.241)	(.699)	(2.412)	
1522 Other Residential Buildings	.927	-.014	-.033	-.128	.571
	(4.943)	(-.158)	(-.295)	(-1.310)	
1542 Industrial Buildings	.733*	-.113	-.127	-.035	.632
	(5.801)	(-1.736)	(-1.729)	(-.484)	
1542 Other Non-residential Buildings	1.024	-.011	-.000	.043	.731
	(10.126)	(-.174)	(-.003)	(.717)	
1611 Highways & Streets	.787*	.083	.041	.157	.810
	(8.836)	(1.546)	(.672)	(2.943)	
1622 Bridge/Tunnel/ Elevated Highway	1.081	-.096	.012	.110	.724
	(5.622)	(-.903)	(.088)	(.832)	
1623 Water/Sewer/ Utility lines	1.169**	.017	.126	.056	.897
	(12.976)	(.365)	(2.160)	(1.204)	
1629 Other Heavy Construction	.550*	.155	.075	.147	.462
	(4.633)	(1.849)	(.857)	(1.777)	
1711 Plumbing/Heating/ Air Conditioning	.835*	-.035	-.060	.005	.850
	(11.819)	(-1.003)	(-1.650)	(.160)	
1721 Painting/Paper Hanging	.858*	-.044	-.050	.062	.934
	(13.579)	(-1.200)	(-1.508)	(1.489)	
1731 Electrical Work	.774*	-.014	-.085	.035	.874
	(11.712)	(-.421)	(-2.264)	(1.032)	
1741 Masonry/Stonework	.813*	.014	-.078	.057	.899
	(10.056)	(.385)	(-1.469)	(1.431)	
1742 Plastering/Drywall/Insulation	.810*	-.016	-.039	.021	.876
	(12.479)	(-.517)	(-1.134)	(.614)	
1743 Tile/Marble/ Mosaic Work	.869	.035	-.044	.011	.863
	(4.645)	(.402)	(-.436)	(.125)	
1751 Carpentering	.706*	-.117	-.174	-.132	.886
	(8.948)	(-2.550)	(-4.020)	(-2.800)	
1752 Floorwork	.534*	.006	-.154	.037	.768
	(5.934)	(.119)	(-2.516)	(.646)	
1761 Roofing/Sheet Metal	.807*	.014	-.044	.019	.878
	(9.646)	(.313)	(-.832)	(.410)	
1771 Concrete Work	.863**	-.053	-.045	-.018	.850
	(11.455)	(-1.309)	(-.931)	(.369)	
1781 Water Well Drilling	.267*	.099	-.123	.134	.437
	(1.005)	(1.155)	(-.960)	(1.351)	
1791 Structural Steel	.820*	-.093	-.087	-.015	.855
	(9.835)	(-2.195)	(-1.945)	(-.271)	
1793 Glass & Glazing	1.110	-.133	-.025	.044	.669
	(3.595)	(-1.727)	(.303)	(.506)	
1794 Excavation/ Foundations	.778*	.013	.068	.154	.804
	(10.518)	(.353)	(1.726)	(3.552)	
1795 Wrecking/ Demolition	.957	.159	.157	.201	.816
	(6.154)	(1.700)	(1.178)	(1.677)	
1796 Equipment Installation	.479*	.045	-.123	-.122	.448
	(1.965)	(.544)	(-1.376)	(-.833)	

[1] Number of observations and source of data same as Table 4.1.

[2] Log V/L = Const + α Log WC + Regional Dummies.

* Significantly different from 1 at .05 level.

** Significantly different from 1 at .10 level.

If these sources of bias are geographic then the use of regional dummies may reduce bias due to misspecification. Such would appear to be the case since our estimates of σ for the ACMS with dummies is, with few exceptions, smaller than the simple ACMS estimates. Moreover, there are now 15 industries in which σ is significantly lower than one.

Our final set of estimates are based upon the Variable Elasticity of Substitution production function, which allows us to test whether σ varies with respect to the capital-labor ratio. We estimate equation (2.11) which for our variables is:

$$\log V/L = \log a + b\log W_C + c\log FK/L + u \tag{4.1}$$

The elasticity of substitution is

$$\bar{\sigma} = \frac{1}{1 + \rho - \frac{mp}{S_k}} \tag{4.2}$$

where $\rho = \frac{1-b}{b}$, $m = \frac{c}{1-b}$, and S_K the share of capital, computed as the residual 1 minus the share of labor. Table 4.9 gives estimates for the VES model while table 4.10 gives estimates of the same model where regional dummies have been added as explanatory variables. In table 4.9 we see that in fourteen industries the coefficient of the capital-labor ratio is significant. It is not significant for the majority of the general building contractors as one might expect, but is always significant for the heavy contractors where capital is more important. The estimate of σ is less than unity only for some of the special trade contractors. Adding regional dummies acts to reduce the variation in the capital-labor ratio between states, and the number of industries with significant FK/L coefficients drops

TABLE 4.9 VES ESTIMATES[1,2]

	COEFFICIENTS OF WC	FK/L	SK	$\bar{\sigma}$	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	1.143 (8.850)	-.061 (-.788)	.503	1.301	.683
1522 Other Residential Buildings	.789 (5.476)	.101 (1.639)	.375	1.080	.597
1542 Industrial Buildings	.686 (6.193)	.170 (2.472)	.395	1.204	.658
1542 Other Non-residential Buildings	.947 (8.422)	.099 (1.320)	.389	1.270	.746
1611 Highways & Streets	.567 (6.962)	.401 (6.982)	.529	2.343	.892
1622 Bridge/Tunnel/ Elevated Highway	.858 (5.977)	.303 (2.295)	.400	3.538	.755
1623 Water/Sewer/ Utility lines	.875 (10.183)	.152 (2.068)	.452	1.318	.898
1629 Other Heavy Construction	.639 (8.211)	.273 (5.441)	.401	2.001	.679
1711 Plumbing/Heating/ Air Conditioning	.867 (13.863)	.051 (1.142)	.392	.997	.845
1721 Painting/Paper Hanging	.884 (14.593)	.063 (1.755)	.411	1.044	.922
1731 Electrical Work	.862 (15.879)	.115 (3.780)	.356	1.273	.878
1741 Masonry/Stonework	.796 (11.879)	.148 (3.354)	.360	1.352	.905
1742 Plastering/Drywall/Insulation	.812 (16.778)	.110 (3.123)	.350	1.184	.893
1743 Tile/Marble/ Mosaic Work	.825 (8.292)	.239 (2.283)	.386	2.166	.904
1751 Carpentering	.702 (9.669)	.103 (1.886)	.377	.966	.836
1752 Floorwork	.659 (6.888)	.070 (1.307)	.460	.777	.652
1761 Roofing/Sheet Metal	.808 (12.578)	.135 (2.346)	.385	1.244	.894
1771 Concrete Work	.801 (16.301)	.167 (5.006)	.457	1.262	.913
1781 Water Well Drilling	.495 (3.415)	.267 (4.218)	.614	.876	.586
1791 Structural Steel	.853 (10.330)	.069 (.948)	.358	1.057	.834
1793 Glass & Glazing	1.203 (5.215)	.116 (1.304)	.437	1.638	.639
1794 Excavation/ Foundations	.534 (7.694)	.327 (4.223)	.605	1.162	.823
1795 Wrecking/ Demolition	.674 (5.903)	.194 (2.518)	.603	.994	.855
1796 Equipment Installation	.720 (3.168)	.037 (.515)	.462	.783	.363

[1]Number of observations and source of data same as Table 4.1.

[2]Log V/L = const + a Log WC + b Log FK/L.

TABLE 4.10 VES ESTIMATES WITH REGIONAL DUMMIES[1,2]

	COEFFICIENTS OF						
	WC	FK/L	CENTRAL	SOUTH	WEST	$\bar{\sigma}$	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	1.079 (7.620)	-.035 (-.446)	.008 (.127)	.035 (.526)	.136 (2.196)	1.009	.709
1522 Other Residential Buildings	.609 (4.035)	.095 (1.497)	-.030 (-.338)	-.039 (-.360)	-.125 (-1.312)	1.083	.586
1542 Industrial Buildings	.682 (5.515)	.157 (2.047)	-.063 (-1.626)	-.063 (-.811)	-.020 (-.287)	1.132	.661
1542 Other Non-residential Buildings	.957 (8.000)	.086 (1.038)	-.010 (-.156)	.010 (.162)	.030 (.484)	1.229	.732
1611 Highways & Streets	.600 (8.192)	.377 (6.105)	.044 (1.094)	.065 (1.437)	.078 (1.856)	2.089	.895
1622 Bridge/Tunnel/ Elevated Highway	.759 (3.650)	.355 (2.692)	-.175 (-1.776)	-.110 (-.832)	.044 (.369)	6.747	.785
1623 Water/Sewer/ Utility lines	1.013 (8.427)	.142 (1.884)	-.008 (-.169)	.096 (1.650)	.046 (1.014)	.1477	.904
1629 Other Heavy Construction	.591 (6.462)	.261 (5.054)	.086 (1.306)	-.001 (-.017)	.062 (.947)	1.693	.684
1711 Plumbing/Heating/ Air Conditioning	.819 (11.111)	.037 (.793)	-.040 (-1.108)	-.059 (-1.591)	-.001 (-.039)	.904	.849
1721 Painting/Paper Hanging	.835 (12.248)	.033 (.897)	-.048 (-1.300)	-.052 (-1.554)	.046 (1.024)	.908	.933
1731 Electrical Work	.772 (12.479)	.083 (2.568)	-.024 (-.742)	-.075 (-2.121)	.009 (.263)	1.007	.889
1741 Masonry/Stonework	.751 (9.171)	.106 (2.157)	-.001 (-.037)	-.052 (-1.138)	.034 (.899)	1.064	.909
1742 Plastering/Drywall/Insulation	.786 (12.677)	.105 (2.333)	-.032 (-1.040)	0.040 (-1.248)	-.021 (-.573)	1.123	.690
1743 Tile/Marble/ Mosaic Work	.728 (4.204)	.255 (2.099)	.053 (.710)	-.038 (-.443)	-.018 (-.242)	2.145	.900
1751 Carpentering	.704 (8.745)	.025 (.460)	-.115 (-2.468)	-.161 (-3.108)	-.130 (-2.706)	.754	.882
1752 Floorwork	.530 (5.992)	.059 (1.329)	-.004 (-.084)	-.156 (-2.603)	.030 (.540)	.608	.775
1761 Roofing/Sheet Metal	.781 (9.432)	.122 (1.605)	-.015 (-.325)	-.033 (-.638)	-.009 (-.179)	1.143	.884
1771 Concrete Work	.803 (13.442)	.170 (4.787)	-.021 (-.670)	.001 (.029)	.026 (.678)	1.279	.910
1781 Water Well Drilling	.498 (2.619)	.271 (4.354)	.188 (3.015)	.078 (.780)	.164 (2.390)	.891	.735
1791 Structural Steel	.776 (7.656)	.061 (.769)	-.082 (-1.815)	-.093 (-2.049)	-.013 (-.247)	.935	.853
1793 Glass & Glazing	1.137 (4.063)	-.124 (-1.763)	.019 (.245)	.070 (.872)	.156 (1.909)	.886	.728
1794 Excavation/ Foundations	.678 (3.586)	.277 (3.911)	-.002 (-.071)	.057 (1.710)	.118 (3.135)	1.251	.861
1795 Wrecking/ Demolition	.813 (5.122)	.162 (1.940)	.113 (1.296)	.147 (1.223)	.148 (1.329)	1.112	.350
1796 Equipment Installation	.469 (1.885)	-.055 (-.643)	.038 (.448)	-.163 (-1.474)	-.127 (-.643)	.419	.426

[1]Number of observations and source of data same as Table 4.1.

[2]Log V/L - const + a Log WC + b Log FK/L + Regional Dummies.

to eleven. Like our ACMS estimates, the addition of the regional dummies to the VES model also lowers the estimate of $\bar{\sigma}$.

Note that the VES estimates of $\bar{\sigma}$ are generally larger than the ACMS estimates of (where $\sigma = \frac{1}{1+\rho}$). This follows from our definition of $\bar{\sigma}$ in equation 4.2. When c is significant it is positive. S_K is also positive so the relationship between $\bar{\sigma}$ and σ depends on the value of ρ. When ρ is greater (less) than zero, $\bar{\sigma}$ is greater (less) than σ.[16] The capital share which we use is much larger than the alternative definition FK/V. A smaller value for S_K increases the value of $\bar{\sigma}$ when the coefficient c is positive. Thus the estimates of $\bar{\sigma}$ which we present represent a lower bound of this elasticity. Unfortunately we are not able to test the hypothesis that $\bar{\sigma}$ differs from one.

Despite the diversity between the various ACMS and VES estimates we have a reasonably good idea of value of the elasticity of substitution in nearly two thirds of our industries. Table 4.11 summarizes these results. Where the coefficient of the capital-labor is not significant we accept the ACMS results. Most evidence suggests that the elasticity of substitution is unity for general building contractors. And if we believe our VES estimates, σ is unity or possibly greater for heavy contractors, By contrast, there are six special trade contractor industries for which σ is less than one (Plumbing, Heating and Air Conditioning; Painting, Paper Hanging, and Decorating; Carpentering; Floor Laying; Water Well Drilling; and Equipment Installation Subcontractors). Of the remaining special trade contractors, σ is at least unity for Terrazo, Tile, and Marble Work; Concrete Work; Glass and Glazing Work; and Wrecking and Demolition Subcontractors.

TABLE 4.11 COMPARISON OF ACMS AND VES ESTIMATES

	ACMS	ACMS + DUMMIES	VES	VES + DUMMIES	PROBABLE VALUE OF σ
1521/1531 Single Family Houses/Operative Builders	1	1	> 1[a]	< 1[a]	1
1522 Other Residential Buildings	1	1	> 1[a]	> 1[a]	1
1542 Industrial Buildings	1	< 1*	> 1	> 1	?
1542 Other Non-residential Buildings	1	1	> 1[a]	> 1[a]	1
1611 Highways & Streets	< 1*	< 1*	> 1	> 1	?
1622 Bridge/Tunnel/Elevated Highway	1	1	> 1	> 1	1 or > 1
1623 Water/Sewer/Utility lines	1	> 1**	> 1	> 1	1 or > 1
1629 Other Heavy Construction	< 1*	< 1*	> 1	> 1	?
1711 Plumbing/Heating/Air Conditioning	1	< 1*	< 1[a]	< 1[a]	< 1
1721 Painting/Paper Hanging	1	< 1*	> 1[a]	< 1[a]	< 1
1731 Electrical Work	1	< 1*	> 1	1	1
1741 Masonry/Stonework	1	< 1*	> 1	> 1	?
1742 Plastering/Drywall/Insulation	< 1*	< 1*	> 1	> 1	?
1743 Tile/Marble/Mosaic Work	1	1	> 1	> 1	1 or > 1
1751 Carpentering	< 1*	< 1*	< 1[a]	< 1[a]	< 1
1752 Floorwork	< 1*	< 1*	< 1[a]	< 1[a]	< 1
1761 Roofing/Sheet Metal	1	< 1*	> 1	> 1[a]	?
1771 Concrete Work	1	1	> 1	> 1	1 or > 1
1781 Water Well Drilling	< 1*	< 1**	< 1	< 1	< 1
1791 Structural Steel	1	< 1*	> 1[a]	> 1[a]	1 or < 1
1793 Glass & Glazing	1	1	> 1[a]	> 1[a]	1 or > 1
1794 Excavation/Foundations	< 1*	< 1*	> 1	> 1	?
1795 Wrecking/Demolition	1	1	1	> 1[a]	1
1796 Equipment Installation	1	< 1*	< 1[a]	< 1[a]	< 1

*Significantly different from 1 at .05 level.

**Significnatly different from 1 at .10 level.

[a]VES term not significant.

Knowledge of the elasticity of substitution is important in evaluating the effects of wage taxes/subsidies, and investment tax credits. Variations in σ between industries can lead to changes in factor shares and the distribution of employment. Since we have evidence of differences in the elasticity of substitution and the functional form (Cobb-Douglas, CES, VES) for the 4 digit construction industries policies designed for the whole sector will have differing impacts in the different industries. For example a policy which increases the wage relative to the price of capital - such as an investment tax credit or approval of regulations which improve union bargaining strength - will have a greater impact on employment for the general building and heavy contractors (where capital is more easily substituted for labor) than for those special trade contractors where $\sigma < 1$. But labor productivity (V/L) will not increase as much for industries in which $\sigma < 1$. These findings underscore both the complexity of the sector and the difficulty of making policy decisions concerning the sector.

In Chapter II we summarized the relationship between the elasticity of substitution and the demand for labor. Our estimates of the demand for labor are given in table 4.12. Although the wage elasticity is less than unity in twenty industries the difference is significant in only five industries. In table 4.13, where we report results including regional dummies as explanatory variables, the number of industries with wage elasticities significantly less than unity rises to eight. Nearly all of the industries having inelastic demand elasticities are special trade contractors, which are less

TABLE 4.12 LABOR DEMAND ESTIMATES[1,2]

	COEFFICIENTS OF		
	V	WC	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	.785 (14.818)	-.892 (-8.654)	.822
1522 Other Residential Buildings	.875 (11.726)	-.899 (-7.392)	.819
1542 Industrial Buildings	1.057 (22.084)	-.864 (-8.154)	.923
1542 Other Non-residential Buildings	.905 (17.498)	-.953 (-9.745)	.859
1611 Highways & Streets	.952 (21.570)	-.850* (-12.597)	.913
1622 Bridge/Tunnel/ Elevated Highway	.943 (15.628)	-1.003 (-7.383)	.906
1623 Water/Sewer/ Utility lines	.996 (30.600)	-1.012 (-17.177)	.961
1629 Other Heavy Construction	1.096 (24.744)	-.801 (-5.538)	.962
1711 Plumbing/Heating/ Air Conditioning	.998 (25.826)	-.900 (-13.019)	.931
1721 Painting/Paper Hanging	.987 (17.996)	-.939 (-12.097)	.900
1731 Electrical Work	1.048 (26.505)	-.979 (-12.265)	.945
1741 Masonry/Stonework	1.016 (19.624)	.967 (-9.658)	.931
1742 Plastering/Drywall/Insulation	1.063 (30.117)	-.937 (-12.859)	.964
1743 Tile/Marble/ Mosaic Work	1.101 (11.094)	-1.035 (-8.801)	.907
1751 Carpentering	1.025 (19.739)	-.804** (-7.581)	.949
1752 Floorwork	1.042 (16.528)	-.707 (-6.213)	.915
1761 Roofing/Sheet Metal	.961 (10.702)	-.862 (-10.747)	.814
1771 Concrete Work	1.009 (19.717)	-.900 (-10.880)	.915
1781 Water Well Drilling	.783 (6.020)	-.368* (-1.761)	.636
1791 Structural Steel	1.004 (20.455)	-.893 (-8.722)	.943
1793 Glass & Glazing	.855 (9.299)	-1.242 (-5.538)	.882
1794 Excavation/ Foundations	1.042 (18.918)	-.743* (-9.479)	.901
1795 Wrecking/ Demolition	.983 (9.796)	-.835 (-5.783)	.856
1796 Equipment Installation	.780 (10.076)	-.228* (-.885)	.908

[1]Number of observations and source of data same as Table 4.1.

[2]$\text{Log } L = \text{const} + \alpha \text{ Log } V + \beta \text{ Log } WC$.

*Significantly different from 1 at .05 level.

TABLE 4.13 LABOR DEMAND ESTIMATES WITH REGIONAL DUMMIES[1,2]

	COEFFICIENTS OF V	WC	CENTRAL	SOUTH	WEST	R^2
1521/1531 Single Family Houses/Operative Builders	.774 (12.257)	-.748* (-5.359)	.001 (.016)	.069 (1.085)	-.052 (-.888)	.831
1522 Other Residential Buildings	.844 (10.001)	-.779 (-3.929)	-.020 (-.226)	.097 (.856)	.112 (1.181)	.819
1542 Industrial Buildings	1.027 (17.682)	-.776 (-4.948)	.111 (1.689)	.109 (1.299)	.036 (.502)	.924
1542 Other Non-residential Buildings	.882 (15.671)	-.874 (-7.238)	.004 (.069)	.033 (.531)	-.050 (-.864)	.657
1611 Highways & Streets	1.022 (17.385)	-.806** (-7.828)	-.093 (-.1546	-.059 (-.750)	-.174 (-2.502)	.921
1622 Bridge/Tunnel/ Elevated Highway	.941 (12.856)	-1.024 (-4.962)	.048 (.390)	-.030 (-.208)	-.166 (-1.104)	.906
1623 Water/Sewer/ Utility lines	1.019 (29.461)	-1.195** (-11.689)	-.012 (-.261)	-.133 (-2.209)	-.051 (-1.070)	.964
1629 Other Heavy Construction	1.083 (21.859)	-.794 (-4.270)	-.139 (-1.697)	-.102 (1.165)	-.115 (-1.385)	.962
1711 Plumbing/Heating/ Air Conditioning	.969 (21.960)	-.782* (-7.635)	.032 (.899)	.072 (1.788)	-.003 (-.099)	.934
1721 Painting/Paper Hanging	1.003 (16.685)	-.662 (-8.286)	.045 (1.178)	-.049 (1.322)	-.062 (-1.452)	.920
1731 Electrical Work	.979 (22.391)	-.733 (-6.792)	.014 (.401)	.094 (2.213)	-.034 (-.995)	.955
1741 Masonry/Stonework	1.012 (18.799)	-.838 (-6.047)	-.014 (-.375)	.066 (1.266)	-.060 (-1.399)	.943
1742 Plastering/Drywall/Insulation	1.077 (28.969)	-.952 (-10.277)	.034 (1.070)	.030 (.912)	-.026 (-.789)	.968
1743 Tile/Marble/ Mosaic Work	1.133 (9.096)	-.917 (-4.802)	-.022 (-.250)	.085 (.800)	.032 (.338)	.884
1751 Carpentering	.971 (20.277)	-.645* (-5.043)	.111 (2.356)	.184 (3.924)	.139 (2.829)	.968
1752 Floorwork	1.028 (18.725)	-.566* (-5.068)	-.002 (-.045)	.149 (2.387)	-.041 (-.704)	.944
1761 Roofing/Sheet Metal	.929 (9.630)	-.751* (-6.629)	-.005 (-.102)	.060 (1.037)	-.009 (-.188)	.815
1771 Concrete Work	1.006 (11.797)	-.874 (-5.307)	.053 (1.291)	.041 (.576)	.016 (.306)	.912
1781 Water Well Drilling	.752 (7.162)	-.128* (-.533)	-.074 (-.972)	.125 (1.108)	-.149 (-1.700)	.776
1791 Structural Steel	1.062 (21.061)	-.905 (-8.423)	.110 (2.498)	.094 (2.135)	.003 (.051)	.953
1793 Glass & Glazing	.864 (9.508)	-1.063 (-3.597)	.107 (1.419)	.025 (.317)	-.078 (-.904)	.696
1794 Excavation/ Foundations	1.108 (20.639)	-.910 (-9.417)	.001 (.033)	-.101 (-2.438)	-.161 (-3.876)	.931
1795 Wrecking/ Demolition	.933 (6.567)	-.842 (-2.870)	-.157 (-1.623)	-.105 (-.601)	-.215 (-1.688)	.865
1796 Equipment Installation	.771 (9.771)	-.045* (-.179)	-.088 (-1.278)	.033 (.417)	.147	.922

[1]Number of observations and source of data same as Table 4.1.

[2]Log L = const + α Log V + ∞ Log WC + Regional Dummies.

*Significantly different from 1 at .05 level.

**Significantly different from 1 at .10 level.

likely to use unskilled labor which can be more easily replaced by mechanization. And, it is basically these industries in which estimates of are significantly less than one in our ACMS models, as we expect from theory.

We must regard these estimates of labor demand in the construction industries as only a first step in examining employment in construction. More complete models separating labor into construction, non-construction worker categories, or including the price of capital as an explanatory variable would prove useful.

3. Aggregate Construction Sector Results

Until now we have put our main emphasis upon examining the 4 digit construction industries. However, it may also be interesting to examine aggregate production functions for the sector as a whole so we can compare our results with Cassimates' time series estimates. We have two sets of estimates. In the first set we use total construction activity information summing all the 4 digit construction industries, including Subdividers and Developers for each state. Our observations are the fifty states plus the District of Columbia. We are not able to subtract data on Subdividers and Developers from our state totals since this information is not reported by the census due to disclosure rules. In the second set, each 4 digit industry is summed for a U.S. total. Our observations are the twenty-four 4 digit industry totals plus the total for industry 1799 - Special Trade Contractors not elsewhere classified. We have excluded Subdividers and Developers. Our variables are defined as before. For the industry aggregation we introduce dummy variables for the major

a. Cobb-Douglas Results

Table 4.14 summarizes all of our Cobb-Douglas results. What is immediately obvious is the lack of agreement between the two types of aggregation. The models with observations aggregated by state, which is analogous to a 2-digit cross section study, give the poorest results, both in terms of fit and in the credibility of the estimates. We suspect that a major reason for these poor results stem from the fact that the subcontractor and developer industry is included in state totals. Recall that in this industry total payroll exceeds value added on due to the subtraction of land receipts from gross output. Another unusual characteristic of this industry is that nearly two-thirds of all workers are nonconstruction workers. This last factor may be one reason for the insignificant coefficient for construction workers in equation 5 of table 4.14. This industry also has regional concentrations, being large in a few States (California and Florida) and relatively small in most other States.

A second reason for the relatively poor results is that aggregation makes a changing composition of output and inputs by States. Each State total sums data from industries having different output elasticities, returns to scale, and elasticities of substitution. Given these fairly large differences among 4 digit industries and also between regions in size, capital intensity, etc., which we established in chapter III, it is not likely that the output and inputs are homogeneous, as the model requires.

Our estimates based upon observations by industry appear much better. In fact the simple Cobb-Douglas estimate (line 2 of

Table 4.14. Cobb-Douglas Estimates for the Construction Sector

Type of Aggregation	Coefficients of L	L_C	L_A	FK	Scale	$\bar{R}^2$	State Dummies	Industry Dummies
1. State	.734 (8.317)			.520 (5.667)	1.254*	.755	No	No
2. Industry	.901 (11.910)			.143 (3.570)	1.044	.968	No	No
3. State	.968 (11.770)			.423 (4.774)	1.391*	.848	Yes	No
4. Industry	.978 (13.461)			.169 (4.398)	1.147*	.975	No	Yes
5. State		.072 (.646)	.582 (7.762)	.463 (7.033)	1.116	.878	No	No
6. Industry		.625 (8.374)	.277 (5.217)	.135 (4.163)	1.035	.979	No	No
7. State		.365 (2.653)	.454 (5.733)	.454 (5.702)	1.243*	.897	Yes	No
8. Industry		.650 (9.817)	.301 (6.596)	.151 (5.183)	1.103*	.986	No	Yes

*Significantly different from 1 at .05 percent level.

table 4.14) agrees closely to the only prior production function study of contract construction.[17] Cassimates estimated a Cobb-Douglas production function for contract construction using time series data from 1929-64. His estimate, which incorporates a time trend to account for technological change, gives a capital coefficient of .178 and a labor coefficient of .846. Our other Cobb-Douglas models also appear to have a more reasonable set of estimates. When dummies are included for our major industry classifications there is evidence of increasing returns to scale.

Despite these seemingly good results we do not place as much weight on these estimates as we do those for the separate 4 digit industries which we reported earlier in this chapter. Our primary reason again relates to differences which we have observed between industries. Our estimates for the sector as a whole assume that all observations are from the same production function. Yet even when we restrict ourselves to the Cobb-Douglas results in our 4-digit estimates we find large differences between industries in the value of the capital and labor coefficients. Moreover our estimates suggest that both σ and the form of the production function also differ among the 4 digit industries.

b. The CES results

Table 4.15 summarized our various estimates of the elasticity of substitution. Looking first at our estimate of σ we find that, with exception of the Kmenta model without dummies, σ is higher in models in which we aggregate by state rather than industry. Our ACMS and Kmenta estimates are all less than 1, but with only one exception (line 3) this difference is not significant so we cannot reject the

Table 4.15 Estimates of the Elasticity of Substitution for the Construction Sector

Type of Aggregation	Type of Model	σ	$\bar{R}^2$	State Dummies	Industry Dummies	Comment
1. State	ACMS	.903 (18.742)	.875	No	No	
2. Industry	ACMS	.692** (3.395)	.402	No	No	
3. State	ACMS	.803* (15.211)	.902	Yes	No	
4. Industry	ACMS	.636** (3.215)	.342	No	Yes	
5. State	Kmenta[1]	.887	.750	No	No	Scale parameter = 1.258*
6. Industry	Kmenta[1]	.942	.966	No	No	Scale parameter = 1.043
7. State	Kmenta[1]	∞**	.855	Yes	No	σ set to ∞ for $\rho < -1$. Scale parameter = 1.358*
8. Industry	Kmenta[1]	.894	.973	No	Yes	Scale parameter = 1.142
9. State	VES[2]	1.466	.949	No	No	Actual estimates of parameters are: $\underset{(24.597)}{.808\ W_C} + \underset{(8.460)}{.193}\ FK/L$
10. Industry	VES[2]	.824	.724	No	No	Actual estimates of parameters are: $\underset{(4.873)}{.565\ W_C} + \underset{(5.285)}{.135\ FK/L}$
11. State	VES[2]	1.346	.951	Yes	No	Actual estimates of parameters are: $\underset{(21.144)}{.792\ W_C} + \underset{(6.832)}{.177\ FK/L}$
12. Industry	VES[2]	1.131	.818	No	Yes	Actual estimates of parameters are: $\underset{(6.428)}{.655\ W_C} + \underset{(7.293)}{.181\ FK/L}$

*Significantly different from 1 at .05 percent level. **Significantly different from 1 at the .10 percent level.
[1]Significance level of $\hat{\sigma}$ determined from squared term. [2]t values for $\hat{\sigma}$ not available.

Cobb-Douglas form from these results. These results are consistent with the Cassimates estimate which is also not significantly different from one.[18] For all the VES estimates the coefficient of the capital labor ratio is significant. The industry dummies appear to be important, increasing both the $\bar{R}^2$ and the estimate of the elasticity of substitution. The very importance of the industry dummies however brings us back to our prior conclusion that the 4 digit estimates are preferred to those presented in this section.

In this chapter we have presented our Cobb-Douglas and CES estimates. These estimates reflect numerous differences among the 4 digit industries. The results using regional dummies suggest that the geographic differences which we described in Chapter III are important in examining the construction process. Using regional dummies we find evidence of increasing returns to scale in about one fourth of the industries, primarily among special trade contractors. We have also presented evidence that the elasticity of substitution is less than one for at least six special trade subcontractors, but appears to be unity for the general building on heavy contractors. Cobb-Douglas and CES estimates using data at levels of higher aggregation were also presented. Due to the differences between 4 digit industries, and due to changing regional output mix the 4 digit estimates are preferred.

Notes to Chapter IV

1. Data from preliminary census reports were obtained from Preliminary Report 1972 Census of Construction Industries, Industry Series CC72(P), U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1974. Final reports were obtained from 1972 Census of Construction Industries, Final Industry Report, Industry Series CC72-1, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1975.

2. Griliches, Z., "Production Functions in Manufacturing: Some Additional Results", Southern Economic Journal, October, 1968, pp. 155-156.

3. Ibid.

4. For a more detailed discussion see Griliches, Z., Review of G.H. Hildebrand and T.C. Liu, Manufacturing Production Functions in the U.S., 1957," Journal of Political Economy, Vol. 74, No. 1, 1965.

5. Maisel, Sherman, Housebuilding in Transition, Berkeley: University of California Press, 1953, Chapter 8.

6. Cassimates, op. cit., p. 66.

7. Fleming, M.C., "Conventional Housebuilding and the Scale of Operations: A Study of Price", Bulletin of the Oxford Institute of Economics and Statistics, May 1967, pp. 109-137.

8. Stevens, Barbara, "Single-Site Economies in the Construction of Multi-Family Housing", Land Economics, February 1975, pp. 50-57.

9. Ibid.

10. BLS bulletin 1821, ibid.

11. We can no longer interpret the labor and capitol coefficients as output elasticities since in the CES function output elasticities are not constant. However, the sum of these coefficients is still a measure of returns to scale.

12. Griliches and Ringstad, op. cit., pp. 77-80. Also see Appendix C.

13. Maddala, G. and Kadane, J., "Estimation of Returns to Scale and the Elasticity of Substitution," Econometrica, July-October, 1967, pp. 419-423.

14. Griliches, Z., "Production Functions in Manufacturing: Some Preliminary Results", op. cit., pp. 286-290.

15. See either Lucas, op. cit., pp. 26-31 or Mayor, op. cit., pp. 153-163.

16. See Nadiri, *op. cit.*, pp. 1156-1157.

17. Cassimates, *op. cit.*, pp. 73-75.

18. *Ibid.*, p. 98.

CHAPTER V

THE ROLE OF MATERIALS

In Chapter II we indicated that in the 4 digit industries which we are examining, subcontracting services and building materials are purchased outside the industry and should be considered as inputs. The level of capital and labor services chosen by the contractor will depend in part upon the relative price of materials and subcontracting as well as the relative price of capital and labor. We also pointed out that substitution of materials for on-site labor has been identified as one of the potential sources of productivity growth in construction. In section 1 we review the various types of substitution which occur in construction. We concentrate primarily upon substitution between building materials and labor. Our goal in section 2 is to examine the elasticity of substitution between materials and the other inputs. Several models are developed and results reported.

1. Substitution in Construction

On the microeconomic level it is easy to find examples of many types of substitution in construction. In some cases substitution of materials for on-site labor is fairly obvious -- for example wallboard has been substituted for plaster thereby reducing the requirement for plasterers. But in other cases a relatively complex set of substitutions can take place for reasons which are difficult to isolate. Consider for example the substitution over

time of reinforced concrete for brick as the main structural material. This type of substitution might occur for a number of reasons such as: (1) A change in design due to changing tastes; (2) An increase in the price of bricks relative to concrete; (3) An increase in the wage rates of masons relative to concrete workers; (4) Increased mechanization or use of specialized equipment to mix, transport, or pump concrete; and (5) The use of metal or fiberglass formwork, which reduces on site carpentry and concrete finishing costs. Note that when one material is substituted for another one effect can be to change skill requirements either from one skill to another (i.e. concrete workers for masons) or from skilled to unskilled worker. Mechanization or the introduction of new building techniques may increase capital requirements but at the same time may also increase the speed of construction which changes financial costs.

An excellent study which illustrates the complexity of substitution in homebuilding is Sara Behmans' Productivity Change for Carpenters and Other Occupations in the Building of Single-Family Dwellings and Related Policy Issues.[1] One of her main objectives is to determine to what extent new building techniques influenced the employment of carpenters, and other trades over time. She compared, in the San Francisco area, single family houses constructed by small builders in 1930 using "cut and fit" method to houses constructed in 1965 which used a large number of prefabricated components. She found for carpenters and other selected on site workers that average physical labor productivity increased at a rate of 3.2 percent per year over the 35 year period. Productivity grew at a rate of 2.5 percent per year for skilled workers but at a higher rate of 6.2

per cent for unskilled workers.[2] One of her major findings was that "The advance in average physical labor productivity occurred in large part from the substitution of material for on-site labor".[3] Wall-board, aluminum windows, precut studs, prefabricated cabinets are examples of the type of substitutions being made. Other factors which influenced productivity growth were: (1) A change in the structure of the homebuilding industry toward "merchant builders" which promoted economies of scale through labor specialization and the purchase of materials in volume at a discount; and (2) Quality changes in both the materials and in the house.[4]

The pattern of substitution appears to be somewhat different in heavy construction. A Bureau of Labor Statistics study has reported that manhour requirements for highway construction per $1000 expenditure in constant 1967 dollars fell 30 percent between 1958 and 1970.[5] During the same period the wage share of contract costs increased slightly from 25.5 percent to 29.4 percent, the materials share declined from 50.6 percent to 45 percent, while the share of overhead and profits (which includes equipment, off site wage, financing, and inventory costs) increased from 25.5 percent to 29.4 percent.[6] These changes are primarily attributed to major advances in equipment and machinery (such as the slip form paving machine which reduced the requirement for both carpenters and wood) which changed both the skill and materials mix. The trend in highway construction has been toward more skilled workers in order to operate heavier, more expensive equipment. The study notes that this is different from the trend "... in building construction, where skilled workers apparently are contributing a declining share and unskilled workers an increasing share of all work performed at the site. The increasing use of prefabricated components in building construction primarily accounts for this ... by shifting skilled jobs from the site to material manufacturing plants..."[7]

From the above examples and studies it is clear not only that substitution between labor, capital and materials is occurring, but also that the process can be relatively complex, differing from one type of construction to another. In this light generalizations about substitution patterns for the sector as a whole should be treated with caution. Having issued this cavaet let us briefly mention material share trends for the sector. Both Cassimates and Sims have computed the ratio of value added to gross construction output in constant dollars. Although both admit that the price indexes they used are not totally appropriate they found that the ratio of value added to gross construction output has declined since 1947.[8] This implies that the real share of materials in gross output has risen, probably due to an increase in the use of more highly fabricated, or prefabricated materials which has replaced some onsite construction operations. In current dollars, construction materials maintained a relatively constant share (57-58 percent) of total construction activity in both the 1957 and the 1963 input-output tables.[9] This implies that the elasticity of substitution between materials and value added is unity.

2. Cobb-Douglas and CES Models

The models in this section are primarily traditional Cobb-Douglas and CES types. Estimates for a three factor Cobb-Douglas model (equation 5.1) are reported in table 5.1.

TABLE 5.1 RESULTS OF ESTIMATING $\text{Log } Y = \text{Const} + \alpha \text{ Log } L + \beta \text{ Log } FK + \gamma \text{ Log } M$

	COEFFICIENTS OF				
	L	FK	M	$\bar{R}^2$	SCALE
1521/1531 Single Family Houses/Operative Builders	.162 (1.820)	.146 (3.021)	.786 (8726)	.876	1.094
1522 • Other Residential Buildings	.106 (1.324)	.098 (2.472)	.748 (9.596)	.923	.953
1542 Industrial Buildings	.257 (2.793)	.196 (3.745)	.545 (5.894)	.954	.997
1542 Other Non-residential Buildings	.162 (1.496)	.264 (5.009)	.597 (4.837)	.883	1.033
1611 Highways & Streets	.059 (.954)	.508 (10.714)	.465 (9.420)	.953	1.032
1622 Bridge/Tunnel/ Elevated Highway	.029 (.196)	.382 (3.995)	.574 (4.718)	.944	.985
1623 Water/Sewer/ Utility lines	.227 (3.600)	.510 (7.050)	.295 (4.260)	.917	1.031
1629 Other Heavy Construction	.460 (5.708)	.189 (3.110)	.415 (6.135)	.977	1.064*
1711 Plumbing/Heating/ Air Conditioning	.133 (1.353)	.140 (2.724)	.832 (6.977)	.926	1.105*
1721 Painting/Paper Hanging	.181 (1.246)	.150 (2.244)	.692 (5.424)	.878	1.024
1731 Electrical Work	.347 (4.252)	.090 (1.698)	.643 (6.832)	.924	1.080**
1741 Masonry/Stonework	.283 (3.155)	.183 (3.007)	.556 (7.893)	.958	1.023
1742 Plastering/Drywall/Insulation	.202 (1.779)	.084 (1.444)	.758 (7.305)	.948	1.043
1743 Tile/Marble/ Mosaic Work	-.122 (-.860)	.219 (1.466)	.933 (5.326)	.899	1.011
1751 Carpentering	.333 (3.704)	.141 (2.530)	.601 (9.813)	.967	1.076
1752 Floorwork	.303 (3.039)	.021 (.382)	.643 (7.530)	.944	.968
1761 Roofing/Sheet Metal	.045 (3.63)	.102 (.969)	.661 (6.103)	.761	.808
1771 Concrete Work	.235 (2.625)	.138 (2.393)	.640 (6.801)	.936	1.013
1781 Water Well Drilling	.380 (2.013)	.172 (3.352)	.444 (3.437)	.910	.996
1791 Structural Steel	.505 (3.299)	.245 (2.001)	.306 (6.837)	.923	1.055
1793 Glass & Glazing	.227 (1.990)	.033 (.423)	.663 (5.161)	.914	1.008
1794 Excavation/ Foundations	.114 (1.277)	.470 (5.876)	.425 (6.373)	.927	.923
1795 Wrecking/ Demolition	.662 (4.973)	.521 (4.634)	.067 (.455)	.836	1.250
1796 Equipment Installation	.877 (5.808)	.030 (.449)	.254 (3.037)	.925	1.160**

[1]Number of observations and source of data same as Table 4.1.

*Significantly different from 1 at .05 level.

**Significantly different from 1 at .10 level.

$$\text{Log } Y = \text{const} + \alpha \text{ Log } L + \beta \text{ Log } FK + \gamma \text{ Log } M \qquad (5.1)$$

Our results for this model, adding regional dummies as explanatory variables, are reported in table 5.2. Both sets estimates may be compared to our results using value added as the dependent variable, which we reported in tables 4.1 and 4.3 in Chapter IV. The coefficient for materials is significant in every industry except (as we would expect) Wrecking and Demolition Subcontractors. Materials appear most important relative to labor and capital for general building contractors. For a number of special trade contractors, the capital coefficient is significant in the value added models but not significant when materials are included as an input. In table 5.1 there are only eight industries in which all coefficients are significant. Adding regional dummies increase the number of industries in which all coefficients are significant to ten.

Like the value added models, adding regional dummies raises the number of industries having increasing returns to scale. Interestingly, increasing returns to scale become significant for the general building contractor of single family houses/operative builders industry. We also notice the same pattern here as in Chapter IV. Adding regional dummies has generally raised the labor coefficient, and in this case lowered both the capital and materials coefficient. In tables 5.1 and 5.2 the number of industries in which all coefficients are significant is much lower than for our value added estimates.

Several factors probably account for these results. Materials usage may often be so closely associated with fluctuations in gross output that when materials are included as an input the effect of

TABLE 5.2 RESULTS OF ESTIMATING $\text{Log } Y = \text{const} + \alpha \text{ Log } L + \beta \text{ Log } FK + \gamma \text{ Log } M$ WITH REGIONAL DUMMIES

	L	FK	M	CENTRAL	SOUTH	WEST	SCALE	$\bar{R}^2$
1521/1531 Single Family Houses/Operative Builders	.258 (2.666)	.084 (1.678)	.794 (8.841)	-.026 (-.516)	-.092 (1.739)	.059 (1.257)	1.135	.904
1522 Other Residential Buildings	.223 (2.501)	.094 (2.459)	.704 (9.054)	.009 (.167)	-.118 (-2.102)	-.029 (-.518)	1.021	.930
1542 Industrial Buildings	.311 (2.843)	.140 (2.437)	.569 (5.783)	-.091 (-1.847)	-.131 (-2.479)	-.058 (-1.136)	1.021	.958
1542 Other Non-residential Buildings	.184 (1.494)	.221 (3.505)	.648 (4.946)	-.058 (-1.045)	-.087 (-1.534)	-.035 (-.638)	1.053	.882
1611 Highways & Streets	.161 (2.376)	.390 (6.459)	.487 (10.109)	.003 (.059)	-.084 (-1.805)	.051 (.997)	1.038	.960
1622 Bridge/Tunnel/ Elevated Highway	.133 (1.093)	.334 (4.740)	.513 (5.443)	-.204 (-3.127)	-.258 (-4.145)	-.045 (-.511)	.980	.971
1623 Water/Sewer/ Utility lines	.368 (5.539)	.420 (6.293)	.256 (4.396)	-.074 (-1.454)	-.177 (-3.578)	.003 (.067)	1.044	.943
1629 Other Heavy Construction	.459 (6.099)	.214 (4.033)	.396 (6.384)	.026 (.443)	-.129 (-2.254)	.024 (.387)	1.068	.983
1711 Plumbing/Heating/ Air Conditioning	.334 (3.507)	.094 (2.085)	.708 (6.766)	-.017 (-.503)	-.140 (-4.387)	-.028 (-.829)	1.137*	.949
1721 Painting/Paper Hanging	.522 (3.244)	.121 (1.920)	.495 (3.858)	.003 (.056)	-.159 (-2.767)	.043 (.536)	1.139	.907
1731 Electrical Work	.576 (7.429)	.055 (1.358)	.503 (6.403)	-.029 (-.795)	-.184 (-4.903)	-.012 (-.315)	1.134	.958
1741 Masonry/Stone-work	.469 (3.803)	.132 (2.224)	.456 (5.359)	-.031 (-.718)	-.157 (-2.878)	-.081 (-1.730)	1.058	.966
1742 Plastering/Dry-wall/Insulation	.277 (2.709)	.087 (1.490)	.682 (7.769)	-.035 (-.884)	-.136 (-3.840)	-.109 (-2.523)	1.046	.965
1743 Tile/Marble/ Mosaic Work	.056 (.382)	.087 (.669)	.773 (4.700)	-.007 (-.101)	-.166 (-2.835)	-.116 (-1.747)	.916	.941
1751 Carpentering	.601 (5.791)	.005 (.098)	.526 (9.320)	-.001 (-.021)	-.185 (-3.217)	-.129 (-2.444)	1.131*	.979
1752 Floorwork	.404 (4.905)	.029 (.678)	.583 (8.308)	.001 (.021)	-.158 (-3.220)	-.035 (-.714)	1.016	.966
1761 Roofing/Sheet Metal	.024 (.130)	.076 (.730)	.818 (5.526)	-.064 (-1.122)	-.123 (-2.122)	-.199 (-2.811)	.918	.832
1771 Concrete Work	.442 (4.243)	.125 (2.389)	.561 (7.573)	-.064 (-1.536)	-.189 (-4.114)	-.037 (-.791)	1.127**	.957
1781 Water Well Drilling	.403 (2.740)	.140 (3.170)	.493 (4.512)	.091 (2.049)	-.060 (-1.242)	.076 (1.506)	1.036	.950
1791 Structural Steel	.458 (3.614)	.310 (3.009)	.263 (6.197)	-.041 (-.041)	-.199 (-3.210)	-.053 (-.657)	1.030	.950
1793 Glass & Glazing	.372 (2.954)	.041 (.481)	.567 (3.953)	-.075 (-1.307)	-.078 (-1.376)	.059 (.800)	.980	.927
1794 Excavation/ Foundations	.193 (1.780)	.441 (5.357)	.395 (5.439)	.002 (.052)	-.034 (-.847)	.045 (.959)	1.029	.927
1795 Wrecking/ Demolition	.895 (6.206)	.413 (3.942)	.063 (.504)	.032 (.297)	-.244 (-2.170)	.168 (1.107)	1.371*	.881
1796 Equipment Installation	.921 (6.679)	-.048 (-.619)	.260 (3.296)	.071 (.946)	-.110 (-.994)	-.120 (-.943)	1.134	.940

[1]Number of observations and source of data same as Table 4.1.

*Significantly different from 1 at .05 level.

**Significantly different from 1 at .10 level.

materials is so dominant that the role of the other inputs is obscured. This would appear to be the case for a number of our industries. In both the general and heavy contractors, and in most of those special trade contractors in which capital is important, it is primarily the labor coefficient which is not significant. The reverse is the case for those of the special trade contractors in which capital is not very important. Increased multicollinearity between the inputs is also a factor in reducing the significance level of the coefficients. Finally, if short run fluctuations in demand influence material usage more than capital or labor usage then materials are more endogeneous than labor or capital. Using materials as an independent variable may lead to greater simultaneous equation bias.[10] For those industries in tables 5.1 and 5.2 having constant returns to scale we attempted to improve our results using a model in which the sum of the output elasticities is constrained to equal unity. We estimated:

$$\text{Log } Y - \text{Log } M = \text{const} + \alpha[\text{Log } L - \text{Log } M] + \beta[\text{Log } \dot{F}K - \text{Log } M] \quad (5.2)$$

This transformation constrains the coefficient of Log M in equation 5.1 to be $(1 - \alpha - \beta)$. Unfortunately, this model either with or without regional dummies, did not improve our previous estimates. Although the value of the coefficients changed slightly due to the constraint, we were not able to add to the number of industries having significant coefficients for all three inputs. Our investigation of CES models is limited since the only input price available is the construction wage, thus we rely on the Kmenta type of linearization of the CES function. The simplest model is analogous to the estimating equation used to estimate the elasticity of substitution between capital and labor. We use:

$$\text{Log } Y = \text{Log } \gamma + v\delta \text{ Log } M + v(1-\delta)\text{Log } L - \frac{1}{2}\rho v\delta(1-\delta)[\log M - \log L]^2 \quad (5.3)$$

We also used V^* (gross output less capital service) as a dependent variable. Our estimates are presented in tables 5.3 and 5.4. For the majority of industries the coefficient of the squared term is not significant so we cannot reject the Cobb-Douglas hypothesis that $\sigma_{ML} = 1$. Where this coefficient is significant either the labor or material coefficient is negative - the wrong sign. Moreover, in almost every industry at least one coefficient is not significant. Since the value of σ_{ML} relies upon the significance levels of these coefficients our estimates of σ_{ML} are not likely to be very accurate. We also experimented with more complex Kmenta models of a type suggested by Griliches and Ringstad.[11] For example we assumed that materials and labor together formed a composite input. We then formed what Griliches and Ringstad term the "nested" CES function:

$$Y = AK^{\beta}[\delta M^{-\rho} + (1 - \delta)L^{-\rho}]^{-v/\rho} \quad (5.4)$$

By expanding around $\rho = 0$ we could derive a Kmenta type estimating equation involving $[\log M - \log L]^2$. However these results, and results involving a similar function having a $[\log M - \log FK]^2$ term were both unsuccessful. We suspect that this lack of success is due to primarily to errors in measurement of variables used in the non-linear approximations. In the case of simple regression such errors will tend

TABLE 5.3 RESULTS OF ESTIMATING $\text{Log } Y = \text{const} + \alpha \text{ Log } L + \beta \text{ Log } M - A\gamma[\text{Log } M - \text{Log } L]^2$ [1]

	L	M	$(M/L)^2$	$\bar{R}^2$	σ_{ML}
1521/1531 Single Family Houses/Operative Builders	-1.798 (-1.128)	2.889 (1.806)	-.388 (-1.298)	.857	1.195
1522 Other Residential Buildings	-1.094 (-.852)	1.965 (1.537)	-.230 (-.936)	.912	1.229
1542 Industrial Buildings	.225 (.095)	.708 (.299)	-.023 (-.048)	.938	.788
1542 Other Non-residential Buildings	3.814 (2.045)	-2.813 (-1.497)	.745 (1.895)	.834	.878
1611 Highways & Streets	-2.350 (2.404)	-1.456 (-1.502)	.440 (2.054)	.849	.813
1622 Bridge/Tunnel/ Elevated Highway	.538 (.132)	.405 (.099)	.041 (.054)	.905	1.550
1623 Water/Sewer/ Utility lines	1.199 (4.027)	-.262 (.801)	.189 (2.350)	.832	.470
1629 Other Heavy Construction	1.542 (2.332)	-.546 (-.810)	.224 (1.499)	.972	.654
1711 Plumbing/Heating/ Air Conditioning	3.764 (1.316)	-2.673 (-.935)	.723 (1.281)	.917	.864
1721 Painting/Paper Hanging	.254 (.410)	.715 (1.190)	.074 (.302)	.860	.857
1731 Electrical Work	-2.315 (-2.305)	3.418 (3.362)	-.531 (-2.651)	.931	1.047
1741 Masonry/Stonework	-.209 (-.355)	1.221 (2.126)	-.160 (-.920)	.948	∞[2]
1742 Plastering/Drywall/Insulation	-.697 (-.346)	1.720 (.858)	-.227 (-.453)	.945	1.632
1743 Tile/Marble/ Mosaic Work	3.581 (1.068)	-2.635 (-.783)	.863 (1.104)	.891	.852
1751 Carpentering	.076 (.163)	1.033 (2.164)	-.122 (-.823)	.959	.225
1752 Floorwork	1.030 (.668)	-.065 (-.043)	.147 (.470)	.944	.191
1761 Roofing/Sheet Metal	-2.645 (-1.740)	3.401 (2.224)	-.607 (-1.754)	.777	1.114
1771 Concrete Work	2.385 (2.898)	-1.422 (-1.746)	.539 (2.657)	.938	.766
1781 Water Well Drilling	2.547 (.914)	-1.640 (-.590)	.419 (.768)	.856	1.222
1791 Structural Steel	1.004 (5.214)	.008 (.038)	.106 (1.594)	.919	∞[2]
1793 Glass & Glazing	1.576 (.567)	-.625 (-.229)	.247 (.483)	.915	.677
1794 Excavation/ Foundations	1.041 (1.021)	-.165 (-.160)	.213 (.707)	.859	.265
1795 Wrecking/ Demolition	.450 (.608)	.744 (.821)	-.272 (.466)	.572	.606
1796 Equipment Installation	2.864 (5.055)	-1.741 (-3.011)	.415 (3.451)	.957	.843

[1] Number of observations and source of data same as Table 4.1.

[2] σ_{ML} set to ∞ when $\rho < -1$.

TABLE 5.4 RESULTS OF ESTIMATING $\text{Log } V^* = \text{const} + \alpha \text{ Log } L + \beta \text{ Log } M - \gamma[\text{Log } M - \text{Log } Y]^2$

	L	M	$(M/L)^2$	$\bar{R}^2$	σ_{ML}
1521/1531 Single Family Houses/Operative Builders	-1.766 (-1.105)	2.862 (1.785)	-.377 (-1.261)	.858	1.195
1522 Other Residential Buildings	-.804 (.600)	1.712 (1.283)	-.177 (-.689)	.911	1.305
1542 Industrial Buildings	.612 (.260)	.335 (.143)	.056 (.117)	.940	1.119
1542 Other Non-residential Buildings	3.851 (2.100)	-2.578 (-1.547)	.754 (1.952)	.836	.838
1611 Highways & Streets	2.100 (2.314)	-1.170 (-1.300)	.398 (2.001)	.879	.768
1622 Bridge/Tunnel/Elevated Highway	.419 (.103)	.522 (.127)	.028 (.038)	.905	1.317
1623 Water/Sewer/Utility lines	1.196 (4.038)	-.255 (-.783)	.191 (2.380)	.834	.459
1629 Other Heavy Construction	1.421 (2.117)	-.387 (-.567)	.194 (1.277)	.973	.578
1711 Plumbing/Heating/Air Conditioning	3.610 (1.254)	-2.511 (-.873)	.690 (1.215)	.917	.857
1721 Painting/Paper Hanging	.085 (.136)	.892 (1.477)	-.007 (-.028)	.858	.847
1731 Electrical Work	-2.342 (-2.304)	3.450 (3.353)	-.538 (-2.655)	.930	1.173
1741 Masonry/Stonework	-.164 (-.278)	1.177 (2.047)	-.147 (-.844)	.948	∞^2
1742 Plastering/Drywall/Insulation	-.802 (-.394)	1.829 (.906)	-.253 (-.502)	.945	1.549
1743 Tile/Marble/Mosaic Work	3.567 (1.058)	-2.615 (-.772)	.860 (1.095)	.891	.851
1751 Carpentering	.078 (.167)	1.031 (2.171)	-.119 (-.810)	.960	.246
1752 Floorwork	.925 (.589)	.048 (.031)	.125 (.380)	.945	∞^2
1761 Roofing/Sheet Metal	-2.687 (-1.727)	3.457 (2.209)	-.620 (-1.747)	.773	1.115
1771 Concrete Work	2.155 (2.544)	-1.164 (-1.389)	.476 (2.27)	.937	.727
1781 Water Well Drilling	1.544 (.622)	-.566 (-.229)	.215 (.442)	.898	.675
1791 Structural Steel	1.001 (5.009)	.007 (.033)	.111 (1.609)	.916	∞^2
1793 Glass & Glazing	1.455 (.515)	-.513 (-.184)	.224 (.430)	.910	.578
1794 Excavation/Foundations	.727 (.692)	.193 (.182)	.128 (.413)	.865	∞^2
1795 Wrecking/Demolition	.697 (.970)	.536 (.609)	-.162 (-.286)	.631	.483
1796 Equipment Installation	2.864 (5.041)	-1.745 (-3.009)	.418 (3.468)	.956	.845

[1]Number of observations and source of data same as Table 4.1.

[2]σ_{ML} set to ∞ when $\rho < -1$.

to bias the coefficients toward zero. Griliches and Ringstad have investigated the degree of bias possible for non-linear estimating procedures such as the Kmenta method and have concluded that "... errors in variables are bad enough in linear models. They are likely to be disastrous to any attempts to estimate additional non-linearity or curvature parameters."[12]

In conclusion, in section 1 of this chapter we were able to demonstrate that substitution of materials for other inputs in construction is complex, has occurred, and differs by type of construction. For the sector as a whole the elasticity of substitution between materials and value added appears to be greater than unity. Our findings in section 2 of this chapter are inconclusive. The three factor Cobb-Douglas results suggest that in at least eight and possibly ten of our industries that we can not reject the hypothesis that the elasticity of substitution between materials and the other inputs is one. The Kmenta results reported in tables 5.3 and 5.4 also suggest this result.

Certainly one factor which is probably affecting our results is the relatively narrow classification of our 4 digit industries. But as we suggest in Chapter IV aggregation for the sector as a whole is not likely to resolve the problem. It does not. We will only report a few results. For example, our three factor Cobb-Douglas results are:

Table 5.5. Aggregate Three Factor Cobb-Douglas Estimates

Type Aggregation	Coefficient of			
	L	FK	M	$\bar{R}^2$
State	.133 (1.460)	.240 (4.736)	.775 (8.127)	.921
Industry	.586 (6.763)	.114 (3.814)	.317 (6.530)	.984

In the State aggregation our labor coefficient is small and not significant. When regional dummies are added the coefficient is significant at the .05 percent level but its value remains small (.286). The industry aggregation results appear better, but our criticism of the industry aggregation in Chapter IV also holds here. Our 4 digit industry estimates reported in this chapter reflect large differences in the construction process among the 4 digit industries. Thus it is not likely that the same homogeneous production function holds for all industries.

Our estimates of the elasticity of substitution between materials and labor (σ_{ML}) using the Kmenta type model (equation 5.3) appear to have reasonable values using either Log Y or Log V^* as the dependent variable for either type of aggregation. For the state aggregation σ_{ML} is .871 using Log Y as the dependent variable and .785 using Log V^* as the dependent variable. For the industry aggregation σ_{ML} is .667 using Log Y as the dependent variable and .583 using Log V^*. The squared term is not significant for the State aggregation, but significant for the Industry aggregation. Thus for our CES estimates the State aggregation, which has a value of σ_{ML} closer to unity,

appears better than the industry aggregation since the weight of our prior evidence suggests a value of σ_{ML} around unity. Neither the State nor the Industry aggregation estimates are likely to be accurate however, since for both sets of regressions the coefficient of Log M is not significant and is negative - the wrong sign.

Given our evidence of substitution in section 1, our results in section 2 are rather discouraging. Our problems stem from limitations in both our construction data and in the models which we have employed. In order to better questions concerning substitutability, better data and more appropriate models are needed. In our concluding chapter we will briefly address these issues.

Notes to Chapter V

1. Behman, Sara, Productivity Change for Carpenters and Other Occupations in the Building of Single-Family Dwellings and Related Policy Issues, Center for Labor Research and Education, Institute of Industrial Relations, University of California, Berkeley, California, 1971.

2. Ibid., pp. xv - xvi.

3. Ibid., p. xvii.

4. Ibid., p. 103.

5. Ball, Robert, "Labor and Materials required for Highway Construction", Monthly Labor Review, June 1973, pp. 42-45.

6. Ibid., p. 43.

7. Ibid., p. 42.

8. Cassimates, Op cit., pp. 103-104 and Sims, op. cit. p. 159. Sims also has a particularly good discussion of the problems associated with deriving an appropriate price indices in construction.

9. Kingie, George, "Construction Input-Output Profile", Construction Review, August 1970, pp. 4-8.

10. See Griliches and Ringstad, Economies of Scale and the Form of the Production Function, op. cit. pp. 108-109, for more detail on this topic.

11. Ibid., p. 119-121.

12. Ibid., p. 199.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Our objective in this thesis has been to examine the Contract Construction Industries using Cobb-Douglas and CES production functions to analyze new data on contract construction which has recently become available in the 1972 Census of Construction Industries. In Chapter II we explained the theoretical models used. In a production function framework a number of strongly simplifying assumptions are necessary. We asserted that the relatively narrow 4 digit classification in the Contract Construction Industries and the fairly large number of observations make our data superior to that used in manufacturing studies. We also showed that there was a considerable regional variation in wage rates and input ratios, which is important for identifying the production function cross sectionally. However, our data is less satisfactory than most manufacturing data for examining differences in the skill level or quality of labor and for examining technological change.

A set of interrelated factors influences construction, such as skill composition, design, size of establishment, degree of unionization, degree of urbanization, and size of construction project, all of which may vary regionally. We describe these factors in Chapter III, but we are not able to specify these factors as variables in

the production function. Instead, we introduce regional dummy variables to reduce error due to misspecification.

We presented our estimates in Chapter IV. We had some difficulty in estimating all of the parameters of interest. We were not able to estimate the effects of changes in capital vintage and had only limited success in examining the separate influence of construction and nonconstruction workers. Our estimates of σ using the Kmenta, ACMS and VES models often differed. Despite these estimation difficulties we were able to learn a great deal about the structure of the construction industries. The following paragraphs summarize the more important conclusions.

Our findings suggest that the elasticity of substitution between capital and labor is less than one for nearly half of the special trade contractors. In contrast for most of the general building contractors and for heavy construction contractors we cannot reject the hypothesis that σ is unity. Differences in σ between industries imply that over time if wage rates increase faster than the price of capital that factor shares and the distribution of employment will change. Our findings suggest that since capital is less easily substituted for labor by special trade contractors that employment within the sector should increase for special trade contractors relative to general building and heavy construction contractors. This indeed has been the case. Mills has computed the change in the distribution of employment between the 1939 and the 1967 Census of Construction Industries. Employment declined from 28.4 to 25.7 percent for general building contractors, and from 27.6 to 25.6 percent for heavy contractors. Employment increased from 42.1 to

46.7 percent for special trade contractors.[1] We computed the change in the distribution of employment between the 1967 and the 1972 census (using the 1972 SIC classification). Employment increased slightly from 27.3 to 27.7 percent for general building contractors, declined from 23.1 to 20.0 percent for heavy contractors, and increased from 49.0to 50.8 percent for special trade contractors. Although these figures are also influenced to a certain extent by differences in the composition of total construction output in the census years, the shift in the distribution of employment toward special trade contractors is clearly evident.

There has been an opposite trend in construction receipts over time. Between 1939 and 1957 Mills showed that the general building contractor share of net construction receipts increased from 26 to 36 percent while the special trade contractor share declined from 44.3 to 34.3 percent. The heavy contractors share declined from 27.3 to 25.3 percent. These trends lead Mills to conclude "... that certain elements of nonresidential building construction (that branch of the industry in which general contracting is most prevalent) have shown high rates of productivity growth since 1939."[3] Our findings imply that one source of this productivity growth has been the ability of the general building contractors to substitute capital for labor more easily than the special trade contractors.

A second major finding of our study is that there are probably increasing returns to scale for a number of the special trade contractors. These findings depend upon accepting our estimates including regional dummies as explanatory variables. We have cited evidence from other studies of economies of scale in single, and multiple family residential construction. Cassimates, using the survivorship technique was not able to detect economies of scale for corporate firms in construction between the years 1954 - 64.[4] He attributes the lack of economies of scale as an institutional problem associated with the subcontracting system. Deu to the bidding system the working relationship between the subcontractor and the general building contractor often terminates with the end of the construction project. Thus it is more difficult for general contractors to maintain or develop organizational efficiency from one project to the next.[5] We attribute our findings of increasing returns to scale in the subcontracting industries to more economical use of skilled labor and greater utilization of complicated and specialized construction equipment. Our findings do not contradict Cassimates. Rather the benefits of increasing returns to scale in the subcontracting industries may be in part dissipated by institutional factors. A frequently made policy suggestion is for the government to take action to stabilize construction demand. This policy would promote a more stable employment of both workers and equipment in Contract Construction and in major supplying industries. Our findings suggest that such a policy might also promote economies of scale in construction. Policies which expand the local market (such as elimination of conflicting building codes in nearby communities) or changes in the contractural system which encourage closer

coordination between general contractors and subcontractors would also allow greater opportunity for further economies of scale.

Our third major finding concerns the great diversity within the construction sector between the 4 digit industries and by geographic region. Of course our finding of diversity is not new. For example, Mills has stated "... construction is less a single industry than a complex and shifting conglomeration of many different specialities - each with its own employment and industrial relations policies."[6] But our production function framework allows us to examine such diversity in a slightly different light. Different elasticities of substitution for our 4-digit industries imply that tax policies which influence wages or the price of capital will have different impacts in different industries. In Chapter IV we briefly investigated the demand for labor in our 4-digit industries. We have also contrasted the 4-digit industry estimates, and estimates based on higher levels of aggregation. These results suggest that more aggregate studies of the construction sector as a whole - such as time series by Cassimates must be interpreted with caution.

In Chapter V we provided evidence that substitution of materials for labor and capital occurs, often in a complex way which differs from one process to another. But we were not very successful using our production function techniques to shed much light concerning the value of the elasticity of substitution between materials and the other inputs. It would appear that σ_{ML} differs between industries although for many we cannot reject the hypothesis that it is unity. For the sector as a whole σ_{MV} is probably one. But these "findings" are more like suspicions than conclusions. Better data and better models are needed to more appropriately answer these questions.

More comparable construction data is necessary. The Bureau of Labor Statistics Bulletins on labor and material requirements for specific building types are especially valuable. More than one per year should be issued and their scope expanded in several ways. For example, more complete information should be collected on the degree of unionization in the sample. More detail concerning the types of prefabrication would also be helpful. These surveys, along with Bureau of the Census information on building characteristics should be used to develop both hedonic price indices on types of construction and regional materials price and wage indices for specific types of construction.

A new type of production function model which appears promising for use in construction is the translog production function.[8] It is a multi-factor function which allows estimation of Allen partial elasticicies of substitution between inputs. However like other production functions some strong simplifying assumptions are required. Constant returns to scale are assumed, and estimation uses the condition that factor shares add to one. The parameters of the function are estimated from a set of semi-logarithmic equations which require data on physical inputs and factor shares. The share of capital is taken as a residual. This may pose a special problem in construction since we have noted that the share of capital in valued added computed as a residual appears much larger than it should be. Thus construction data may be no more appropriate for this type of function than the ones which we have used. Despite these potential problems the translog function may turn out to be a good vehicle for examining substitution of materials with other inputs.

Notes to Chapter VI

1. Mills, D. Quinn, _Industrial Relations and Manpower in Construction_, _op_. _cit_., pp. 10-12.

2. _ibid_.

3. _ibid_., p. 10.

4. Cassimates, pp. 58-60.

5. _ibid_., p. 68.

6. Mills, p. 141.

7. Sims, _op_. _cit_., has an excellent discussion of other statistical needs in construction.

8. For a discussion of this function which summarizes its major properties see, Berndt, Ernst R., and Christensen, Laurits R., "The Translog Function and the Substitution of Equipment, Structures, and Labor in U.S. Manufacturing 1929-68", _Journal of Econometrics_, 1 (1973), pp. 81-114.

BIBLIOGRAPHY

BIBLIOGRAPHY

Ball, Robert, "Labor and Material Requirements for Apartment Construction", Monthly Labor Review, January 1975, pp. 70-73.

Ball, Robert, "Labor and Materials Required for Highway Construction", Monthly Labor Review, June 1973, pp. 42-45.

Behman, Sara, Productivity Change for Carpenters and Other Occupations in the Building of Single-Family Dwellings and Related Policy Issues, Center for Labor Research and Education, Institute of Industrial Relations, University of California, Berkeley, California, 1971.

Berndt, Ernst R., and Christensen, Laurits R., "The Translog Function and the Substitution of Equipment, Structures, and Labor in U.S. Manufacturing 1929-68", Journal of Econometrics 1, 1973, pp. 81-114.

Bridge, J.L., Applied Econometrics, North-Holland Publishing Co., Amsterdam, 1971.

Cassimates, Peter, Economics of the Construction Industry, The National Industrial Conference Board, Studies in Business Economics, No. 111, New York, 1969.

Colean, M., and Newcomb, R., Stabilizing Construction: The Record and the Potential, McGraw-Hill, New York, 1952.

Dacy, Douglas, "Productivity and Price Trends in Construction since 1947", Review of Economics and Statistics, November, 1965, pp. 406-411.

Dietz, Alfred, The Building Industry, prepared for the Commission on Urban Problems, Department of Architecture, M.I.T., Cambridge, 1968.

Domar, Evsey, Comment in The Theory and Empirical Analysis of Production, Murry Brown, ed., NBER Studies in Income and Wealth, Vol. 31, Columbia University Press, New York, 1967, pp. 471-472.

Ferguson, C.E., The Neoclassical Theory of Production and Distribution, Cambridge University Press, Cmabridge, England, 1969.

Fleming, M.C., "Conventional Housebuilding and the Scale of Operations: A Study of Price", Bulletin of the Oxford Institute of Economics and Statistics, May, 1969, pp. 109-137.

Goldblatt, Abraham, "Construction in 1972", Construction Review, April, 1973, pp. 4-9.

Goldblatt, Abraham, "Profile of New One-Family Homes", Construction Review, February, 1973, pp. 4-8.

Gordon, R.J., "A New View of Real Investment in Structures, 1919-1966", Review of Economics and Statistics, November, 1968, pp. 417-428.

Griliches, Zvi, A review of G.H. Hildebrand and T.C. Liu, "Manufacturing Production Functions in the U.S., 1957", Journal of Political Economy, January-February, 1965, pp. 100-101.

Griliches, Zvi, "Production Functions in Manufacturing: Some Additional Results", The Southern Economic Journal, October, 1968.

Griliches, Zvi, "Production Functions in Manufacturing: Some Preliminary Results", in Murray Brown, ed., The Theory and Empirical Analysis of Production, NBER Studies in Income and Wealth, Vol. 31, New York, 1967.

Griliches, Zvi, and Ringstad, V., Economies of Scale and the Form of the Production Function, North-Holland Publishing Co., Amsterdam, 1971.

Haber, W., and Levinson, H., Labor Relations and Productivity in the Building Trades, Bureau of Industrial Relations, University of Michigan, Ann Arbor, 1956.

Kingie, George, "Construction Input-Output Profile", Construction Review, August, 1970, pp. 4-8.

Kmenta, J., Elements of Econometrics, The Macmillan Co., New York 1971.

Liu, Ta-Chung, and Hildebrand, George, Manufacturing Production Functions in the United States, 1957, New York State School of Industrial and Labor Relations, Cornell University, Ithaca, 1965.

Lucas, Robert E., Substitution Between Labor and Capital in U.S. Manufacturing, unpublished doctoral dissertation, University of Chicago, 1964.

Maddala, G., and Kadane, J., "Estimation of Returns to Scale and the Elasticity of Substitution", Econometrica, July-October, 1967, pp. 419-423.

Maisel, Sherman, Housebuilding in Transition, University of California Press, Berkeley, 1953.

Marschak, J., and Andrews, W., "Random Simultaneous Equations and the Theory of Production", Econometrica, July-October, 1944, pp. 143-205.

Mayor, Thomas, "Some Theoretical Difficulties in the Estimation of the Elasticity of Substitution from Cross-Section Data", Western Economic Journal, June, 1969, pp. 153-163.

Mills, D. Quinn, Industrial Relations and Manpower in Construction, M.I.T. Press, Cambridge, 1972.

Minasian, Jora, "Elasticities of Substitution and Constant Output Demand Curves for Labor", Journal of Political Economy, June, 1961, pp. 261-270.

Nadiri, M. Ishaq, "Some Approaches to the Theory and Measurement of Total Factor Productivity: A Survey", Journal of Economic Literature, December, 1970, pp. 1137-1177.

Nerlove, Marc, "Recent Empirical Studies in the CES and Related Production Functions" in Murray Brown, ed., The Theory and Empirical Analysis of Production, NBER Studies of Income and Wealth, Vol. 31, New York, 1967.

Rossow, Janet, and Moavenyadah, Fred, The Construction Industry, Department of Civil Engineering, M.I.T., Cmabridge, 1974.

Sims, Christopher, "Efficiency in the Construction Industry", in the President's Committee on Urban Housing, Technical Studies: Housing Costs, Production Efficiency, Finance, Manpower, Land, Vol. II, U.S. Government Printing Office, Washington, D.C., 1968, pp. 145-176.

Solow, R.M., "A Contribution to the Theory of Economic Growth", Quarterly Journal of Economics, February, 1956, pp. 65-94.

Stevens, Barbara, "Single-Site Economies in the Construction of Multi-Family Housing", Land Economics, February, 1975, pp. 50-57.

Studies by the Staff of the Cabinet Committee on Price Stability, U.S. Government Printing Office, Washington, D.C., 1969.

U.S. Bureau of Labor Statistics, Compensation in the Construction Industry, Bulletin 1656, Washington, D.C., 1970.

U.S. Bureau of Labor Statistics, Industry Wage Survey: Contract Construction September, 1972, Bulletin 1853, Washington, D.C., 1975.

U.S. Bureau of Labor Statistics, Labor and Material Requirements for Public Housing Construction 1968, Bulletin 1821, Washington, D.C., 1974.

U.S. Bureau of the Census, 1972 Census of Construction Industries, Final Industry Reports, Industry Series CC72-I, Washington, D.C., 1975.

U.S. Bureau of the Census, Preliminary Report, 1972 Census of Construction Industries, Industry Series CC 72(P), Washington, D.C., 1974-75.

U.S. Bureau of the Census, U.S. Census of Population; 1970, Number of Inhabitants, Final Report PC(1)-A1, United States Summary, Washington, D.C., 1971.

Zellner, A., Kmenta, J., and Dreze, J., "Specification and Estimation of Cobb-Douglas Production Function Models", Econometrica, October, 1966, pp. 784-95.