Title
The Production Function in the Public Sector: Production of Postal Services in the United States Post Office

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Publication Date
1971

Peer reviewed

Monograph No. 14

The Production Function in the Public Sector: Production of Postal Services in the United States Post Office

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January 1971

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FOREWORD

There are a few comments I would like to make 18 months after completing this study.

The emphasis of the work changes from that of assessing efficiency of particular offices to the question of economies of scale. One interested in the efficiency question would estimate an efficient production frontier, deviations from which can only be positive. This can better be done through mathematical programming than through econometric techniques.

There are some unresolved issues involved here with labor markets. Some of our econometric results indicate that post offices use more labor where wages are higher. This is uneconomic behavior in long-run equilibrium but might happen in the short run if labor quality is lower where the wages are higher. Labor quality warrants further study.

New data have become available through the Post Office's Postal Source Data System. Superior output measures are now available in the Work Load Recording System.

I should acknowledge the extensive comments given me by Henri Tulkens of Louvain, Belgium and the fruitful liaison I have had with the Post Office through John Martin, Peter Freck and Robert Cohen of the Institute for Defense Analyses.

Leonard Merewitz

November, 1970

ABSTRACT

I studied 156 of the largest post offices in the U.S. to demonstrate the usefulness of comparisons of performance among remote offices providing a service in the public sector. Performance indicators are needed for such enterprises because the usual market test of profitability is absent.

Two types of post-office activity were defined: Intra, consisting of mail processing and window services, and extra, consisting of collection and delivery. Production correspondences were specified for each activity, the factors being labor, mechanization or vehicles, and floorspace; and the outputs, physical types of mail, such as outgoing cancelled letters and incoming parcels, and window services.

Offices are assumed to face a quasi-concave programming problem of minimizing costs subject to output constraints and factor prices. Alternative transformation functions such as the "transcendental" and "CES" were explored. Both have the proper curvature in output space and the CES was adjudged preferable to the Cobb-Douglas which was used in the bulk of the study. The same qualitative results on returns to scale were found whatever the functional form employed.

Major findings are that there are increasing returns to scale in both intra and extra office activity in small and medium offices. In the largest fifty offices there are decreasing returns to scale. The optimal size office seems to be about 1400 employees. Most of the country's 32,000 offices ought to be merged where possible, but the largest ought to be decentralized. If the usual procedure of estimating a single cost function for the entire sample were used, the richness of the data would

not have been uncovered for the only result to emerge would be decreasing returns to size of office over all. A natural reduced form to estimate is the set of derived demands for factors, but cost functions are more efficient and more economical of parameters to estimate.

The central performance indicator discussed was costliness, a comprehensive measure subsuming productivity (or technical efficiency) and input effectiveness (or price efficiency). If an office is technically efficient it is on the production frontier. If it is price efficient, it uses inputs in the correct proportions given factor prices. Adjusted costliness figures were derived so that offices which faced high factor prices were not unduly penalized. There were significant differences among the fifteen postal regions in costliness adjusted for factor price variation and productivity but not in input effectiveness. This suggests that post offices, being run according to a Postal Manual, are of uniform management efficiency but that certain offices hired inferior factors. Indeed, there was a significant interregional variation in labor quality: labor of lower quality being available to offices in the Northeast and far West where post-office employment was relatively less attractive than elsewhere at a roughly uniform national wage. This hypothesis was corroborated by results from derived-demand equations which showed that offices facing higher wage rates used more labor hours. This was necessary because each man-hour was of lower quality than elsewhere. Area Wage Boards to adjust compensation to local market conditions would be advisable.

Marginal costs were derived for the various types of mail handled both from cost functions and as shadow prices of the quasi-concave programming problem.

The method is effective and capable of being implemented. A prospectus for its application to hospitals was given. Such an application should be more fruitful because hospitals are managed in a more decentralized fashion than are post offices.

ACKNOWLEDGMENTS

My advisor, Thomas Rothenberg, combined attention to econometric detail with an awareness of the facts of microeconomic life in order to steer me towards not only the profitable but the possible. Dale Jorgenson gave me a great deal of momentum at the outset. The remaining members of my committee, Daniel McFadden and Aaron Wildavsky were also very helpful whenever I called on them. Others at Berkeley who contributed are Roland Artle, George Break, Ronald Choy, Abba Lerner, Thomas Marschak, William Mattson, Ralph Miller, Lee Preston, Earl Rolph, Bernard Saffran and Paul Zarembka.

I am very indebted to Ronald B. Lee, Jonathan Cunitz, William Kearney, Donald Ratajczak, Rosalinda Reynolds Ratacjczak and Nathan Schacter of the Post Office Department in Washington, D.C. Mr. Lee, now Assistant Postmaster-General for Planning, Marketing and Systems Analysis, kindly gave me access to unpublished data and incurred substantial data processing costs in order to obtain the capital data used in this study. Mr. Kearney gave me excellent access to data on leases and rentals of buildings. He also gave me good data on employee complements and much useful advice about the Post Office Department in general. At the San Francisco Regional Office, Walter Robinson was very able and willing to help as was Worth Daniels.

The Woodrow Wilson Fellowship Foundation gave me support at the outset of my graduate studies and also in the Dissertation Fellowship which supported this thesis. Thanks also to the National Science Foundation for support to initiate this study, write a prospectus and to travel to Washington to determine its feasibility. The Institute of Business and Economic

Research and the Schools of Business Administration assisted me towards the completion of the study.

Exemplary typing assistance was given me by Marcia Uzane, Ellen McGibbon and Claire Gilchrist.

I owe a great debt to my colleague in life, Sheila Feinstein Merewitz.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1: MOTIVATION

A. A Method to Evaluate Efficiency of Production When Output Prices Are Absent or Unusable

Efficiency in government expenditure is a problem which grows more important as the share of the public sector in economic activity increases. A large and increasing share of our national output of goods and services is produced in sectors where it is not subject to sale and valuation in a free market. This is true most notably of government output produced in the public sector, but is also true of the entire "grants economy" as well as many goods and services produced in the private sector but sold to government. Finally, some services like medical care are sold both to governments and to individuals, but the prices charged may not reflect social costs. Traditionally, surgery fees have subsidized maternity care and the well-to-do have subsidized the poor. Total government expenditures in the United States at the federal and state and local levels grew from eight to twenty-eight percent of GNP in the period from 1900 to 1966.[1]

We can expect the share of the public sector to increase as a concomitant of economic growth. "Wagner's Law" states that the income elasticity of demand for government services is greater than one [82]. The share of government will also increase as a consequence of the trend

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[1] [49, pp. 97-115], with more recent figures from [19a, p. 3].

of demand away from goods to services because the production of services absorb more government than the production of goods.

Not only are aggregate government expenditures likely to increase, but expenditures are likely to be in service of State and local needs rather than in service of national needs. In the past the national fisc has been much more well-endowed than those of States or localities. Therefore, the residual needs are in the domain of the latter. Whether funded with federal or with State and local funds, services demanded like education, medical care, or outdoor recreation will be of the type produced under similar conditions at many remote locations.

My thesis is that the production function, especially the multi-product production function will be useful in analyzing expenditures for such purposes. Industrial arts and creative writing are often taught in the same high school; the same hospital has surgery and maternity departments; a multi-purpose reservoir may provide flood control as well as recreation. In the absence of market prices, what defensible way is there to aggregate the benefits of educating the technically skilled and the creative; appendectomies and births; angler-days and flood control? I propose that these multiple outputs be left explicitly in physical terms without applying a vector of questionable monetary weights and that they be arguments in a multi-product production function like the one I will investigate.

The production function is a basic notion in economic theory. Knowing it, we can derive many of the propositions of price theory such as the degree of returns to scale, and, given price data, optimum factor proportions for an economic agent whose objective is known. I hope to show that this notion is operational and that it can be useful in the evaluation of public expenditures.

The only proper context in which to discuss efficiency is one in which a production function has been properly specified. To discuss labor productivity or the rate of return to capital may be the best we can do in many cases, but both are clearly inferior to more comprehensive statements which we can make if we have estimated a production function and can study the deviations of productive units from this norm.

Data are not so readily available to estimate production functions in commercial enterprises. Firms' inputs and outputs are considered proprietary information and the Bureau of the Census, which collects such data on a sample basis, is enjoined by law from disclosing data which would allow individual firms to be identified. Public enterprise operates to some extent "in a fishbowl" in that it should have no fear that competitors will learn trade secrets.

It was not only because I believe that specifying and estimating a production function is a prerequisite to discussing efficiency and that I believed data would be available to me in standard form from the Post Office Department (POD) that I chose to undertake the project. The Post Office is a case of a government agency which provides several services simultaneously, that is, it exhibits "multiproduction,"[2] and produces these services under similar conditions at many remote locations. Outputs of government are rarely commensurable in any convenient metric like

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[2] I use this term apologetically as the noun form of the adjective "multiproduct." A longer alternative would be "multiple production." I mean to distinguish this case from "joint production" which I reserve for multiproduction in which the outputs are produced in fixed proportions to each other. I owe this distinction to Earl Rolph.

dollars. Study of them suffers from an input bias. That is why they enter the national accounts at factor cost. Weights used to aggregate several outputs are often largely arbitrary.[3] This, incidentally, is a source of criticism of benefit-cost analyses. Otto Eckstein early suggested that outputs of water resource development for which market prices are not available should be excluded from benefit-cost analyses [19]. This intentional ignoring of real project outputs is hardly satisfactor, however. Thus the method I propose, if successful in evaluating efficiency at individual post offices in the following pilot project, will be of a very general applicability, useful in evaluating the efficiency of offices of, for example, the Social Security Administration, local police and fire protection, hospitals, public health programs, school systems and park departments.

Efficiency <u>ratings</u> are not the end product of a study of efficiency. A study of efficiency should not merely end by congratulating the efficient and chiding the wasteful. It should seek to identify optimal factor proportions and the best scale on which to provide the service in question. Thus each post office will be viewed as an experiment in the production of postal services and the results of the best experiment may be applicable elsewhere. One of the great arguments for States' rights and local autonomy is that similar problems faced in each State mean that fifty different social laboratories are running a constant simulation experiment and presumably contributing to knowledge on the subject. One of the many

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[3]For example, the National Park Service has suggested using one price, $1.60 per visitor-day, for its recreational services throughout the country.

definitions of systems analysis is "a careful examination of alternative methods of accomplishing the same results" [76, p. 8]. In that sense this study will be a systems analysis of the activities of individual post offices.

B. Post Office as Public Expenditure

The Post Office is interesting and important in its own right. It currently spends on the order of $6 billion per year and employs 700,000 people. All of this is effected through a regional administration of fifteen offices. If first-round impact on the economy is the criterion for comparison, then the POD is of slightly greater magnitude than NASA ever became. NASA spent nearly equivalent amounts through many prime and subcontractors whose many decisions affected the economy. Most Post Office decisions are made by headquarters and the fifteen regional offices.

There have been many reports in the mass media which indicated that certain offices were having problems recently.[4] Chicago was subject to some publicity on its postal problems in early October 1966 when its problems were acute. One article [62, pp. 21-24] claimed that 10 million pieces were tied up and that some first class mail from the same city took 21 days to be delivered. Investigation of the relative economic efficiency of individual plants is, therefore, a timely problem.

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[4] Business Week, 5 November 1966, March, 1967; U.S. News and World Report, 7 November 1966; Fortune, March, 1967; Saturday Review, December, 1966; Newsweek, 1 May 1967, 9 October 1967.

The POD, most observers agree, is capital short. In 1908 the Penrose-Overstreet Commission found a "lamentable lack of labor-saving devices throughout the postal system" and the Hoover Commission found similarly later. Since all expenditures are on current account and there does not exist a capital budget, part of the postal deficit in the growing POD represents capital formation. Only recently, wrote Dziadek in 1959 [18], has the POD made any attempt to keep systematic records of plant and equipment. Perhaps the administration of post offices by other government agencies such as the General Services Administration and the Treasury Department may constitute a partial explanation of the lack of property accounting in the POD [62, pp. 21-24]. Congressmen tend to oppose capital expenditures for an organization which has a chronic deficit, but the deficit is, at least in part, the result of Congressional policy. Congress makes all the rates and directs the POD to perform non-reimbursable public services.

In addition to the stinginess of Congress regarding capital formation, an _a priori_ case suggests that there is a bias which favors labor and structures over mechanization. The President appoints all postmasters on the recommendation of local Congressmen. Hence local Congressmen have at least indirect control of the number of jobs equal to the number of new men hired during their tenure, if they can choose the postmaster. Therefore, there may be some tendency for Congressmen to prefer substitution of labor for equipment on political grounds even when equipment-labor substitution would appear warranted on economic grounds. Furthermore, Congressmen may point with pride to new postal facilities built during their tenure as economic activity brought into the Congressional district by them. Thus, by the general "porkbarrel" phenomenon observed in the fields of water resource development, highway construction and aerospace contracting, there is an upward bias in expenditure. Economic efficiency is a poor relation of political expediency.

C. Recent Attention to Government Expenditure: The Advent of PPBS

The Hoover Commission on Governmental Reorganization and Efficiency recommended the use of Program or Performance Budgeting in 1949, but the recommendation lay dormant until David Novick revived it in a RAND research report in 1954 [57]. He stressed attention to the outputs or missions of agencies rather than inputs or costs exclusively; a program orientation including parts of several departments rather than strict departmental orientation; five-year budgets attentive to the future commitments that present expenditures implied. Arthur Smithies published a study of the American budgetary process in which he said, "The appropriations process serves the dual purpose of reviewing the past and of programming for the future, and is . . . satisfactory in neither respect" [66, p. 17]. Jesse Burkhead [11] stressed "performance budgeting" which has a retrospective and evaluative emphasis where program budgeting has a prospective and planning connotation. Expenditures were to be viewed less with distrustful scrutiny and more with emphasis on the relation of expenditures to objectives. At RAND the ideas were made operational with regard to military budgets. Five-year Force and Financial Plans were able to show the implications on military posture of various expenditure levels.

Soon the technology began to transfer from one giant of government spending (defense) to another (public investment), especially in water resources. By 1958 two books appeared on that subject by Roland McKean [47] and Otto Eckstein [19]. Problems of the statement of objectives, planning future implications of present commitments, discounting future benefits and the uncertainty of the military scenario or future hydrology were common to both applications. A collection of essays on the military applications appeared in 1960 by Charles J. Hitch, Roland McKean and others at RAND, The Economics of Defense in the Nuclear Age. In 1961 when Hitch moved to Washington as Assistant Secretary of Defense, Comptroller, he began to implement program budgeting in the military establishment. Its success there was reason to increase the effort at RAND where internally-sponsored research proceeded on the application of program budgeting to all programs of the federal government. On 25 August 1965 President Johnson, in a memorandum to the heads of all departments and agencies, announced "that we would begin to introduce a new planning-programming-budgeting system in Government." The research sponsored by RAND was quickly accepted for publication by the Harvard University Press and a special abridged edition was made available to government personnel in a Government Printing Office volume [57]. The frantic scramble started as each agency looked for personnel competent to do the work and began the painful business of introspection.

The task of the POD was considerably simpler than those of other departments, for it has few overlaps with other agencies. Perhaps program budgeting should not have been ordered from departments, but instead from outside observers who could define the programs irrespective of department lines. For example, if natural resource development were a program and water resource development a subprogram, it would include elements in the Army Corps of Engineers, the Department of the Interior's Bureau of Reclamation in the federal government, and many State water agencies if the program were to be comprehensive.

Program budgeting is an attempt to see better how the President's objectives are being executed, but it does not solve the problem of assessing the degree of fulfillment of the several programs. That is the subject of performance budgeting which focuses attention on economy and efficiency. The existence of program budgeting implies that objectives have been defined and information systems established for estimating the resources being committed to each objective. The pilot exercise I shall do in the following pages is an example of a type of performance budgeting which might benefit from the data forthcoming from planning-programming-budgeting systems.

Chapter 2: RELEVANT LITERATURE

A. Recent Studies of the POD

Students of government efficiency have been giving attention to the POD for a long time: probably for as long, but certainly not so intensively, as they have been studying the military. This attention is due partially to its importance as the largest non-military agency, but it is also due to the fact that the problems are more tractable than they might be with other agencies. Comparable data on POD outputs exist back to 1879 [42, pp. 341-359].

The Bureau of Labor Statistics undertook a study as early as 1932 to arrive at a statistical estimate of changes in the productivity of labor [8, p. 4]. Its author, Witt Bowden, recognized then as we must recognize now, that "quality of output is not measurable in terms of quantity of output and is therefore omitted; but the amount of labor devoted to improving the quality of service cannot be [omitted] . . ." [8, p. 54].

Bowden's study concerned itself with thirteen POD outputs. Henry Lytton added four: international air, and surface, domestic air, and certified mail in order to study labor productivity, defined as weighted output divided by labor input, between 1947 and 1958. He found that productivity increased 13%, an average of 1.25% per year, but that between 1951 and 1958 the index rose from 112 to 113 only, fluctuating in that period. Lytton concluded [42, p. 349] that:

> . . . the productivity advance has apparently slowed down, recently, even over the long run. However, it should pick up almost as soon as new mechanical and electronic devices of sorting, facing, cancelling and handling of the mail make their appearance in full force in Post Offices generally throughout the United States.

Lytton's was a pilot study also considering the Veteran's Administration, Commodity Stabilization Service and other routine government agencies. A more recent Bureau of the Budget (BoB) attempted to measure the improvement over time to determine: which agencies were amenable to productivity measurement, how to do it, and in which areas of application such data would be useful [21, p. 11]. Again, aggregate time series were employed with the list of outputs now expanded to 21. Weights were again proportional to inputs: man-hours or total costs.

> No allowance was made for an implicit interest cost and depreciation on capital goods commanded by the agencies. This would seem to be a defect in the total real cost measures, associated in part with deficiencies in Federal Government cost accounting procedures. Neither was a real cost estimated for the floorspace and utilities furnished free of charge by the General Services Administration [34, p. 15].
>
> The BoB introduction implicitly acknowledges this criticism by saying:
>
> Measures of manpower productivity, while useful in themselves and as indicators of the overall trends in resource productivity are only partial indices of overall performance. The latter is reflected in the measures relating the output to all the resource inputs subject to measurement [21, p. 15].

The Post Office study displayed an anomaly which I believe has a simple explanation. In the period fiscal years 1953 through 1962 the productivity of space occupancy <u>fell</u> 15.6% while the productivities of purchased transportation increased 14.6% and personal services productivity increased 2.2%. These figures are derived from an implicit production function that holds output per unit of input of each type constant over time. This is evident from the description of their derivation:

> While overall service volume increased 15.9% the real transportation needed to keep up with the service expansion increased, because of the offsetting changes in service mix, only 9.2%. In effect, however, the real transportation outlays declined by 4.7% and a productivity gain of 14.6% was realized.[1]

Space occupancy appears to have decreased in productivity per unit because more was used than predicted by the fixed technical coefficients. I interpret the result to mean that floorspace, a proxy for all capital, was increased not only to increase output but through substitution of capital for labor and substitution of postal vehicles for purchased transportation.

Man-hours is the numéraire of the BoB study. Physical output quantities are multiplied by factors representing "man-hours per unit of output in 1962" to get "weighted output." The decline of man-hours per unit of output may be due to increased efficiency. More likely it may be due to capital inputs. The report acknowledges this limitation in part: "A rising productivity index may, for example, reflect technology and systems improvement rather than a more efficient labor force,"[2] but it never tries to explain the dramatic decline in the productivity of floorspace. I have argued above that the growing importance of mechanization in the POD no longer allows neglecting capital inputs or using floorspace as a proxy. The same technology is available to each of the 160 offices I shall study. Some use it and others do not so that we have an ideal situation in which to study the impact of the added inputs of capital and varying factor proportions on efficiency.

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[1] 1.092/0.953 = 1.146 [21, p. 70], Table 12 and below.

[2] [21, p. 232], "Limitations of the Productivity Indexes."

There are some very basic differences between the type of study I propose and the BoB productivity studies. Those studies were a natural extension of some of the work done by Kendrick [33] and others on productivity in various industries with an emphasis on change over time, much in the spirit of Denison's work [16] on growth over time. Very little attention is given to the efficiency of the organizations at the outset of the time span of the study. The organization may have achieved increases in productivity because it began the period in a poor relative position just as the growth rates of "follower" countries are higher than those of established ones. My study will attempt to measure the performance of remote offices under constant technology.

Many economic studies of the POD have paid great attention to the postal rate structure. This was true of Jane Kennedy's article [35, pp. 185 ff], as it was true of Baratz's later and more comprehensive work. Kennedy discussed the structure of postal services: rates and volume of business from 1930 to 1955; the financial results of postal operations; the cost allocation problem of the POD; and its pricing policy.

A study which was more in the spirit of my own, <u>The Productivity of the U. S. Post Office: An Intertemporal and Cross-Sectional Study of Post Office Labor Productivity</u>, was done in 1959 by Fred Dziadek. As the title indicates, Dziadek interested himself in the performance of 42 offices in 1954 and 1958, as well as in the changes in the POD over time. Using data from the Work Measurement System, as I shall do, he found labor productivity higher at first-class offices than at second; however, productivity and size were inversely correlated within classes. He also found labor productivity greater in cities where earnings differentials between postal and non-postal wages most favored POD employees. This argues for the importance of labor quality variation which I shall have occasion to discuss later. My major criticism of this competent study is his use of labor productivity as the variable of interest, thereby ignoring plant and equipment. This may have been justified at some point in time but the post office "industrial revolution" to which he refers has made inattention to capital inputs indefensible.

Baratz [5, pp. 305-314; 6], like Kennedy, gives most attention to pricing policy, but in so doing he looks into the structure and behavior of postal costs. He goes through a taxonomy distinguishing fixed from variable costs to show that a large fraction of POD costs are fixed. Thus, the POD operates in the range of decreasing costs for marginal units of output. Since the POD was labor intensive over the period of Lytton's study, he attributes the increase in labor productivity to economies of scale [5]. Further, he quotes Dziadek on the U-shaped average cost curve of the POD "industry" [18]. He also shows that the average expense per piece of mail decreased between 1953 and 1959 (corrected for price changes) from 4.24 to 3.84 cents and that marginal cost was below average cost at 2.24 cents. Thus he concludes that the POD as a whole shows increasing returns to scale, but he speculated that Lytton's finding on the slowing down of productivity growth meant that the POD was reaching the "bottom of the U" and was about to run into increasing costs. Of course, this finding would be neutralized if there were further inputs of capital, suggesting that the optimal scale of POD activities is at an even greater level.

Baratz stresses the "variable character of the short-run demand for postal services." He refers here to the fact that post offices receive mail unevenly distributed over hours of the day. Peaks in activity come in the late afternoon and early morning. Business mailers tend to post their mail at the close of office hours while incoming mail arrives between 3 and 7 a.m. Mailers have been encouraged to mail throughout the day in a program of Accelerated Business Collection and Delivery wherein the Post Office promises that mail posted before 11 will arrive before 3 in the business district of a single city. The problem remains and causes a real peak-loading problem which requires more equipment and larger staffs and has implications on the allocation of postal costs as I discuss below.

Baratz' main interest in costs is to ascertain how the costs of the different classes of mail bear on the application of normative pricing rules. The POD maintains an elaborate annual cost analysis by class of mail, the Cost Ascertainment System (CAS). Kennedy and Baratz adjudged this system satisfactory as far as any allocation of joint costs can be. I feel that the CAS may put too great a burden on third-class mail because it receives deferred handling during times when resources are hired but not fully employed and have a shadow price near zero. With this caveat in mind, let us briefly review the usual conclusions on the comparative costs of handling the several classes of mail.

Table I-1 shows that average revenue from first-class mail (letters and postcards) is usually just greater than average costs. Second-class (newspapers and magazines) covers about one-quarter of average costs; third-class (advertising circulars and pieces under eight ounces) covers 65% of costs; and fourth-class (parcel post) does not quite cover average costs.

Table II-1. Fraction of costs covered by the several classes of mail.

Class	Average Revenue/Average Cost
First	1.12
Second	.24
Third	.65
Fourth	.83

Source: POD, Cost Ascertainment Report, 1965, Exhibit II, "Unit Revenues and Accrued Costs," p. 19.

Baratz went on to investigate marginal costs and found them considerably and slightly less than average costs for first and third classes, respectively. Thus the price of first class is substantially above marginal cost and the price for third is much less than marginal cost. At the margin the social cost of "junk" mail is greater than the social benefit. Hence, there is a case for saying that the output mix is not efficient from the point of view of resource allocation in the economy. If this is true, it is the fault of the Congress, which sets the rates and decides what services the POD should perform. These decisions also largely determine the size of the postal deficit so that it says little about the efficiency of the POD in achieving the goals specified by Congress.

The following study is not directed at making normative statements about postal rates. Nevertheless, shadow prices will be estimated for types of work done at post offices which may be broadly representative of the service given certain classes of mail. The correspondence between the outputs I consider and the several classes of mail is not nearly one-to-one, however. Furthermore, I exclude from this study inter-city transportation of the mails.

B. Previous Work on Production Functions

The Cobb-Douglas production function was introduced in 1928 when Paul Douglas and Charles Cobb put forth "A Theory of Production" in the American Economic Review.[3] Douglas used the theory to compare the actual share of labor in total product to what might be expected if their theory of production was true and constant returns to scale and the product exhaustion theorem obtained [17].

Other economists soon responded to the invitation and fitted the function to firm data where Douglas had investigated aggregate data. The restriction of linear homogeneity was soon dropped as returns to scale became a variable of considerable interest to economists. It remains a matter of taste whether we reserve the name "Cobb-Douglas" for production functions of a certain form with constant returns to scale or allow non-constant returns in the class of Cobb-Douglas production functions. I adopt the latter view.

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[3] [13, pp. 139-165]. Knut Wicksell had discussed such a function in 1923, "A Mathematical Analysis of Dr. Akerman's Problem," Economisk Tidskrift, Vol. 25, 1923, pp. 157-180, translated into English by E. Classen, and reprinted as part of an appendix to Wicksell's Lectures on Political Economy, Vol. I (London: Routledge and Kegan Paul, 1934). Edgeworth is usually credited with introducing the production function idea into economics in 1889: F. Y. Edgeworth, Collected Papers, Vol. II (London: London School, 1925), p. 298. A comprehensive historical bibliography is given in the standard reference, Paul Douglas, "Are There Laws of Production?", Presidential Address, American Economic Review, Vol. 38, 1948, pp. 1-42.

Jacob Marschak and William Andrews [45, pp. 143-205] soon pointed out that the relationship between output and inputs is a confluent relation which does not describe the production function but only the net effects of differences among firms. Other regularities, like the firm's objective function and constraints, should be taken into account. Output will not, then, be simply a function of inputs, but all will be simultaneously determined as functions of the things the firm takes as given: the prices of output and inputs, in the case of a profit maximizing price-taker in output and factor markets. Their work lay buried in a wartime issue of *Econometrica* while early econometricians like Lawrence Klein and Gerhard Tintner went ahead estimating production functions as an exercise in the new science of econometrics [36, pp. 226-236; 69].

Klein's work is particularly interesting, for he suggests the behavioral formulation appropriate to a regulated industry. He studied railroads which

> . . . are required as public service enterprises to accept traffic as offered. . . . In the short run the problem of the individual road is to meet a given volume of traffic the most economical way. . . . A second important institutional fact is that prices received for passenger and freight services are fixed by the control body [37].

This is precisely the formulation I believe appropriate to a study of the POD. Furthermore, Klein estimates a function which is equivalent to a multiproduct production function because one of his outputs, X_1, ton-miles of freight, is a function of passenger miles, another output. Klein's estimated function is:

$$X_1^{\alpha_1} = A\, X_2^{\alpha_2}\, V_3^{\alpha_3}\, V_4^{\alpha_4}\, V_5^{\alpha_5} \tag{1}$$

where the $\{V_j\}$ are inputs, and the estimates were

$$\hat{\alpha}_1 = -.16 \quad \sum_{j=3}^{5} \hat{\alpha}_j = 1.29 \ .$$

The second output, net passenger miles, is put on the right-hand side because, as Koopmans points out:

> In the case of joint production of several commodities, all outputs but one are placed side by side with the inputs as "independent variables" or arguments of the production function. The dependent variable is then defined as the maximum output of the singled-out commodity attainable from the specified inputs along with other specified outputs [39, p. 69].

Technically, the relationship between inputs and outputs should be called a production correspondence and not a function in the case of multiproduction because the relation is not single-valued. Several constellations of outputs, all representing a constant "aggregate" or "composite" output, can be produced from a given input vector. There is a single maximum output of one good associated with given inputs and given levels of other outputs, so the production relation defined in this way is a function.

In his study of the electrical generating industry Marc Nerlove [54] used the behavioral formulation of Klein, but exploited the statistical insights of Marschak and Andrews and the analytical tool of the cost function refined most up to that time by Ronald Shephard [64].

The cost function is defined as the minimum cost necessary to produce a stipulated output level at fixed input prices. It is one reduced form of the structural system of simultaneous equations given by the objective function, cost of inputs (to be minimized), the stipulated outputs and the production function. Shephard and Hirofumi Uzawa [80, pp. 216-220] have proved the duality and one-to-one correspondence between cost and production functions.

Another reduced form is the group of derived demand equations for inputs whose arguments are stipulated output levels and exogenously determined factor prices. Nerlove chose to estimate the cost function to improve the efficiency of his estimates by incorporating all the restrictions in one equation. Nerlove's objective was to get the best estimates possible of the structural parameters, especially the degree of returns to scale

$$r = a_1 + a_2 + a_3$$

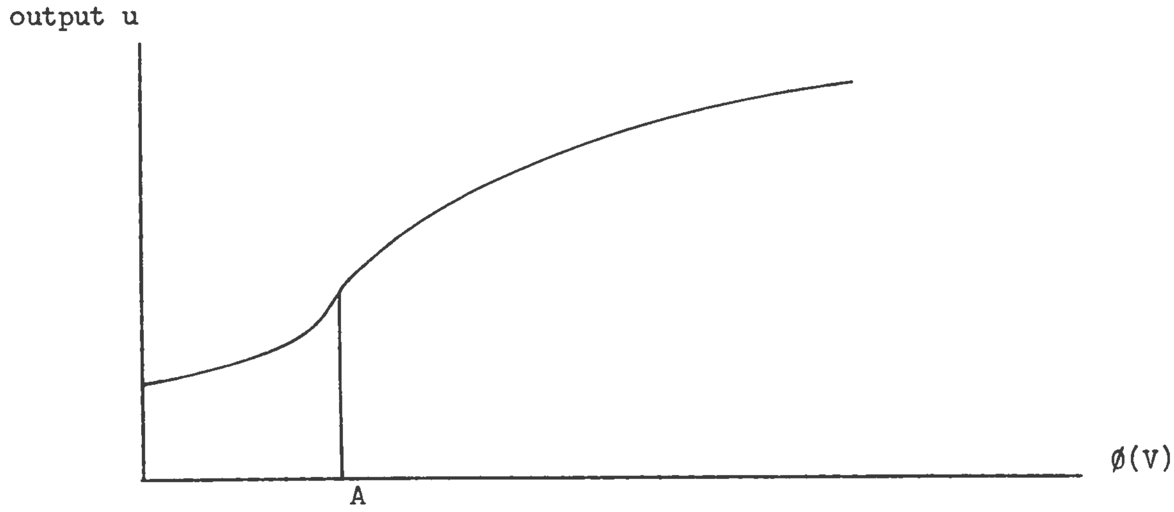
where $\{a_i\}$ are elasticities of output with respect to inputs, exponents in a Cobb-Douglas function. Another objective might be to test hypotheses, e.g. the derived demand equations are homogeneous of degree zero in the prices, and of degree $1/r$ in output.

Mathematicians, Shephard for one, chide economists for writing down analytic forms of the production function and estimating one function over an entire range of outputs. Shephard suggests that economists write down $\phi(V)$, some function of inputs, homogeneous of degree one and then consider, a homothetic production function

$$u = F(\phi(V))$$

which is a monotonic transform of ϕ. The dependent variable, u, should be "curve fitted" against $\phi(V)$ in various regions. When the scatter appears concave, as in the range beyond A in Figure II-1, a concave function should be fitted; in a convex region, a convex function $u = F(\phi(V))$ should be fitted [65, pp. 29-36].

Figure II-1.



Nerlove's work remains relatively impervious to such a criticism because of his innovation in stratifying his sample into groups of homogeneous scale. Unfortunately, he fitted the same cost function in each output range without justifying this first from the scatter.

Daniel McFadden [46] has made several advances over Nerlove's work on the same industry. He is able to test the hypothesis of homotheticity and, in fact, rejects it, finding a capital-using bias in the higher output ranges. Further, his use of a constant elasticity of substitution (CES) function allowed him to estimate elasticities of substitution between labor and capital, labor and raw materials, and raw materials and capital. Nerlove had implicitly assumed unitary elasticities of substitution in his Cobb-Douglas function and dismissed the nascent CES form, at the time, because he could not see how to define different elasticities of substitution for different combinations of factors. McFadden improved on Arrow, Chenery, Solow and Minhas by testing returns to scale also.

Chapter 3: CASTING THE PROBLEM

A. What Services Are Produced

The POD is currently operated from headquarters in Washington, D.C., through fifteen Regional Offices. The services performed by the POD can be seen from its program budget. The program categories are:

1. Direct Services to Mailers
2. Processing of Mail
3. Delivery Services
4. Transportation of Mail
5. Auxiliary Services
6. Enforcing Postal Laws
7. Research and Development
8. General Postal Support

To give an idea of the finer divisions in this classification we list some program subcategories under Direct Services to Mailers, and further, some program elements under the last subcategory:

a. window and counter services
b. self-service installations
c. mail acceptance services
   (1) collection from chutes and boxes
   (2) acceptance of mail at post office platforms
   (3) acceptance of mail on mailers' premises

Most of the Program Categories are self explanatory, save 5, Auxiliary Services. This covers processing postal claims and offering services, not directly related to mail processing, to other government agencies such as displaying posters of those "Wanted by the F.B.I." Transportation includes not only international and intercity but intracity and intrapost-office as well.

To compare this with the traditional object budget classification, the latter is given also:

I. Administration and Regional Operation

II. Operations

III. Transportation

IV. Facilities

V. Plant and Equipment

VI. Research and Development and Engineering

These object budget categories form the basis for the POD's administrative division into bureaus and represent major objects of POD expenditures.

I shall analyze POD activities in two parts: intra post-office activity and extra post-office activity. I shall be interested in the first two program categories for the first and programs 3 and the intracity parts of 4 in the second. The corresponding rubrics in the object classification which will interest me are mainly II, IV and V.

B. <u>Fixed or Variable Proportions?</u>

One natural casting of these problems might be in terms of activity analysis. Henri Tulkens [70] breaks down postal operations into processing units in doing his programming analysis of the Belgian postal service. Each unit has input requirements and output characteristics. For example, a manual culling and facing table requires four operators, 0.5 loading and unloading operators, 4.2 square meters of space and processes 8400 pieces per hour. A Telefunken culling machine requires three operators, one maintenance man, 10.94 square meters of space, and 13 kilowatts of power in order to process 18,000 pieces per hour [70, p. 75, Table II.3]. He then makes the reasonable assumption of constant returns to scale in the sense of identical replication. Such a formulation requires case studies of each separate technology used in the sample. This requires great engineering knowledge of the facts of postal production, which I do not have. I do not believe this information is necessary in order to make useful statements about the comparative efficiency of remote agents producing in the public sector.

This study will be cast in a neoclassical production-function spirit in which fixed proportions among inputs and outputs is not imposed. This study can be seen as a limiting case of the kind Tulkens has done. As long as there are a large number of activities, cross-sectional price variation may result in different offices' using different factor proportions. If there are enough rays from the origin on which offices can produce, then we may assume that they can produce anywhere along the spectrum of factor proportions.

What this study does deny, is the model of post office production which asserts that factors are used in fixed proportions at all offices. Unfortunately, that model is not uncommon. It is implicit in any study which concentrates on labor productivity, for example. If one office's labor productivity is greater than another's, then that is interesting if labor can be taken as a proxy for all inputs, i.e. if labor and other inputs are used in fixed proportions so that once we know how much labor was used, we also know how many machine hours and square feet of floorspace were used. Otherwise, one office's labor productivity may be very high because it has automated all actions at a cost which is uneconomic given relative factor prices.

As a simple test of whether all offices use the same technology, I suggest looking at factor proportions cross-sectionally to see whether inputs are combined in fixed proportions. Do they vary much or remain roughly constant? Means and standard deviations are given for each proportion in Table III-1. Coefficients of variation show that these ratios are hardly constant. In fact, all the input ratios are more variable than the factor price ratio, e.g. the coefficients of variation are .42, 1.45 and 1.23 vs. .27 for intra post-office activity.

Table III-1. Factor proportions in post offices.

		Mean	s.d.	Coefficient of variation
	Intra			
$V_7/(V_6+V_8)$	Labor-floorspace	6.95	(2.91)	.42
V_7/O_9	Labor-mech.	23.93	(34.77)	1.45
V_8/O_9	Space-mech.	3.71	(4.58)	1.23
	Extra			
V_7/V_8	Labor-space	22.33	(132.00)	6.00
V_7/O_9	Labor-vehicles	15.64	(6.04)	.39
V_8/O_9	Space-vehicles	2.31	(1.86)	.81
	Factor Prices			
	Wage/floorspace price	3.30	(.90)	.27

Past studies of efficiency in the Post Office have neglected capital inputs almost entirely. This was not entirely the fault of the men doing the studies for, other than structures, some vehicles and routine office equipment, the POD has had very little capital until recently. In 1914 the value of land and buildings was 97% of the total value of postal holdings. Mailsters (motorcycles with a postal superstructure) were introduced in 1957 to mechanize city delivery service. As of 1959 only two offices had mechanical sorting equipment. Capital-labor substitution is very possible as the Department is recently discovering. Ninety-seven large offices have had some degree of mechanization installed very recently; 205 high-speed facer-cancellers have been installed in 72 offices; an optical scanner has been installed in the Detroit office which reads typed and printed ZIP codes and sorts mail at the rate of 36,000 pieces per hour. Detroit also has closed-circuit television with cameras at strategic points along a conveyor system, to regulate the workload, prevent jams and assist in preventing damage to mail. A machine which separates parcel post for individual destinations is now being used in 28 offices. Sack sorters to convey sacks and pouches directly to work areas within the post office or to railroad and truck loading positions with a minimum of manual handling are now in use in 36 offices; 39 offices are using letter sorters [74].

Plans call for the optical scanner to be expanded to six additional post offices where eight additional readers will be used. A program for "saturating the country with" a process of stamp-tagging with luminescent material to improve the recognition capability of the facer-canceller machine has begun in the Cincinnati Region [74, p. 49]. Acceleration in research and development in the POD can be expected to follow the appointment in 1966 of Leo Packer as Assistant Postmaster General for research and development. Packer was formerly engineering manager of Xerox Corporation.

It is not true that mechanization is the solution to all of the POD problems and the latest technology need not be efficient in every office. Dziadek found labor productivity higher at first-class offices than at second-class offices. Since the former are more capital intensive than the latter, this is a *prima facie* case for the importance of capital in the production function. The existence of a negative inter-regional association between output per square foot of building space and productivity is likely to be indicative of a positive inter-regional association between total amount of capital per unit of output and productivity [18, p. 139]. Since he used floorspace as a proxy for all capital (more true in 1958 than it is now), Dziadek's studies of labor productivity were fairly conclusive on the positive association of the capital-output ratio and the efficiency of postal employees, but one would expect this result if there is any capital-labor substitution. On the other hand, labor productivity and size were inversely correlated in 42 large offices. Labor productivity results are not definitive as I have discussed above in critiques of Dziadek's study and one by the Bureau of the Budget.

The POD cannot introduce mechanization simultaneously everywhere. Capital rationing is imposed by the absence of a capital account and an implicit constraint on the postal deficit. Furthermore, the floors in some old buildings will simply not stand the weight of the new machinery (one reason floorspace is no longer a good proxy for total capital). But this is ideal from my point of view, for it allows me to study a range of production possibilities with varying factor inputs. One of the true contributions of systems analysis is to identify all the reasonable alternatives for the accomplishment of a given task. Individual post offices may be viewed as experiments in seeking optimal factor proportions and scale for the production of postal services.

C. Behavioral Formulation

I will assume that the POD behaves so as to minimize the cost of handling the mail. The POD has little control over the output it produces; that is exogenously determined. It must deliver what the people of the U.S. deposit in the boxes. Factor prices are also beyond its control; these are determined exogenously by the market. Congress determines its output prices which may have some impact on limiting demand for postal services, but in any case this decision is out of the hands of the POD, although it may and does make recommendations about postal rate changes. In no case can one visualize the POD restricting output in order to raise price. Congress also determines the wage scales of postal employees. Although the POD might be visualized as wielding monopsony power as the employer of 700,000 people, it has only a small impact on the labor market in each city.

There is a Postal Manual which enumerates the conditions necessary to request off-the-shelf equipment. Manpower is the major resource which is budgeted and this is done by the 15 Regional Offices. Although postmasters do not have autonomy in their choice of factor inputs, nevertheless, we may assay the performance of individual offices. Regional offices exercise management so that it is interesting to compare performance among regions.

I have assumed that each office minimizes cost subject to the same technology. In fact, the POD probably endeavors to minimize total postal costs. This may and does imply that the technology differs among offices. One office may be directed to process mail to a fine degree to obviate certain processing operations at the next office. Some mail is even sorted <u>en route</u>, although this is a dying phenomenon of railroad mail transportation. The only information I have on this problem is some scattered measures of "residue" mail that leaves an office not sorted above a threshold level. Whether or not an office is a Sectional Center, serving its surrounding offices as a central location, will also be known.

D. Intra-Post Office Activity Model

The following model seems to be the best compromise between economy of parameters and equations on the one hand, and justice and verisimilitude in the description of real post-office production on the other. Four inputs and five outputs comprise the arguments of the interior production correspondence. One of the inputs, GSA floorspace, is considered fixed, not freely expandable by the local or regional office.[1] Table III-2 summarizes the inputs, outputs, and prices with which we worked and the notation used for them.

The aggregation scheme for outputs was developed through experimentation. At first, ten outputs (five varieties of outgoing and four of

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[1]In the recent past the POD has preferred to contract for space with private entrepreneurs rather than have GSA build its space.

incoming) were used, but the multicollinearity problem was severe. The other extreme would be a weighted sum of the ten original outputs with weights coming from POD time and motion studies. In the case of "second-class" mail we have borrowed some of the POD-calculated factors representing man-hours per thousand pieces.

There is one factor for which no price is available: mechanization. This price does not vary cross-sectionally. Equipment is bought in a national market unlike plant (called herein floorspace) and labor.

Let us develop a theory of restricted variation for five fixed outputs $(X_1,\ldots,X_5)$, a fixed input, V_6, and three variable inputs, V_7, V_8, O_9. Each office takes as given the outputs it must produce and the prices (w_7, w_8) at which it can hire variable factors.

The objective is to minimize variable factor cost, or equivalently, to maximize "cost savings":

$$-C = -w_7V_7 - w_8V_8 - O_9 \,. \tag{1}$$

The constraints which restrict the variation are (a) that the office be within its feasible production set:

$$Q(X) \leq Y(V) \tag{2}$$

where

$$Q(X) = \prod_{i=1}^{5} X_i^{\alpha_i} \qquad Y(V) = A \prod_{j=6}^{8} V_j^{\alpha_j} \left(\frac{O_9}{w_9} \right)^{\alpha_9} ; \tag{3}$$

(b) that actual production not fall short of stipulated levels:

Table III-2. Intra post-office activity: inputs, outputs, prices and notation.

Inputs			Prices
V_6	GSA floorspace in square feet	m_6	\$/ft^2-yr
V_7	Inside labor[a] in man-hours	w_7	\$/man-hr
V_8	Inside (+ 1/2 platform) space, leased and rented, in square feet	w_8	\$/ft^2-yr
O_9	Imputed outlay[b] on equipment = W_9V_9 (unobserved)	w_9	

Outputs (all in thousands)		Shadow Prices
X_1	Incoming and outgoing cancelled letters (largely first, but some third class)	m_1
X_2	"Second class"[c]	m_2
X_3	Outgoing non-cancelled letters	m_3
X_4	Fourth class: parcels, incoming and outgoing	m_4
X_5	Window services as measured by postal revenues, in thousands of dollars	m_5

[a] Includes (1) clerk-mailhandler, (2) supervisors, (3) cleaning and protective maintenance, (4) equipment and building maintenance.

[b] Composed of straight-line book depreciation plus an imputed interest charge equal to seven percent of the undepreciated book value of capital stock.

[c] .189 outgoing flats + .359 outgoing small parcels and rolls (SPR's) + .193 incoming flats + .259 incoming SPR's. Some third class included in small parcels and some first class among flats. These weights are derived from POD time and motion studies, POD Form 2335, "Operation Analysis," November, 1966.

$$X_i \geq \overline{X}_i \qquad\qquad i = 1,\ldots,5 \quad , \text{ and} \qquad (4)$$

(c) that use of the fixed factor not exceed capacity:

$$V_6 \leq \overline{V}_6. \qquad (5)$$

The functions in (3) are "Cobb-Douglas" in inputs and in outputs because both Q(X) and Y(V) are homogeneous functions involving each argument raised to a constant power. If Y, equal to Q(X) on the production frontier, is interpreted as an intermediate product, "composite output" into which inputs are first transformed and is then itself transformed into $X_1,\ldots,X_5$ in a second stage, then the $\{a_j\}$ for j=6,...,9 are elasticities of "output" with respect to inputs.

In the LaGrangean expression

$$L(V;m) = -w_7V_7 - w_8V_8 - O_9 + m_0[Y(V) - Q(X)] + \sum_{i=1}^{5} m_i(X_i-\overline{X}_i) + m_6(\overline{V}_6 - V_6) \qquad (6)$$

the objective function (1) is linear, hence quasi-concave, as are all constraints save (2).

In the theory of the firm under a profit maximization behavioral formulation Y(V) is assumed to be concave; increasing returns to scale are disallowed. I wish to estimate a model which imposes no constraint on the degree of returns to scale so that I can estimate returns to scale. I assume merely that Y(V) is quasi-concave. Decreasing, constant and increasing returns to scale functions are all quasi-concave, i.e. they all have convex isoquants. When the constant-for-each-office, Q(X), is subtracted from Y(V), as it is in the LaGrangean expression (7), the difference is still a quasi-concave function. Thus, the problem is to maximize a quasi-concave function under quasi-concave constraints which define a convex domain. The Arrow-Enthoven extension 12 [18, p. 139] of the Kuhn-Tucker theorem applies and we need not check second-order conditions, the major benefit of so casting the problem [44, pp. 662-681].

The undetermined multipliers may be interpreted as partial derivatives of L with respect to the constraint levels: increases in cost savings associated with increases in the constraints:

$L_Q = -m_o$ = marginal cost savings of increasing composite output

$L_Y = m_o$ = marginal cost savings of increasing composite input

$L_{\bar{X}_1} = -m_1$ = marginal cost savings of output 1

m_1 = marginal cost of output 1

$L_{\bar{X}_2} = -m_2$ = marginal cost savings of output 2

m_2 = marginal cost of output 2

$L_{\bar{V}_6} = m_6$ = marginal cost savings of a unit of fixed factor, the shadow price of GSA floorspace

$m_i \geq 0$ $(i=0,1,2,\ldots,5)$ by the non-negativity constraints of the quasi-concave programming problem.

A maximum of the objective function (1) corresponds to a saddle point of (6), conditions for which are:

$$L_7 = -w_7 + m_o\, \alpha_7\, Y(V)/V_7 \leq 0 \quad \text{(a)}$$

$$L_8 = -w_8 + m_o\, \alpha_8\, Y(V)/V_8 \leq 0 \quad \text{(b)}$$

$$L_9 = -w_9 + m_o\, \alpha_9\, Y(V)/V_9 \leq 0 \quad \text{(c)}$$

$$L_6 = m_o\, \alpha_6\, Y(V)/V_6 - m_6 \leq 0 \quad \text{(d)} \qquad (7)$$

$$L_{m_o} = Y(V) - Q(X) \geq 0 \quad \text{(e)}$$

$$L_{m_i} = X_i - \bar{X}_i \geq 0 \quad \text{(f)}$$

$$L_{m_6} = \bar{V}_6 - V_6 \geq 0 \quad \text{(g)}$$

and

$$\sum_{j=6}^{9} L_j V_j + m_o[Y(V) - Q(X)] + \sum_{i=1}^{5} m_i(X_i - \bar{X}_i) + m_6(\bar{V}_6 - V_6) = 0 \qquad (8)$$

at the saddle point $(\hat{V}_j, \hat{m}_k)$ which makes L a maximum in the $\{V_j\}$ and a minimum in the $\{m_k\}$.

The complementary slackness condition (g) says that if any of the inequalities hold strictly then the corresponding input is not used, output is not produced or shadow price is zero. Let us assume that an interior solution exists such that all variables are positive at their optimal levels. This simplifies the economic interpretation of (7):

(a) The marginal outlay on V_7 equals the marginal value product in "cost savings." Cost savings is the numeraire throughout.

(d) The shadow price of GSA floorspace equals its marginal value product.

(e)-(g) are simply the constraints of the problem.

Equations (7) define the structural form of the model. Letting lower-case letters be logarithms of their upper-case counterparts and vice versa (the "case-logarithm" convention), we have

$$Hv = Bx :$$

$$\begin{pmatrix} -1 & 1 & 0 \\ -1 & 0 & 1 \\ \alpha_7 & \alpha_8 & \alpha_9 \end{pmatrix} \begin{pmatrix} v_7 \\ v_8 \\ o_9 \end{pmatrix} = \begin{pmatrix} (A_8 - A_7) & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \\ (A_9 - A_7) & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ (\alpha_9 W_9 - a) & \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & -\alpha_6 & 0 & 0 \end{pmatrix} \begin{pmatrix} 1 \\ \bar{x}_1 \\ \bar{x}_2 \\ \vdots \\ \bar{x}_5 \\ \bar{v}_6 \\ W_7 \\ W_8 \end{pmatrix} \qquad (9)$$

whose reduced form is $v = H^{-1} Bx$

$$\begin{pmatrix} v_7 \\ v_8 \\ o_9 \end{pmatrix} = \frac{1}{\Sigma} \begin{pmatrix} C_7 & \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & -\alpha_6 & -(\alpha_8+\alpha_9) & \alpha_8 \\ C_8 & \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & -\alpha_6 & \alpha_7 & -(\alpha_7+\alpha_9) \\ C_9 & \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & -\alpha_6 & \alpha_7 & \alpha_8 \end{pmatrix} x$$

where $\Sigma = \alpha_7 + \alpha_8 + \alpha_9$

and $C_7 = [(\alpha_8+\alpha_9) A_7 - \alpha_8 A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a]$

$C_8 = [-\alpha_7 A_7 + (\alpha_7+\alpha_9) A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a]$

$C_9 = [-\alpha_7 A_7 - \alpha_8 A_8 + (\alpha_7+\alpha_8) A_9 + \alpha_9 W_9 - a]$.

Solutions for shadow prices are also interesting:

Let $m = (M_0, M_1, M_2, M_3, M_4, M_5, M_6)^T$

where T indicates the vector transpose

$x^* = x$ without its first element, unity.

Then we have

$$m = d + G\,x^*$$

$$\text{where} \quad d = \frac{1}{\Sigma}\begin{pmatrix} -\alpha_7 A_7 - \alpha_8 A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a \\ -\alpha_7 A_7 - \alpha_8 A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a + A_1\Sigma \\ \cdots \\ -\alpha_7 A_7 - \alpha_8 A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a + A_5\Sigma \\ -\alpha_7 A_7 - \alpha_8 A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a + A_6\Sigma \end{pmatrix}$$

$$G = \left(\frac{1}{\Sigma}\right)\begin{bmatrix} \alpha_1(1-\Sigma) & [\alpha_2(1-\Sigma)] & [\alpha_3(1-\Sigma)] & [\alpha_4(1-\Sigma)] & [\alpha_5(1-\Sigma)] & -\alpha_6 & \alpha_7 & \alpha_8 \\ (\alpha_1-\Sigma) & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & -\alpha_6 & \alpha_7 & \alpha_8 \\ \alpha_1 & (\alpha_2-\Sigma) & \alpha_3 & \alpha_4 & \alpha_5 & -\alpha_6 & \alpha_7 & \alpha_8 \\ \alpha_1 & \alpha_2 & (\alpha_3-\Sigma) & \alpha_4 & \alpha_5 & -\alpha_6 & \alpha_7 & \alpha_8 \\ \alpha_1 & \alpha_2 & \alpha_3 & (\alpha_4-\Sigma) & \alpha_5 & -\alpha_6 & \alpha_7 & \alpha_8 \\ \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & (\alpha_5-\Sigma) & -\alpha_6 & \alpha_7 & \alpha_8 \\ \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 & \alpha_5 & -(\alpha_6+\Sigma) & \alpha_7 & \alpha_8 \end{bmatrix}$$

For most purposes we consider post offices multiproduct firms. In grouping offices by size and in direct estimation of a production function we shall have occasion to use a scalar measure of output. The scalar measure of output was calculated from the following weighted sum of the ten original outputs.

Output = 1.91 Outgoing cancelled letters + 1.40 Outgoing non-cancelled letters + 1.87 Outgoing flats + 7.00 Outgoing parcels + 3.55 Outgoing SPR's + 1.47 Incoming letters + 1.92 Incoming flats + 7.70 Incoming parcels + 2.58 Incoming SPR's + 17.00 Window services.[2]

E. Questions Asked

In discussing the empirical results it is useful to keep clearly in mind the questions we are asking and to organize our reporting of these results around those questions.

We ask whether there are economies of scale in post offices and if so, what is the optimal size of office?

We seek to identify the factors that are most important in accounting for postal costs. That done, we try to quantify marginal costs of the several outputs. Then we ask: Which post offices are costly relative to average and total costs we would predict for them, and why are some more costly than others?

Which offices are productive or technically efficient? Which of the several suggested analytical forms of the production correspondence best describes postal multiproduction?

Finally, we compare offices to each other, based on the performance indicators we will derive costliness, productivity and price efficiency. Do recently mechanized offices perform better than others? Are there any

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[2]Source: POD Form 2335 "Operation Analysis," November, 1966, and my own estimate of cost to the POD of $64.37 per $1,000 of window services. At a wage rate of $3.76 per hour this implies a cost of approximately 17 man-hours per $1,000 of window services.

significant differences in the performance of the fifteen Regional Offices as indicated by the performance of offices in the several regions?

F. Method of Answering These Questions

As usual, depending on the questions we are interested in, different means of approach might be appropriate. For example, in deciding what type of aggregation of several outputs is best we may try several functional forms for the transformation function. In asking how substitutable the inputs are, we may simply aggregate the outputs linearly.

Our strategy for answering these questions involves making inferences from several types of analysis:

1. Reduced form estimates
    a. Cost functions for intra (and extra) post-office activity
        1) under a Cobb-Douglas model of multiproduction
        2) under a transcendental transformation function
        3) under a CES transformation function
    b. Derived demand functions for the three factors of production in intra (and extra) post-office activity
        1) under a Cobb-Douglas model of multiproduction
            a) with constraints imposed by the model
            b) without constraints

2. Structural estimates
    a. of the production correspondence through ordinary least-squares
    b. of the output elasticities in a Cobb-Douglas model through factor-shares formulae
    c. of the degree of returns to scale in the context of a "CES" transformation function

d. of the elasticity of substitution among inputs (1) from marginal productivity conditions arising out of cost-minimizing responses to cross-sectionally changing factor prices; (2) from estimates of Maclarin's series expansions about the Cobb-Douglas case

3. One-way analyses of variance among the fifteen postal regions

   a. of costliness

   b. of productivity

   c. of input efficiency

4. Exercises parallel to many of those above on the contrafactual assumption that all offices face the same factor prices. These exercises yield estimates of adjusted costliness in which an office is not penalized if it faces high factor prices

5. Comparisons between groups of offices that were recently mechanized and those which were not.

Chapter 4: THE EVIDENCE

A. The Sample

In general, the post offices in this sample are drawn from the largest 164 in the United States' system of 33,624 post offices (in Postal Fiscal Year 1966). A post office may consist of several stations but it is all the men, machinery and buildings under the jurisdiction of a postmaster. They are the offices in the Work Measurement System (WMS), data on which are retained at headquarters of the POD in Washington, D.C. They represent 164 of the 1166 postal installations on which WMS records are maintained. The several possible ways of measuring "size" of post office do not always agree precisely. One criterion is the employee complement; another is a weighted index of output based on weights which reflect the labor requirements of several types of mail.

Of the 164 largest offices on the first criterion, the following are excluded:

1. Because no output data were available:

   Corpus Christi, Texas; Ogden, Utah; St. Petersburg, Florida.

2. Because no capital property figures were available:

   Texarkana, Texas; Dallas, Texas; Jersey City, New Jersey; Hicksville, New York.

3. Because their main mission is processing and transferring transit mails and originating parcel post and are, therefore, not entirely comparable to the bulk of the sample:

   North Suburban, South Suburban (Chicago), Illinois.

4. Because they are not included in the Work Measurement System: Alexandria, Virginia; Dearborn, Michigan; Silver Spring, Maryland; Anaheim, California; Evansville, Indiana; Saginaw, Michigan; Stockton, California; Riverside, California; Lynn, Massachusetts; New Brunswick, New Jersey.

B. The Data

In the main, our output data is first-handling pieces. A first-handling piece is any item a post office handles for the first time. The office could be the office of origin, destination or an office reached in transit. Some offices sort mail to a finer degree than others. In some cases a first-handling piece will go through a "primary," a "secondary," and a "tertiary" sort, yet it will rate as output in these data like a piece which was only handled once at a Sectional Center. Sectional Centers are nodes, or points of mail accumulation, in the postal delivery scheme. Each sectional center serves as the mail accumulation point for all offices in its tributary area -- all other offices with the same first three numerals of the ZIP code.

Assuming each post office has the same production function when the degree of sorting is not the same in each office is problematic. Either a different quantity of service is produced at each office or the service is performed to a different quality. All offices do sort some mail to a fine degree. What fraction this represents at any given office is unknown. This is an inherent problem with the data available.

Table IV-1. Key to the order of post offices.

1. Kansas City, Kans.
2. Kansas City, Mo.
3. Knoxville
4. Lansing
5. Lincoln
6. Little Rock
7. Long Island City
8. Louisville
9. Lubbock
10. Madison
11. Memphis
12. Milwaukee
13. Minneapolis
14. Mobile
15. Montgomery
16. Nashville
17. Newark
18. New Orleans
19. Norfolk
20. Oklahoma City
21. Omaha
22. Paterson
23. Peoria
24. Philadelphia
25. Phoenix
26. Pittsburgh
27. Portland, Ore.
28. Reading
29. Richmond
30. Rochester
31. St. Louis
32. St. Paul
33. Salt Lake City
34. San Antonio
35. San Juan
36. Scranton
37. Seattle
38. Shreveport
39. Sioux City
40. South Bend
41. Spokane
42. Syracuse
43. Tacoma
44. Terre Haute
45. Toledo
46. Topeka
47. Trenton
48. Tucson
49. Tulsa
50. Utica
51. Washington
52. White Plains
53. Wichita
54. Wilkes-Barre
55. Wilmington
56. Yonkers
57. Youngstown
58. Amarillo
59. Arlington, Va.
60. Baton Rouge
61. Bethlehem
62. Charleston
63. Eugene
64. Evanston
65. Garden City
66. Gary
67. Hackensack
68. Kalamazoo
69. Lexington, Ky.
*70. North Suburban (Chicago)
71. Rockford
72. Schenectady
73. Shawnee Mission
74. Springfield, Ill.
75. Springfield, Mo.
76. Staten Island
77. Jamaica
*78. South Suburban (Chicago)
79. Canton
80. Columbia
81. Fort Lauderdale
82. Greensboro
83. Portland, Me.
84. Atlanta
85. Charlotte
86. Jacksonville
87. Miami
88. Orlando
89. Pensacola
90. Raleigh
91. Tampa
92. Winston-Salem
93. Bridgeport
94. Hartford
95. New Haven
96. Stamford
97. Waterbury
98. Boston
99. Springfield, Mass.
100. Worcester
101. Providence
102. Los Angeles
103. San Francisco
104. Oakland
105. Sacramento
106. San Diego
107. Honolulu
108. Long Beach
109. San Jose
110. Pasadena
111. Berkeley
112. Fresno
113. Van Nuys
114. Glendale
115. Santa Ana
116. Palo Alto
117. Santa Monica
118. Santa Barbara
119. North Hollywood
120. San Bernardino
121. Las Vegas
122. Bakersfield
123. Inglewood
124. Whittier
125. New York
126. Akron
127. Albany
128. Albuquerque
129. Austin
130. Baltimore
131. Binghampton
132. Birmingham
133. Bronx
134. Brooklyn
135. Buffalo
136. Camden
137. Chattanooga
138. Chicago
139. Cincinnati
140. Cleveland
141. Colorado Springs
142. Columbus
143. Dayton
144. Denver
145. Des Moines
146. Detroit
147. Elizabeth
148. El Paso
149. Erie
150. Flint
151. Flushing
152. Fort Wayne
153. Fort Worth
154. Grand Rapids
155. Harrisburg
156. Houston
157. Indianapolis
158. Jackson

*Numbers 70 and 78 were omitted from the sample because of non-comparability with other offices.

TABLE IV 2

OUTPUTS AT EACH OFFICE

NUMBER	OUTGOING: CANCELLED LETTERS	OUTGOING: NON CAN-CELLED LETTERS	OUTGOING: FLATS	OUTGOING: PARCELS	OUTGOING: SMALL PARCELS & ROLLS	INCOMING: LETTERS	INCOMING: FLATS	INCOMING: PARCELS	INCOMING: SMALL PARCELS & ROLLS	WINDOW SERVICE	NUMBER
1	21094	30966	7287	2690	4347	54391	14065	1072	926	3334	1
2	111870	507365	177193	52591	96404	347535	82064	7070	10507	42115	2
3	33344	58958	35393	11205	19460	70137	19897	2711	653	4501	3
4	25792	65159	15685	4117	10168	71637	23265	1840	931	6059	4
5	29201	51225	10969	3155	8498	70405	21478	1675	1317	7134	5
6	29596	80418	24094	6130	19647	89492	22519	2788	0	5847	6
7	32363	51236	6761	6029	6365	81133	13189	1611	3473	10198	7
8	82527	146230	27330	9750	30567	247212	55174	3301	4839	19393	8
9	25437	27037	5396	1881	6874	68384	14189	1807	1568	3109	9
10	41371	72480	12078	4108	8778	97900	29672	2272	0	7808	10
11	76416	205968	59949	25874	29958	247074	48588	5373	2020	16708	11
12	143810	277134	63503	22845	49358	426354	115768	7589	12218	30426	12
13	158479	207549	44986	15249	0	428724	111593	9060	0	38686	13
14	31670	27822	5515	3568	4999	86515	22602	1844	791	3704	14
15	24076	40193	5546	1757	6386	58351	14970	1601	0	3979	15
16	58031	153016	40442	12053	23398	165849	37966	3632	3479	15827	16
17	78853	772755	107349	15595	105602	362430	65864	5953	3983	18959	17
18	100251	212971	31473	13372	39231	257608	51452	4096	3985	15816	18
19	45799	59680	11624	7294	13799	126593	32140	4507	3352	5542	19
20	72292	110384	22302	10920	12809	192525	53144	3062	2319	13787	20
21	62631	179542	44090	12616	28428	179419	55914	3961	8857	14598	21
22	27126	62826	9728	4839	12882	71248	18016	933	2333	5606	22
23	31235	39387	6583	4375	12028	91476	29287	1447	1699	5696	23
24	304760	921884	161650	66193	145007	967669	218594	16437	22664	81069	24
25	87749	83080	11348	3641	6033	222038	44488	2977	4034	12995	25
26	170506	426355	133379	25986	127633	495558	151031	6875	12468	31973	26
27	108081	226016	44008	12703	36478	299671	57622	4384	8700	22341	27
28	24935	38689	4273	1316	5206	62040	13037	977	0	4040	28

NUMBER	OUTGOING CANCELLED LETTERS	OUTGOING NON CAN-CELLED LETTERS	OUTGOING FLATS	OUTGOING PARCELS	OUTGOING SMALL PARCELS & ROLLS	INCOMING LETTERS	INCOMING FLATS	INCOMING PARCELS	INCOMING SMALL PARCELS & ROLLS	WINDOW SERVICE	NUMBER
29	63876	117353	20759	8287	13248	202569	39217	3361	3218	15057	29
30	78175	117845	22783	8559	21524	219425	51501	3178	14866	15967	30
31	231813	459906	102149	43584	101207	714632	186784	9249	19542	51548	31
32	79179	410487	108448	24790	119220	250987	63970	3531	6894	20173	32
33	60779	104404	33692	6777	18468	152611	32884	2457	6605	10341	33
34	67082	84966	13720	6784	21361	223610	43885	4803	6719	12597	34
35	31716	89493	16940	1043	7240	86257	24173	1053	3207	5662	35
36	21587	61382	2580	11087	11735	76538	12323	1819	2959	5438	36
37	139741	284547	46747	14007	24761	332794	72300	6103	9447	25920	37
38	32946	59652	10455	3547	8874	64853	18244	2042	1916	5013	38
39	16224	34662	13669	2420	12089	39322	12091	792	0	2472	39
40	24689	50131	11457	2250	9384	62789	24625	1509	1590	3598	40
41	37681	91361	40343	9422	23277	89625	26679	2906	1842	5543	41
42	50398	95718	17261	5038	22591	132689	23353	1816	6214	9469	42
43	39586	35203	9209	2364	4374	92087	23902	2238	2991	4702	43
44	12966	35033	2893	15642	3736	50949	9963	1705	583	4974	44
45	59663	80025	11950	4580	10411	171494	38453	2368	8363	9532	45
46	23985	36171	7833	3395	3679	60064	12360	2131	3256	5055	46
47	39645	113948	15504	3093	7718	109863	20984	1605	1715	6891	47
48	46443	17579	6224	1621	4885	108023	25414	1785	5259	4866	48
49	59635	112381	11919	3757	4295	147113	36005	2375	2157	12253	49
50	17523	62827	7315	2871	16559	48936	11017	624	0	3158	50
51	268423	1211764	362153	50755	288861	803600	224636	15215	36466	54765	51
52	18810	121323	18006	4046	30271	63178	13314	883	619	4926	52
53	50514	55945	14684	6931	10201	127616	35738	2006	1930	7873	53
54	20949	41864	2523	3725	6439	59018	13912	1547	0	3469	54
55	37490	51228	7923	1442	7513	105149	22916	2028	2665	6556	55
56	34262	44578	5428	3337	7680	126838	31606	1303	1748	4552	56
57	30435	41108	7476	2656	7595	79932	22200	1979	2726	3777	57
58	25776	41262	8809	3898	10791	77208	16320	1685	1084	3749	58
59	30218	12530	5214	972	636	87520	24608	1246	2507	2911	59
60	31286	32787	8209	2597	3286	88264	20016	1513	1372	4628	60

NUMBER	OUTGOING CANCELLED LETTERS	OUTGOING NON CAN-CELLED LETTERS	OUTGOING FLATS	OUTGOING PARCELS	OUTGOING SMALL PARCELS & ROLLS	INCOMING LETTERS	INCOMING FLATS	INCOMING PARCELS	INCOMING SMALL PARCELS & ROLLS	WINDOW SERVICE	NUMBER
61	38463	70084	13881	4051	18918	91643	20713	1519	3669	1945	61
62	23181	58836	9566	2243	11778	71568	16787	1448	836	4159	62
63	21968	17228	4864	1243	2177	55901	15412	1109	0	2262	63
64	19823	22118	7735	1466	1067	79051	17715	701	0	4461	64
65	10702	30751	3789	2344	1341	58669	6522	3338	0	9012	65
66	21499	38938	4182	3649	5308	64314	15622	690	938	2339	66
67	25133	103876	18482	4627	19172	61045	23894	736	0	4152	67
68	20488	71954	18317	6165	12897	63362	19658	1376	927	3452	68
69	23335	36736	10513	2106	9476	73566	18832	1531	1413	3413	69
70	0	312103	56133	1335	57915	0	0	0	1	1	70
71	30129	36111	4095	2040	4857	78221	21037	1145	1625	4482	71
72	23154	12124	6079	812	2389	55243	15492	1053	811	3149	72
73	22129	17921	2749	1015	985	78471	22518	1185	2528	3217	73
74	24574	87793	10924	3289	11277	71444	17523	1090	1045	6224	74
75	19523	36578	6447	2059	8452	50079	11066	834	3662	2799	75
76	26861	4419	1231	416	1469	66379	15532	683	1164	2125	76
77	82581	504250	51904	12357	75555	255175	54058	2522	6540	9092	77
78	0	179803	12714	69487	37557	0	0	0	0	1	78
79	27680	63202	9192	2173	10686	78462	23266	1021	0	4176	79
80	31432	101917	40550	10437	17850	76726	18144	2509	0	5108	80
81	50045	13107	4368	1090	672	94517	34823	1819	0	5090	81
82	25195	114336	56891	18284	38675	69352	18323	2121	0	7034	82
83	20208	76953	30203	7069	16196	48217	12362	990	0	3257	83
84	117956	650325	136908	61125	80488	571668	146530	11179	20562	38841	84
85	48218	138387	16735	8777	15883	133562	30029	3716	667	11007	85
86	61582	263741	77271	18380	60553	214048	49080	3404	11962	11342	86
87	176519	203121	33232	8775	37879	411285	77967	7816	19987	26030	87
88	39555	79688	27577	2425	20613	110214	24070	2898	4083	5148	88
89	19871	16155	4662	929	390	50594	14575	1155	52	2216	89
90	22216	83098	11923	5319	4750	79477	15804	2085	5434	5646	90
91	53658	125660	10105	5713	17822	143265	27336	3068	4919	7676	91
92	21994	23992	2179	1418	1070	60754	13936	1179	1352	3371	92

NUMBER	OUTGOING CANCELLED LETTERS	OUTGOING NON CANCELLED LETTERS	OUTGOING FLATS	OUTGOING PARCELS	OUTGOING SMALL PARCELS & ROLLS	INCOMING LETTERS	INCOMING FLATS	INCOMING PARCELS	INCOMING SMALL PARCELS & ROLLS	WINDOW SERVICE	NUMBER
93	33779	37989	6798	2139	3039	96999	22496	1893	2002	5806	93
94	62313	171277	26545	5434	23705	165206	42560	1626	5486	24189	94
95	45358	193072	56668	9203	38652	157355	47026	2513	1972	8592	95
96	17296	64572	8472	1938	10990	54957	8596	1021	3131	3608	96
97	16855	33780	3955	1011	7272	42216	10521	545	605	2240	97
98	340738	799682	98156	36931	131470	1091104	245269	14067	40352	71204	98
99	30736	149747	81021	24525	62535	68681	20502	1385	962	6614	99
100	31250	65824	7213	3110	12685	82013	18303	1336	3131	5311	100
101	64824	215113	31706	7205	31988	168652	35507	4056	7938	10614	101
102	371406	1088153	182051	41604	108736	1119090	281071	13922	35868	105998	102
103	198562	813278	169161	44517	134459	620195	125403	9870	25959	54610	103
104	72889	291356	54951	21562	57875	197587	43222	2952	5093	14224	104
105	69375	150010	24604	4778	19209	200520	35798	2848	7075	13285	105
106	100241	115128	22193	4875	15595	254333	73164	4692	4523	12143	106
107	58094	72967	14480	3188	11418	135550	24317	2348	7555	9365	107
108	63191	106444	25898	1522	4651	165435	33067	2568	1815	9609	108
109	56744	86588	14062	4640	8938	150389	47280	3870	2534	7507	109
110	40030	81095	13108	3754	8172	102805	21069	1696	1085	6278	110
111	30901	21212	6682	1016	1265	86476	17353	1204	2802	5074	111
112	39558	36942	5833	1727	3204	91651	20020	1577	2378	5263	112
113	44164	130141	19766	3908	17260	109815	20781	1003	1960	4876	113
114	25319	35342	4621	1817	2907	63366	15042	900	825	3775	114
115	28824	141457	21304	3705	19040	82315	13651	1150	1677	5028	115
116	23494	39039	11596	1626	2607	56925	18649	813	2882	4150	116
117	22526	35004	3500	744	1820	57686	14225	727	183	3295	117
118	22329	6882	2315	540	514	54489	13194	791	1466	2507	118
119	27594	15316	3721	968	2287	70684	19883	859	1779	4222	119
120	21788	77475	11563	3175	15352	58661	14183	950	456	3137	120
121	30690	22462	10008	1649	6713	75554	16098	1966	616	3030	121
122	26709	27113	6597	2165	2130	65071	16385	846	798	2908	122
123	20498	143836	28008	5793	38453	55357	12911	588	1362	2597	123

	OUTGOING					INCOMING					
NUMBER	CANCELLED LETTERS	NON CANCELLED LETTERS	FLATS	PARCELS	SMALL PARCELS & ROLLS	LETTERS	FLATS	PARCELS	SMALL PARCELS & ROLLS	WINDOW SERVICE	NUMBER
124	21966	49953	9648	864	11787	55335	13906	1264	1112	2325	124
125	772594	2673280	759315	206173	626079	2474317	544464	38452	201138	304888	125
126	45581	91918	23341	2232	3531	137123	38337	2587	3891	9780	126
127	36702	186729	32336	7848	31843	108867	17919	2626	1890	11514	127
128	42396	30250	6841	1760	6843	91870	27358	2413	3777	5131	128
129	42973	71642	10798	1929	7751	119357	26509	3021	2571	7552	129
130	189012	367153	69507	15166	58387	578594	156233	11000	17928	31301	130
131	17054	45403	9271	3273	18347	39147	10560	813	798	2279	131
132	64465	191702	67756	12047	40619	176920	41678	3097	4151	12316	132
133	146221	50976	8521	5756	6952	508799	109443	4116	17775	14386	133
134	283864	147785	22177	19017	33434	926982	180434	6795	41758	39454	134
135	107127	348007	129326	14975	59239	355812	102537	3727	9192	19298	135
136	27396	168147	25286	3927	38044	88894	17636	1081	900	6283	136
137	30504	49424	14166	2954	11159	73767	16906	2336	671	5375	137
138	610139	2158863	410344	146281	302766	2340653	489678	40678	84570	233790	138
139	137277	459605	216831	42335	133828	454587	103144	5840	17980	30977	139
140	229275	459676	125211	26134	63262	721399	181349	11123	34036	48711	140
141	28022	15918	5073	2226	2803	68527	15009	2305	1371	3489	141
142	97516	222769	37505	13088	24745	329487	94804	4148	3199	24226	142
143	76014	101665	33273	5665	17204	197880	61312	3056	4070	28097	143
144	140823	284663	53264	18727	50940	337098	80819	7161	11900	27406	144
145	56471	212653	48357	8685	17474	184593	36759	2723	2540	19770	145
146	266817	637104	233451	47609	87899	757320	250395	12700	6675	61727	146
147	25954	24715	3760	1298	2655	76209	18733	846	570	4575	147
148	38421	22374	4527	2110	6192	92273	18002	2029	2324	4770	148
149	24429	24684	4695	1646	4769	68297	13727	1547	1094	3411	149
150	33946	44150	12786	2220	6242	72152	19882	1289	5520	5006	150
151	118181	36578	6256	3427	6140	313732	70550	3177	11439	11368	151
152	34297	62608	18588	3107	7147	94650	22828	1606	2379	5939	152
153	66568	138942	47268	24165	26324	195049	49006	2957	2555	12664	153
154	51049	53009	15996	4013	11338	123449	31802	1813	4587	8450	154
155	28146	132562	27572	8936	18939	85273	16881	0	2593	9537	155

	OUTGOING					INCOMING					
NUMBER	CANCELLED LETTERS	NON CAN-CELLED LETTERS	FLATS	PARCELS	SMALL PARCELS & ROLLS	LETTERS	FLATS	PARCELS	SMALL PARCELS & ROLLS	WINDOW SERVICE	NUMBER
156	183262	195413	32971	9889	24383	617794	125607	7875	15038	33136	156
157	122249	322811	103531	28186	53658	405507	87910	7417	9717	27655	157
158	31658	61692	10466	3840	11893	70029	17136	1408	1108	5518	158

Units: First-handling pieces in thousands; Window services in thousands of dollars of postal revenue, but unit used in statistical analysis was millions of dollars.

Source: POD Form 2397: "Summary of Basic Operating Data," Work Measurement System.

TABLE IV 3

INTRA POST OFFICE INPUTS AND SECTIONAL CENTER DUMMY

NUMBER	INSIDE LABOR 10^3 hours	INSIDE SPACE 10^3 sq.ft.	GSA SPACE 10^3 sq.ft.	MECHANIZ. OUTLAY $\$10^3$	SEC.CENT. DUMMY	NUMBER
1	389.16	112.39	15.89	32.10	1	1
2	6069.31	282.59	489.31	404.24	1	2
3	835.47	63.88	71.16	188.86	1	3
4	591.11	43.12	63.37	29.87	1	4
5	625.78	25.89	224.53	33.18	1	5
6	464.98	84.18	52.40	40.98	1	6
7	1006.26	67.63	64.78	35.95	0	7
8	2195.14	163.04	134.83	96.64	1	8
9	388.77	28.50	18.39	14.01	1	9
10	746.95	62.93	49.80	34.85	1	10
11	2397.06	158.86	.10	122.00	1	11
12	4188.09	342.06	180.91	122.49	1	12
13	3956.04	152.32	430.95	185.86	1	13
14	520.09	67.15	25.89	30.36	1	14
15	457.14	19.75	33.89	24.34	1	15
16	1634.35	78.49	149.01	189.81	1	16
17	4064.31	167.17	210.19	99.48	1	17
18	2790.57	66.42	423.69	131.89	1	18
19	1069.56	120.42	81.01	54.22	1	19
20	1667.37	387.22	202.76	79.12	1	20
21	2040.60	403.83	42.01	109.07	1	21
22	732.16	19.39	72.17	40.57	1	22
23	633.97	66.69	103.96	24.83	1	23
24	12357.27	560.60	187.17	828.82	1	24
25	1461.18	166.49	59.50	75.41	0	25
26	7368.73	325.71	632.79	454.41	1	26
27	2945.40	500.70	69.69	165.34	1	27
28	433.11	52.83	57.00	24.68	1	28
29	1718.14	82.27	172.78	91.10	1	29
30	2155.98	94.44	219.64	93.41	1	30

NUMBER	INSIDE LABOR	INSIDE SPACE	GSA SPACE	MECHANIZ. OUTLAY	SEC.CENT. DUMMY	NUMBER
31	7600.73	377.66	742.48	389.55	1	31
32	3748.08	198.74	448.99	137.28	1	32
33	1222.92	89.57	167.17	56.04	1	33
34	1713.00	176.27	96.25	71.95	1	34
35	1096.63	60.04	67.49	46.99	1	35
36	552.80	57.23	104.27	32.79	1	36
37	3579.58	656.55	54.22	232.99	1	37
38	633.97	110.94	19.61	32.33	1	38
39	425.39	64.97	69.20	42.01	1	39
40	436.59	41.93	74.37	22.26	1	40
41	1065.29	186.98	87.88	106.70	1	41
42	1241.41	96.45	125.71	53.95	1	42
43	712.66	83.68	38.71	44.43	1	43
44	345.50	11.95	40.00	14.91	1	44
45	1363.76	121.27	78.57	264.54	1	45
46	468.72	29.25	80.80	26.71	1	46
47	916.90	91.65	47.32	37.75	1	47
48	623.28	78.81	22.00	36.63	1	48
49	1166.78	79.36	242.02	88.77	1	49
50	454.41	28.39	78.02	20.76	1	50
51	11801.71	301.27	1629.45	775.11	0	51
52	779.77	62.43	28.11	25.61	0	52
53	893.37	92.02	58.79	47.18	1	53
54	404.24	27.14	75.87	22.56	1	54
55	793.93	47.47	50.00	27.97	1	55
56	684.71	63.50	78.34	28.79	0	56
57	686.77	67.90	53.41	28.25	1	57
58	460.36	34.81	134.16	21.54	1	58
59	510.39	48.28	22.60	20.31	0	59
60	562.84	42.31	34.88	29.11	1	60
61	697.15	122.00	14.60	30.57	0	61
62	515.43	29.96	78.18	27.22	1	62
63	297.38	38.94	24.80	16.33	1	63
64	418.64	9.60	70.11	15.50	0	64
65	308.59	14.40	20.91	10.15	0	65

NUMBER	INSIDE LABOR	INSIDE SPACE	GSA SPACE	MECHANIZ. OUTLAY	SEC.CENT. DUMMY	NUMBER
66	480.58	31.50	46.48	23.69	1	66
67	627.03	46.99	2.40	20.35	1	67
68	542.40	101.80	10.50	24.61	1	68
69	541.86	37.64	32.59	21.12	1	69
71	587.57	44.97	79.60	25.10	1	71
72	442.31	30.39	42.10	19.38	0	72
73	367.97	70.88	.10	21.33	0	73
74	602.45	36.31	34.40	25.48	1	74
75	416.96	31.94	43.90	192.29	1	75
76	487.85	110.83	.10	25.08	0	76
77	4175.54	237.46	97.03	103.96	0	77
79	539.15	42.82	63.69	23.52	1	79
80	884.48	26.10	39.10	45.74	1	80
81	642.26	88.68	9.60	32.75	0	81
82	1187.97	273.96	77.48	81.61	1	82
83	875.68	52.72	93.04	32.39	1	83
84	6020.95	234.39	330.30	251.39	1	84
85	1275.38	90.56	84.86	52.14	1	85
86	2221.64	123.97	122.24	81.53	1	86
87	3659.20	420.31	159.65	289.17	1	87
88	1024.54	118.04	54.22	47.04	1	88
89	350.02	25.69	15.71	18.03	1	89
90	688.83	55.09	43.51	28.70	1	90
91	1099.93	44.21	37.60	44.17	1	91
92	413.64	36.31	56.88	24.48	0	92
93	710.52	46.48	73.70	28.82	0	93
94	1976.34	105.21	137.14	65.56	1	94
95	2230.54	162.88	105.64	75.94	1	95
96	463.59	11.50	35.80	18.90	1	96
97	394.65	27.91	47.80	18.03	1	97
98	13521.01	562.28	1012.32	659.84	1	98
99	2385.11	150.05	65.63	196.57	1	99
100	597.65	25.89	103.03	30.45	1	100
101	2050.83	273.14	71.38	56.15	1	101
102	13946.73	473.43	1322.13	887.14	0	102

NUMBER	INSIDE LABOR	INSIDE SPACE	GSA SPACE	MECHANIZ. OUTLAY	SEC.CENT. DUMMY	NUMBER
103	9857.62	355.67	710.52	297.08	1	103
104	3206.71	131.24	87.88	115.12	1	104
105	1697.65	76.71	70.53	84.35	1	105
106	2006.20	50.30	70.04	86.14	1	106
107	1093.35	33.78	43.90	53.14	1	107
108	1199.91	64.33	95.58	52.30	1	108
109	1258.91	142.17	46.62	54.93	1	109
110	767.39	50.40	59.03	34.67	1	110
111	520.09	31.09	59.09	24.98	0	111
112	684.03	51.52	53.09	31.00	1	112
113	864.37	69.27	8.80	30.42	1	113
114	508.26	15.30	65.30	27.17	0	114
115	697.15	46.71	31.19	28.62	1	115
116	472.01	32.69	20.91	20.47	0	116
117	397.03	22.81	30.60	15.66	0	117
118	356.02	16.20	44.88	17.24	0	118
119	387.61	40.00	17.39	19.95	0	119
120	514.40	27.19	39.41	19.97	1	120
121	571.92	48.52	23.59	20.35	1	121
122	404.64	69.97	17.00	20.82	1	122
123	800.31	71.02	11.10	27.55	1	123
124	426.67	52.83	15.60	22.22	1	124
125	51021.38	1143.67	4171.37	2162.46	0	125
126	1107.65	96.93	52.98	39.10	1	126
127	1519.29	132.42	87.18	49.90	1	127
128	727.78	67.29	44.39	40.94	1	128
129	872.18	34.99	128.25	45.24	1	129
130	5431.66	240.33	312.31	247.30	1	130
131	464.05	33.12	64.33	16.63	1	131
132	1919.85	127.87	151.56	72.60	1	132
133	3670.19	271.51	204.59	106.80	0	133
134	8006.43	666.47	496.21	256.47	0	134
135	4268.42	697.15	29.20	153.39	1	135
136	962.95	86.66	32.88	34.23	1	136
137	580.56	43.12	48.00	31.66	1	137
138	32435.22	500.20	999.25	2527.54	0	138

NUMBER	INSIDE LABOR	INSIDE SPACE	GSA SPACE	MECHANIZ. OUTLAY	SEC.CENT. DUMMY	NUMBER
139	6014.93	474.85	592.20	256.21	1	139
140	8535.59	645.48	545.60	562.28	1	140
141	492.75	43.21	41.89	22.20	1	141
142	2612.34	158.22	108.96	103.34	1	142
143	1662.37	144.17	72.39	3.71	1	143
144	3512.21	730.70	799.51	422.84	1	144
145	1513.23	74.89	185.49	72.66	1	145
146	9662.43	1355.60	266.93	1490.70	1	146
147	423.27	30.11	35.52	19.67	0	147
148	749.20	126.34	29.99	43.95	1	148
149	422.84	40.89	54.60	23.67	1	149
150	701.35	143.74	20.31	102.72	1	150
151	2499.88	174.51	95.97	81.37	0	151
152	644.19	51.62	76.94	25.38	1	152
153	1469.97	130.06	236.51	86.40	1	153
154	887.14	310.75	.10	137.96	1	154
155	1492.19	275.61	.10	278.94	1	155
156	4328.60	755.97	93.50	217.24	0	156
157	4052.14	195.98	253.92	146.06	1	157
158	544.03	51.11	26.90	33.62	1	158

C. Estimation of Factor Prices

The model laid out in Chapter 3 has three variable factors in each production function: labor, floor space, and machines. We find it difficult to measure the input of machines in homogeneous physical units, so we measure, instead, the imputed outlay on machines. This leaves labor and floor space. Problems were encountered in estimation of factor prices of each, but satisfactory results were obtained in both cases.

C-1. The Price of Labor

The POD uses a uniform national pay scale, but labor quality, seniority and market conditions vary cross-sectionally. Hence, the price of labor will vary over the sample.

It would be nice if we could measure labor quality and use as the labor input quality-corrected physical units. Unfortunately, I have not found a way to quantify labor quality. In fact, this study concludes that the labor available to post offices is not of constant quality. At this stage of the study we do assume all labor hours are of equivalent quality.

Most postal workers are in the Postal Field Service 4 category, starting salary for which in 1966 was $5,265 per year, or $2.53 per hour. Compare this to an average nonpostal wage of $3.16 per hour in San Francisco, $2.88 in California as a whole, on the one hand, and $1.92 in the South. Table IV-4 gives these data systematically.

If the post offices are roughly cost minimizers, then they should equate the marginal cost savings of an extra unit of labor to the average labor price they actually pay. Cost per man-hour was calculated using two sources: (1) Annual Report of the Postmaster General, Financial Supplement, 1966, Table 107, which gives salaries including fringe benefits

TABLE IV 4

FACTOR PRICES AT EACH OFFICE

NUMBER	WAGE	FLOORSPACE COST	NUMBER
1	3.40	1.25	1
2	3.93	1.04	2
3	3.72	.75	3
4	3.79	1.22	4
5	3.55	1.28	5
6	3.35	1.15	6
7	3.91	1.15	7
8	3.36	.93	8
9	3.71	.93	9
10	3.63	1.23	10
11	3.72	1.03	11
12	3.63	1.49	12
13	3.62	1.68	13
14	3.56	.85	14
15	3.56	.97	15
16	3.72	1.17	16
17	3.74	1.56	17
18	3.56	1.74	18
19	3.44	1.03	19
20	3.50	1.17	20
21	3.55	1.45	21
22	3.74	1.65	22
23	3.65	.97	23
24	3.70	1.78	24
25	3.64	.83	25
26	3.70	1.36	26
27	3.80	1.45	27
28	3.70	1.10	28
29	3.44	1.14	29
30	3.91	1.70	30
31	3.93	1.14	31
32	3.62	.75	32
33	4.09	.53	33
34	3.71	.88	34
35	3.81	1.40	35
36	3.70	.89	36
37	3.63	1.11	37
38	3.56	.97	38

NUMBER	WAGE	FLOORSPACE COST	NUMBER
39	3.56	1.11	39
40	3.72	1.69	40
41	3.63	1.27	41
42	3.91	1.33	42
43	3.63	.67	43
44	3.72	1.01	44
45	3.85	1.14	45
46	3.40	.77	46
47	3.74	1.19	47
48	3.64	.90	48
49	3.50	1.11	49
50	3.91	.61	50
51	3.44	2.30	51
52	3.91	1.73	52
53	3.40	1.09	53
54	3.70	1.25	54
55	3.82	1.07	55
56	3.91	1.66	56
57	3.85	.90	57
58	3.71	1.02	58
59	3.44	1.63	59
60	3.56	1.35	60
61	3.70	1.01	61
62	3.20	1.57	62
63	3.80	1.24	63
64	3.65	1.30	64
65	3.91	1.56	65
66	3.72	1.07	66
67	3.74	1.07	56
68	3.79	1.23	68
69	3.36	.87	69
71	3.65	1.23	71
72	3.91	1.39	72
73	3.40	1.31	73
74	3.65	.87	74
75	3.93	.97	75
76	3.91	1.76	76
77	3.91	1.56	77
79	3.85	.95	79

NUMBER	WAGE	FLOORSPACE COST	NUMBER
80	3.69	.95	80
81	3.81	.99	81
82	3.63	.89	82
83	3.60	1.18	83
84	3.62	1.09	84
85	3.63	.96	85
86	3.81	.90	86
87	3.81	1.42	87
88	3.81	1.10	88
89	3.81	.63	89
90	3.63	1.29	90
91	3.81	.99	91
92	3.63	1.03	92
93	3.90	1.34	93
94	3.90	1.37	94
95	3.90	.83	95
96	3.90	1.88	96
97	3.90	1.32	97
98	3.83	1.38	98
99	3.83	1.66	99
100	3.83	1.13	100
101	3.80	1.07	101
102	3.75	1.49	102
103	3.61	.97	103
104	3.61	1.24	104
105	3.67	1.28	105
106	3.74	1.45	106
107	3.65	1.35	107
108	3.71	1.25	108
109	3.60	1.73	109
110	3.77	1.28	110
111	3.68	1.37	111
112	3.70	.96	112
113	3.59	1.13	113
114	3.71	1.50	114
115	3.58	1.02	115
116	3.68	1.02	116
117	3.77	1.39	117
118	3.70	.83	118

NUMBER	WAGE	FLOORSPACE COST	NUMBER
119	3.72	1.17	119
120	3.60	.82	120
121	3.51	.80	121
122	3.75	.83	122
123	3.45	1.22	123
124	3.67	1.05	124
125	3.91	2.11	125
126	3.85	1.04	126
127	3.91	1.18	127
128	3.54	.88	128
129	3.71	.72	129
130	3.44	1.42	130
131	3.91	1.70	131
132	3.56	.96	132
133	3.91	1.58	133
134	3.91	1.53	134
135	3.91	1.03	135
136	3.74	1.23	136
137	3.72	.98	137
138	3.65	1.37	138
139	3.85	1.64	139
140	3.85	1.07	140
141	3.85	1.01	141
142	3.85	.89	142
143	3.85	.86	143
144	3.85	1.06	144
145	3.56	1.33	145
146	3.79	1.49	146
147	3.74	1.31	147
148	3.71	1.06	148
149	3.70	1.05	149
150	3.79	1.25	150
151	3.91	1.40	151
152	3.72	1.12	152
153	3.71	1.07	153
154	3.79	1.45	154
155	3.70	2.13	155
156	3.71	1.26	156
157	3.72	1.19	157
158	3.44	.94	158
Mean	3.71	1.20	

and the number of paid postal employees in each State; (2) more detailed data were available to me for California, Honolulu, and Las Vegas, from unpublished data in the books of the San Francisco Regional Office.

Fifty-two different annual wages were calculable from source 1, while twenty-three observations were available from source 2. This gave 75 observations on the price of labor in the 156 cities in our sample.

The California detail is useful in adjusting State averages. Cities in our sample are large. Wage levels are higher in large cities than in smaller cities or rural areas. Therefore, if we compare the State average labor cost per man-hour for California, \$3.48, with the calculated average for cities on which I have data, \$3.67, we find that we should multiply State averages by 1.054. The mean POD employee worked .956 man-years or 1892 hours in PFY 66 so man-year figures have to be divided by 1892 to yield man-hours. California data pertained to calendar year 1967, centered on June, 1967, while PFY 66 is centered on January 1966. The distance between these two dates is 1.5 years. Because of seniority and statutory pay increases[1] salaries increase 5% per year; we can convert observations on calendar year 1967 to PFY 66 by dividing by 1.076. Other personnel costs amount to 7.69% of salary costs [74, Table 804]. Hence we can convert salary cost per man-hour to total labor cost by multiplying by the factor 1.0769. The net result of these two adjustments is to multiply by 1.0008, which we can safely call unity.

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[1]Public Law 89-504, effective 2 July 1966, increased salaries by 2.9%. "This was the fifth statutory increase in salary enacted for postal employees since 1962, bringing the average increase for postal employees during the five-year period to a fraction more than 25 percent" [74, 1967, p. 129].

High-salaried workers who work at Washington, D.C. headquarters have apparently been allocated to Maryland and Virginia where these workers live, and low-salaried workers to the District of Columbia, where they live. Therefore, the Washington wage must be adjusted upwards and the Virginia and Maryland wage downwards. The average labor price in the Bureau of Operations over the country was $3.265 [74, Table 302]. When this is adjusted for the large cities of our sample we have $3.441 for the price of labor in Virginia, Maryland and Washington, D.C.

C-2. <u>The Price of Floor Space</u>

In the case of floor space, again, the obvious statistical procedure did not prove to be practical for estimation of the factor price.

At its leased and rented facilities, the POD keeps good records on annual rental cost and the amounts of interior, platform, and outside space rented at each location. Since there are typically twenty or thirty stations under the management of each post office, the obvious procedure would be to estimate the following function for each separate location:

$$R = a + b_i I + b_p P + b_o O + e \qquad (1)$$

where: R = annual rental cost of the location

I = square feet of interior space rented

P = square feet of platform space rented

O = square feet of outside space rented.

We could constrain a to be zero (force the regression line through the origin) and then interpret the b_j ($j=i,p,o$) as the prices of the three types of space. Unfortunately, the model of equation (1) is misspecified. Location is not included. It is well known that rental prices can vary by a factor of 100 within a city, depending on location. The results of estimating (1) were useless.

Information gained from realty specialists at POD headquarters and at the San Francisco Regional Office indicated that the POD uses the following approximations for planning purposes:

$b_i = 2b_p$ (the price of interior space is twice that of platform space)

$b_o =$ \$.20 per square foot per year.

Doubting that the price of outside space was a universal constant, I adopted, instead:

$$5b_o = b_i \, .$$

Now, for each city let TR be the total of annual rental charges for each location. The mean floorspace price for the city can be estimated by the following ratio:

$$b_i = \frac{TR}{(I + .5p + .20)}$$

The results for each city in the sample are available in Table IV-4.

Certain infirmities of these data should be mentioned. They are as good as the simplifying assumptions above. They are average prices the post offices actually pay and are not necessarily representative of the cost of other types of floor space. They tend to be higher if the post-office buildings in a city are newer.

Since the prices of different types of floor space are proportional, they cannot appear together as independent variables in a regression. The regression coefficient of b_i must be interpreted as a linear combination of the coefficients of the $\{b_j\}$. For example, if the equation for the derived demand for interior space were:

$$\ln V_8 = \alpha + \beta \ln b_i + \gamma \ln b_p + \delta \ln \bar{X}_1 + \eta \ln \bar{X}_2 + \ldots \quad (2)$$

$$\text{since } b_i = 2b_p$$

$$\ln V_8 = \alpha + \gamma \ln 1/2 + (\beta+\gamma) \ln b_i + \delta \ln \bar{X}_1 + \eta \ln \bar{X}_2 \,. \quad (3)$$

The estimated coefficient of $\ln b_i$ is an estimate not of β as in (2), but of $(\beta+\gamma)$ as in (3).

Chapter 5: INTRA POST-OFFICE ACTIVITY

A. Cost Functions

Work by Shephard [64, 65], Uzawa [80], McFadden [46a], and Rosse [62a] suggest that we may just as well work on the cost function as on the production function because of the duality between cost and production functions.[1] Since the cost function is a reduced form, it is preferable from an econometric point of view, to estimate it.

One very useful result I shall exploit is that when the production structure is homothetic, the cost function factors into a part dependent on output, $f(X)$, and a linear homogeneous function of factor prices, $P(w)$,

$$C(w;X) \;=\; f(X) \cdot P(w) \;.$$

For single- or vector-valued output, if the production function is homogeneous of degree k in the factors, then the cost function is homogeneous of degree $1/k$ in X, i.e. $f(X)$ is homogeneous of degree $1/k$.

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[1]Let $X = (X_1,\ldots,X_m)$ be a post-office output and $V^T = (V_1,\ldots,V_n)$ be post-office input, and $w = (w_1,\ldots,w_n)$ be prices for the inputs V. Let $L(X)$ be the set of all V that will produce X and define a total cost function $C(w;X) = \min\{w\,V : V \text{ is in } L(X)\}$. If we assume: (A) for all nonnegative X, $L(X)$ is a nonempty closed set consisting of nonnegative inputs V, then $C(w;X)$ always exists and is uniquely determined by w and X. If, in addition,

- (C) disposal activities are costless, then
- (A') $C(w;X)$ is defined and nonnegative for all semi-positive w and X and is continuous and homogeneous of degree one in w.
- (B') $C(w;X)$ is a concave function of w, and
- (C') $C(w;X)$ is nondecreasing in X.

The burden of the foregoing theorem is that when neo-classical assumptions are made, cost-minimizing behavior posited and input prices given, then a well-defined cost function will exist for vector-valued post-office output.

Both the Cobb-Douglas and CES production correspondences are homogeneous in factors so that their cost functions will be homogeneous to the inverse degree in outputs. For such analytical forms, the degree of homogeneity of the production function will define increasing, constant, or decreasing returns to scale.

The cost function[2] for intra post-office activity according to the Cobb-Douglas model is

$$\ln C \;=\; \text{const.} + \frac{1}{\Sigma}\left(\sum_{i=1}^{5} \alpha_i x_i - \alpha_6 v_6 + \alpha_7 W_7 + \alpha_8 W_8\right) \tag{1}$$

where the constant $= \frac{1}{\Sigma}(-\alpha_7 A_7 - \alpha_8 A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a) + \ln \Sigma$.

Results of estimation of this equation are shown in the first line of Table V-1. All estimated regression coefficients are significantly different from (s.d.f.) zero at the .05 level save those of third class, GSA space, and the sectional center dummy.

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[2]We can check this cost function with the use of the following theorem. If a cost function, $C(w;X)$, is differentiable with respect to prices, then $\partial C/\partial w_i \;=\; V_i(w;X)$ where V_i is the cost-minimizing input of the ith factor needed to produce output X. That is, derived demand functions are simply the partial price derivatives of the cost function. Differentiating equation (1) with respect to w_7, the price of labor, gives $\frac{\partial C}{\partial w_7} = \frac{C}{w_7}\,\frac{\alpha_7}{\Sigma}$. Taking the logarithm of this, we have

$$\ln C - \ln \Sigma + A_7 - W_7 \;=\; \frac{1}{\Sigma}\left[(\alpha_8+\alpha_9)\,A_7 - \alpha_8 A_8 - \alpha_9 A_9 + \alpha_9 W_9 - a\right]$$
$$+ \frac{1}{\Sigma}\left(\sum_{i=1}^{5} \alpha_i x_i - \alpha_6 v_6\right) - \frac{(\alpha_8+\alpha_9)}{\Sigma}\, W_7 + \frac{\alpha_8}{\Sigma}\, W_8$$

which is, in fact, the derived demand for labor.

Table V-1. Intra post-office cost functions.

Group	C_j	Independent Variable									R^2/SSE
		x1	x2	x3	x4	x5	v_6	W_7	W_8	SC	
All 156 offices 7/11/68 p. 57	-4.96 (.707)	.461 (.057)	.428 (.053)	.027 (.036)	.075 (.033)	.124 (.050)	-.009 (.009)	1.87 (.291)	.134 (.052)	-.041 (.036	.980 3.235
<u>Employment</u>[a]											
52 small offices 7/11/68 p. 48	-1.95 (1.36)	.397 (.106)	.324 (.075)	.010 (.054)	.036 (.046)	.007 (.008)	-.001 (.014)	1.29 (.391)	.060 (.070)	-.039 (.047)	.735 .550
52 medium offices 7/11/68 p. 39	-2.81 (1.76)	.287 (.123)	.214 (.130)	.073 (.071)	.137 (.077)	.160 (.112)	-.014 (.018)	2.46 (.623)	.198 (.113)	.031 (.100)	.771 1.118
52 large offices 7/11/68 p. 30	-4.59 (1.18)	.399 (.087)	.359 (.118)	.105 (.069)	.109 (.068)	.068 (.076)	.005 (.017)	1.89 (.506)	.204 (.086)	-.092 (.061)	.976 .772
<u>Output</u>[b]											
<u>Small</u> 8/7/68 p. 90	-4.03 (1.68)	.554 (.125)	.340 (.085)	-.035 (.060)	.034 (.060)	.053 (.115)	.001 (.015)	1.70 (.403)	.032 (.072)	.022 (.064)	.735 .657
Medium 8/7/68 p. 81	-4.27 (1.76)	.360 (.111)	.357 (.122)	.097 (.075)	.101 (.071)	.246 (.101)	-.006 (.018)	1.81 (.657)	.211 (.115)	-.052 (.088)	.769 1.211
Large 8/7/68 p. 63	-5.01 (1.20)	.424 (.089)	.385 (.121)	.091 (.071)	.108 (.071)	.046 (.077)	.0026 (.017)	1.94 (.521)	.189 (.092)	-.084 (.069)	.975 .819

[a]Grouped according to employment criterion.

[b]Grouped according to output criterion.

Intra post-office cost is most elastic to first- and then second-class mail. Third class, or outgoing noncancelled letters, takes virtually no intra post-office labor. Such mail is presorted by ZIP code and does not have to be put through the culling, edging, stacking, facing and cancelling processes. The relatively low cost elasticity of parcels is surprising and leads to the suspicion (coupled with extra post-office results) that the parcel data may have some errors.

The cost function should be homogeneous of degree one in factor prices, i.e. the coefficients of all factor prices should sum to unity. Only two factor prices are present in the equation and their sum exceeds two. A negative coefficient for the price of capital would have no sensible economic interpretation. The high cost elasticity of the wage rate is probably caused by our assumption of constant quality labor. Those offices which pay high wages are in cities where the nonpostal wage is also high. It is also true that in such cities the POD can attract only labor of a relatively lower quality than in other cities. Hence more labor hours must be used in high-wage cities to accomplish a task that could be done with less labor in a lower-wage city. We have the anomaly of the POD's paying higher wages to lower quality labor. This argument is corroborated by the derived demand for labor equations which show a positive elasticity with respect to the wage rate. More labor hours are demanded where the wage is high. We can only conclude that those labor hours are generally of a lower quality. Furthermore, we shall see in Chapter 6 that the Northeast and far West regions are significantly less productive than the South and the interior. It is concluded that the POD is able to attract lower quality labor in those regions.

Costs appear to be lower ceteris paribus in sectional centers. The relatively high standard error of that coefficient indicates that this result is not very precise. Sectional centers handle many first-handling pieces but do not sort them all so thoroughly as an office of final destination.

A-1. Returns to Scale

The returns-to-scale parameter

$$\rho = \sum_{j=6}^{9} \alpha_j / \sum_{i=1}^{5} \alpha_i$$

is simply the degree of homogeneity in inputs of the production correspondence. It can be estimated as

$$r = \frac{1 - b_6}{\sum_{i=1}^{5} b_i}$$

where the $\{b_i\}$ are the regression coefficients of the outputs $(i=1,\ldots,5)$ and b_6 that of GSA space. According to the theory $\sum_{i=1}^{5} b_i$ is an estimate of $\sum_{i=1}^{5} \frac{\alpha_i}{\Sigma}$, where $\Sigma = \alpha_7 + \alpha_8 + \alpha_9$, and b_6 is an estimate of $-\alpha_6/\Sigma$.

Although r is the estimated returns parameter, sampling theory is more easily derived for the statistic $s = \sum_{i=1}^{6} b_i$. Let us consider the case of decreasing returns to scale, $\rho < 1$, which implies

$$\Sigma < \sum_{i=1}^{5} \alpha_i - \alpha_6 \quad \text{or} \quad 1 < \sum_{i=1}^{5} \alpha_i/\Sigma - \alpha_6/\Sigma .$$

Our estimate of this phenomenon would be $s > 1$. Similarly, $s < 1$ indicates increasing returns to scale and $s = 1$ indicates constant returns to scale, the null hypothesis. The variance of s is given by

$$\mathrm{Var}\,(s) \quad = \quad \sum_{i=1}^{6} \mathrm{Var}\,(b_i) + 2 \sum_{\substack{i=1 \\ i\,<\,j}}^{5} \sum_{j=2}^{6} \mathrm{Cov}\,(b_i, b_j) \; .$$

Table V-2 shows in the first row that the overall cost function indicates r = .905, decreasing returns to scale. Column 3 shows s with its standard error beneath. We conclude that there are significantly decreasing returns to size of office in intra post-office activity on the basis of the Cobb-Douglas cost function.

A-2. Stratified Sample

The degree of returns to scale may not be independent of the level of output. It may vary systematically with output. We may try, as Nerlove did [52, pp. 119 ff.], to approximate the actual cost function by a series of segments of functions linear in logarithms.

We have stratified the sample of 156 offices into three subsamples of 52 offices each on the criteria of authorized employee complements [79], and a scalar measure of output of each office. The groups we used are listed in Tables V-3 through V-5.

a. First stratification. The returns-to-scale parameters are given in Table V-2, column 5, indicating increasing returns to scale in the smallest offices, persisting in medium-sized offices and, finally, decreasing returns to scale in the largest offices. This suggests that the optimal size post office would be in the medium or large group, near

Table V-2. Returns to scale in intra post-office activity.

(1)	(2)	(3)		(4)	(5)	(6)
Group	n	$s = \sum_{i=1}^{6} b_i$ (S.E.) Criterion[a]		Student's t[a]	$r = \frac{1 - b_6}{\sum_{i=1}^{5} b_i}$	Returns to scale
		Emplymt.	Output			
All	156	1.106 (.015)	1.106 (.015)	7.07	.905	decreasing
Small	52	.773 (.095)	.948 (.096)	-2.39 - .55	1.293 1.054	increasing increasing
Medium	52	.857 (.103)	1.154 (.112)	-1.39 1.37	1.164 .867	increasing decreasing
Large[b]	52	1.045 (.035)	1.056 (.036)	1.29 1.56	.957 .946	decreasing decreasing

[a]Two criteria have been used to form size groups of post offices: an employment and an output criterion. Columns (3), (4), (5), and (6) report statistics estimated for the groups formed under each criterion. In columns (4), (5), and (6) the upper figure refers to the employment criterion and the lower to the output criterion.

[b]An analysis excluding New York and Chicago gave virtually identical results.

Table V-3. Fifty-two large offices.

Identifying number	City	Identifying number	City
125	New York	77	Jamaica
138	Chicago	144	Denver
98	Boston	18	New Orleans
102	Los Angeles	27	Portland, Ore.
24	Philadelphia	104	Oakland
51	Washington	142	Columbus
146	Detroit	151	Flushing
140	Cleveland	11	Memphis
103	San Francisco	99	Springfield, Mass.
134	Brooklyn	8	Louisville
26	Pittsburgh	106	San Diego
31	St. Louis	86	Jacksonville
130	Baltimore	21	Omaha
139	Cincinnati	34	San Antonio
2	Kansas City, Mo.	30	Rochester
84	Atlanta	94	Hartford
156	Houston	101	Providence
12	Milwaukee	105	Sacramento
13	Minneapolis	20	Oklahoma City
157	Indianapolis	132	Birmingham
87	Miami	95	New Haven
32	St. Paul	m 25	Phoenix
135	Buffalo	153	Fort Worth
17	Newark	143	Dayton
133	Bronx	29	Richmond
37	Seattle	16	Nashville

m: office in medium group under output criterion of stratification.

Table V-4. Fifty-two medium offices.

Identifying number	City	Identifying number	City
45	Toledo	136	Camden
l 145	Des Moines	s 57	Youngstown
109	San Jose	113	Van Nuys
108	Long Beach	100	Worcester
85	Charlotte	83	Portland, Me.
33	Salt Lake City	10	Madison
42	Syracuse	110	Pasadena
49	Tulsa	80	Columbia
127	Albany	s 112	Fresno
126	Akron	56	Yonkers
155	Harrisburg	s 93	Bridgeport
19	Norfolk	22	Paterson
41	Spokane	s 150	Flint
82	Greensboro	3	Knoxville
7	Long Island City	s 81	Ft. Lauderdale
91	Tampa	s 43	Tacoma
107	Honolulu	115	Santa Ana
154	Grand Rapids	123	Inglewood
53	Wichita	137	Chattanooga
88	Orlando	6	Little Rock
35	San Juan	s 38	Shreveport
128	Albuquerque	48	Tucson
47	Trenton	23	Peoria
129	Austin	s 71	Rockford
55	Wilmington	67	Hackensack
s 148	El Paso	s 59	Arlington, Va.

l: office in large group under output criterion.

s: office in small group under output criterion.

Table V-5. Fifty-two small offices.

Identifying number	City	Identifying number	City
m 152	Fort Wayne	1	Kansas City, Kans.
m 52	White Plains	15	Montgomery
m 90	Raleigh	46	Topeka
14	Mobile	149	Erie
m 5	Lincoln	28	Reading
79	Canton	92	Winston-Salem
121	Las Vegas	116	Palo Alto
60	Baton Rouge	124	Whittier
m 74	Springfield, Ill.	147	Elizabeth
111	Berkeley	122	Bakersfield
m 4	Lansing	54	Wilkes-Barre
m 61	Bethlehem	96	Stamford
69	Lexington	40	South Bend
76	Staten Island	50	Utica
m 158	Jackson	9	Lubbock
m 36	Scranton	64	Evanston
114	Glendale	117	Santa Monica
66	Gary	97	Waterbury
m 68	Kalamazoo	75	Springfield, Mo.
58	Amarillo	39	Sioux City
62	Charleston, W. Va.	89	Pensacola
141	Colorado Springs	118	Santa Barbara
119	North Hollywood	131	Binghampton
73	Shawnee Mission	63	Eugene
120	San Bernardino	44	Terre Haute
72	Schenectady	65	Garden City

m: office in medium group under output criterion.

the border. Our "small" offices are still roughly among the largest 160 of the country's 33,624. This finding suggests that offices among the largest 100 in the nation are most efficient and that others should be agglomerated where possible, eliminating smaller offices. The optimal size appears to be an office with about 1400 employees.

b. Alternative stratification. Employee complements should be a good index of the workload of an office but they need not be. An alternative criterion for grouping offices of similar "size" is a scalar measure of output, which can be obtained by using POD-supplied weights applied to the vector of outputs in each office. These weights reflect the labor requirement of each type of mail handling and delivery.[3]

Results for this stratification are given in the lower half of Tables V-1 and V-2. In general the results were less precise for grouping under the output criterion. The large group was virtually the same under both criteria.

c. Tests for validity of stratification. There is a systematic way to test for the validity of these foregoing stratifications. We can see if there is a significant reduction in sum of squared errors when three groups are estimated separately versus the case of a single estimating relationship imposed on the pooled sample. In other words, the maintained hypothesis is that cost is to be explained by thirty regressors in the case of intra cost functions : ten in each group: a constant term, five outputs, two factor prices, one fixed factor and the sectional center dummy variable. The hypothesis to be tested is that all offices have the

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[3]These weights are available in Chapter 3.

same cost function parameters independent of size. Let S_{10} represent the sum of squared errors when ten regressors are used. Now, if the error terms in our regression are normally distributed, independent and homoscedastic, then

$$F = \frac{(S_{10} - S_{30})/20}{S_{30}/126}$$

is distributed as F with 20 and 126 degrees of freedom. The data to calculate this test statistic appears in the last column of Table V-1. For the employment stratification we have F = 2.05, which indicates that stratification is significant at the .01 level. For the output stratification, however, the sum of squared errors is not significantly reduced by fitting the more complicated model: F = 1.28 while the critical value of F at the .05 level is 1.65.

In general, then, stratification is valid statistically and employee complements perform better than output as a criterion.

B. Derived Demand Functions

The set of derived demand functions for factors of production is another reduced form of the Cobb-Douglas model. Some results that bear on economies of scale ought to be mentioned here. They give results very similar to those inferred from the cost function. This is not surprising for the labor equation is very similar to the overall cost function. Labor is the overwhelming component (80 percent) of total postal costs. Nevertheless, the other equations all indicate decreasing returns to scale as well with r between .87 and .90. The floorspace equation alone indicates more pronounced decreasing returns to scale with an estimated returns parameter of .73.

All functions are homogeneous of degree approximately 1.1 in outputs with the demand for floorspace growing slightly faster as all outputs increase proportionately.

Certain constraints are implied by the economic theory of derived demand under cost minimization when a Cobb-Douglas hypothesis is maintained. Examples of these constraints may be seen by examining the complete model in Chapter 3, e.g. the first output enters all derived demand equations in the same form and so on for all outputs. Further constraints on the coefficients of prices might have been imposed but were not, e.g. each derived demand is homogeneous of degree zero in factor prices. Constraints on output coefficients imply that each derived demand equation is homogeneous of the same degree in outputs and this is closely related (but for handling the fixed factor) to the inverse of the degree of returns to scale. Constrained estimates appear in Table V-7.

The constrained reduced-form estimates also suggest decreasing returns to scale with 4 equal to .95. A standard error is not available for this statistic because it is prohibitively expensive to calculate a covariance matrix for regression coefficients in a group of constrained regression equations with so many constraints. Indications are that the constrained estimates are more precise than either the unconstrained derived demand equations or the cost function. Each standard error of output and GSA floorspace (but not factor price) coefficient is smaller than its counterpart in the unconstrained derived demand curve for labor and in the interior cost function (cf. Table V-6). If we use the standard error of the corresponding statistic in the cost function, .015, we can reject the null hypothesis of constant returns to scale in favor of decreasing returns.

Derived-demand functions for factors of production: labor, space, and mechanization, are given in Table V-6.

One notable feature of these double-logarithmic regression equations is the high coefficients of multiple determination (R^2). In all cases we have .79 or better, which is rare for both cross-sectional and double-logarithmic regressions, and rare with so many observations. This result makes us suspect heteroscedasticity, e.g. higher errors for the larger observations, but the dependent variable has been transformed by taking its natural logarithm, a usual guard against heteroscedasticity [60a, pp. 49 ff.].

If we look at the sum of squared residuals, the second entry in the last column of Table V-1, we see that there is no systematic tendency for this statistic to increase as we move from small to medium and large in the stratified sample. The sum of squared residuals is monotonically related to the standard error of estimate, which does not rise as we go from small to large either. They were .113, .163 and .136, respectively, under the employment stratification. This is not evidence of pronounced heteroscedasticity.

The similarity of the labor equation to the cost function of the preceding section should be noted. Its R^2 is the same as that for the cost function and the estimated coefficients are almost identical to those of the cost function.

The coefficients of the independent variables are interpretable as elasticities of demand for labor with respect to increases in the

Table V-6. **Derived demands for factors of production--intra post office.**

Factor	C_i	Independent Variables									R^2/SSE	$s = \sum_{i=1}^{6} c_i$	r
		x1	x2	x3	x4	x5	v_6	W_7	W_8	SC			
Labor 5/27/68 p. 87	-5.09 (.706)	.465 (.057)	.413 (.053)	.043 (.036)	.068 (.033)	.122 (.050)	-.0007 (.009)	.911 (.291)	.108 (.052)	-.052 (.291)	.98 3.24	1.1103 (.0152	.900
Space 5/27/68 p. 99	-8.42 (2.29)	.603 (.184)	.740 (.172)	-.298 (.117)	.162 (.108)	-.058 (.162)	-.160 (.030)	.754 (.945)	-.070 (.169)	.196 (.117)	.79 34.1	.989 (.0496)	1.01
Mechanization 5/27/68 p. 91	-7.06 (2.37)	.423 (.190)	.425 (.178)	-.103 (.121)	.296 (.111)	.068 (.167)	-.034 (.031)	.168 (.976)	.324 (.175)	.125 (.121)	.81 36.4	1.075 (.0509	.932
Adjusted mechanization 5/27/68 p. 95	-7.95 (2.41)	.472 (.193)	.392 (.181)	-.118 (.123)	.306 (.113)	.050 (.170)	-.023 (.032)	.528 (.993)	.371 (.178)	.140 (.123)	.81 37.7	1.102	.928

outputs. As such, they should always be positive, assuming marginal productivities of each factor positive in all uses. They are all positive and all but third class are s.d.f. 0 in the labor equation. The only estimated elasticities that are negative are those with respect to third-class mail in the space and mechanization equations and the revenues coefficient in the floorspace equation. Only in the case of floorspace is the coefficient s.d.f. 0.

Most of the other elasticities are positive. Window service does not appear to be too demanding on factors other than labor. This result is not hard to believe. That it should appear to require negative floorspace is surprising, but this coefficient is not significant. We all know the tiny but busy postal windows in central business districts, which use little space but collect a great deal of revenue. Berkeley has one at Sather Gate, and I imagine others exist on Wall and Montgomery Streets.

The negative elasticities of outgoing noncancelled letters in the space and mechanization equations is troublesome. Such mail does not usually linger in the post office of origin very long, but it is impossible to rationalize its taking negative floorspace. Again, it may use up no machine services, but hardly negative machine services.

Factor prices seem to influence demands for factors in ways we would expect. The demand for labor is significantly greater where the floorspace price is high, suggesting some substitution of labor for floorspace. Where floorspace is expensive, it is economized so that only a small mail inventory can be accommodated. Labor in the form of more night work and a larger staff can move the mail more quickly through the office.

The demand for mechanization is positively affected by high floorspace costs, indicating the possibility of some equipment-plant substitution as well.

The demand for labor is also greater in cities where the wage is high. This suggests that either post offices are intentionally uneconomic or, more likely, that labor quality is lower in high-wage cities where many alternatives to post-office employment exist.

According to economic theory derived demand functions should be homogeneous of degree zero in factor prices. If all prices were to double and the post office had to produce the same outputs, management would have no choice but to demand the same quantities of factors. There is no room to substitute cheap factors for dear when all prices change proportionately. Our estimated derived-demand equations do not satisfy this property. One factor price is unobservable, w_9, but its coefficient would be negative only in the mechanization equation. Since demand curves slope downwards, the wage coefficient in the labor equation should be negative, but it is significantly greater than zero.

The Sectional Center dummy in Table V-6 suggests that they use less labor than regular post offices and more floorspace. This is consonant with the function of a Sectional Center: to do minimal sortation to the mail it handles but to handle large quantities of mail for its tributary areas. Results here are not very precise, however.

The adjusted mechanization equation in Table V-6 is an attempt to deal with the capacity-utilization problem, applying the utilization rate to nominal amounts of mechanization use as derived from expected depreciation plus imputed interest charges. Results do not appear to be very different from the unadjusted mechanization equation.

The coefficient of GSA space is of the expected sign. This is treated as a fixed factor endowment. The more an office is endowed with, the less it needs use of the other factors of production. This negative influence is significant on the amount of other space it must lease and rent. Leased and rented space is a substitute for GSA space.

Certain constraints are suggested by the economic theory of derived demand under cost minimization in a Cobb-Douglas case. Increased estimation efficiency can be obtained by imposing these constraints and estimating a "constrained reduced form." Examples of the constraints may be seen in the reduced form of the complete model of intra post-office activity, e.g. the first output enters all derived demand equations in the same form, etc. Constrained estimates appear in Table V-7.

In the constrained equations all output coefficients are of the expected sign save that for revenues. Third class is again perverse in the labor equation. Factor prices have significant coefficients only in the labor equation. Theory says they should add up to zero, but they are both positive. Constraints on price coefficients have not been imposed in this constrained reduced form.

C. Evidence from Structural Estimates

So far, all our estimates have been from reduced forms of one type or another. What do the structural estimates show?

Ordinary least-squares on the production correspondence directly gives nonsensical results for the Cobb-Douglas production function, but may be adduced to make an inference about the transformation function and

Table V-7. Derived demands for factors constrained to satisfy certain properties of the Cobb-Douglas model.

	C_i	Independent Variables								$s = \sum_{i=1}^{6} b_i$ [a]
		x1	x2	x3	x4	x5	v_6	W_7	W_8	
v_7	-5.48 (.67)	.462 (.042)	.529 (.041)	-.102 (.027)	.180 (.025)	.052 (.038)	-.065 (.007)	1.13 (.379)	.170 (.063)	1.0565 (.0152)
v_8	-7.02 (1.77)	.462 (.111)	.529 (.107)	-.102 (.071)	.180 (.067)	.052 (.101)	-.065 (.019)	.374 (.998)	-.199 (.166)	1.0565 (.0496)
o_9	-7.03 (1.72)	.462 (.109)	.529 (.104)	-.102 (.069)	.180 (.065)	.052 (.098)	-.065 (.018)	.012 (.972)	.262 (.162)	1.0565 (.0509)

[a] Standard errors have been borrowed from Table V-6 because they were prohibitively expensive to calculate here with so many constraints.

economies of scale. Line 1 of Table V-8 yields estimates (once we assume $\alpha_7 \equiv 1$) that allow us to estimate:

$$\sum_{j=6}^{9} \alpha_j / \sum_{i=1}^{5} \alpha_i = .883 ,$$

which would indicate decreasing returns to scale for intra post-office activity, corroborating earlier results.

Table V-8. Structural estimates.

Source	$\sum_{i=1}^{5} \alpha_i$	α_6	α_7	α_8	α_9
Table IX-1	.967	-.009	1.000[a]	- .047	-.090
2 SLS	-.341	-.192	1.000[a]	-1.080	-.568

[a]By assumption.

Two-stage least squares on the production function gives very imprecise results:

$$\sum_{j=6}^{9} \alpha_j / \sum_{i=1}^{5} \alpha_i = -.840/-.341 = 2.46 .$$

These results are hardly credible and not consistent with our other results.

Other than the production function itself, the structural form of our cost minimization model has three marginal productivity conditions that can be divided one by the other to yield:

$$v_8 - v_7 = (W_7 - W_8) + \ln \alpha_8 - \ln \alpha_7$$

$$o_9 - v_7 = W_7 + \ln \alpha_9 - \ln \alpha_7 .$$

All the observable variables can be brought to one side:

$$(v_8 + W_8 - v_7 - W_7) = \ln (\alpha_8/\alpha_7) = -3.746$$

$$(o_9 - v_7 - W_7) = \ln (\alpha_9/\alpha_7) = -4.318 .$$ [4]

Estimates of $\ln (\alpha_8/\alpha_7)$ and $\ln (\alpha_9/\alpha_7)$ may now be obtained simply by taking the average of the LHS's over the sample. These estimates are recorded on the RHS. They imply $\hat{\alpha}_7/\alpha_8 = 42.3$, $\hat{\alpha}_7/\alpha_9 = 75.0$.

Let $z = v_7 + 1/42.3\ v_8 + 1/75\ o_9$.

Now, the following equation can be estimated:[5]

$$z = \underset{(.622)}{\overset{}{\frac{\alpha_9 W_9 - a}{\alpha_7}}} + \frac{\alpha_1}{\alpha_7} x_1 + \frac{\alpha_2}{\alpha_7} x_2 + \frac{\alpha_3}{\alpha_7} x_3 + \frac{\alpha_4}{\alpha_7} x_4 + \frac{\alpha_5}{\alpha_7} x_5 - \frac{\alpha_6}{\alpha_7} v_6 \qquad (3)$$

$$\begin{array}{ccccccc} -4.144 & .493 & .461 & .015 & .053 & .150 & -.008 \\ (.622) & (.060) & (.057) & (.058) & (.036) & (.054) & (.010) \end{array} .$$

[4]From calculations 5/27/68, pp. 66, 77.

[5]From calculations 6/24/68, p. 28.

Again assuming $\alpha_7 \equiv 1$, we have $\alpha_8 = .0236$, $\alpha_9 = .0133$ and

$$r = \frac{\sum_{j=7}^{9} \hat{\alpha}_j/\alpha_7 - (-\hat{\alpha}_6/\alpha_7)}{\sum_{i=1}^{5} \alpha_i/\alpha_7} = \frac{1.0369 + .0077}{1.172} = .8913$$

which implies decreasing returns to scale.

Further evidence on returns to scale can be gleaned from direct estimation of the CES production function with a scalar measure of output. Results will be fully reported under the rubric of Postal Production, but it is relevant here to mention that a point estimate of a returns-to-scale parameter was .8736 with a standard error of .01, indicating again very significant decreasing returns to scale.

D. Conclusion

The purpose of coming at the question of returns to scale from several different angles was to guard against getting results that are simply a result of one functional form or approach. As we hoped, all the reasonable results were consistent. There are decreasing returns to scale in the production of intra post-office services and constant returns to scale in the production of extra post-office services. We found this from Cobb-Douglas cost functions, as well as from cost functions derived from a model with CES aggregation of outputs. Then we stratified the sample and found increasing returns to scale in the small offices, indicating that the optimal size of post office was larger than those in that group.

On the other hand, the overall decreasing returns to scale inference suggests that the largest offices are too large to be efficient. When the criterion for stratifying the sample was changed from employee complements to weighted output, the results were similar but less precise. In that case we could never reject a constant returns to scale hypothesis, but overall decreasing returns to scale remained, of course. This fact indicates that our results on the optimal size of office are not very robust and should not be acted upon without more compelling evidence. Further analysis yields improvements, however, as we shall see.

The derived demand equations showed what the cost functions showed: decreasing returns to scale in intra post-office activity. This was true both of unconstrained and constrained reduced forms.

Structural estimation gave results similar to reduced-form estimation. Direct estimation of the production function showed decreasing returns to scale as did estimation first of the parameters of the Cobb-Douglas production function and then of the transformation function using the initial estimates as "extraneous" estimates. Two-stage least-squares estimation gave very poor results and was the only path which did not corroborate our other experience.

Chapter 6: PERFORMANCE INDICATORS FOR INTRA POST-OFFICE ACTIVITY

There are several criteria on which to evaluate the performance of offices:

(1) Costliness of two types:

a. the ratio of total cost to predicted total cost based on an estimated total cost function, total costliness;

b. adjusted total costliness: the ratio of total costs assuming factor prices in each city are the same to predicted total costs under the same assumption.

The second index is the result of gedankenexperimente. It is not actually observed. It abstracts from factor price variation: the greatest single source of variations in postal costs across the country.

(2) Productivity measurements measured as relative deviations from a Taylor's series approximation to the CES production function.

(3) If we take adjusted total costliness times productivity and consider the inverse, we have a measure of input efficiency.

As we have mentioned the Regional Offices make the important decisions. If there are differences they should display themselves in an analysis of variance of offices' performances by regions.

In these analyses of variance we obtain an estimate of the variance of the performance indicator and then are able to compare the variance between regions with the sample variance. If mean performance indicators in the fifteen postal regions vary considerably relative to the sample variance we may say that a significant difference exists among the regions.

The criterion is a ratio which follows the F distribution and may be compared to tabulated values seeking to reject the hypothesis of no difference among the regions.

Costliness may be due to high factor prices for which the post office is not at fault. In fact, the following relationship between costliness and factor prices for intra post-office production was derived:

$$\text{Costliness} = \underset{(.3200)}{-.7995} + \underset{(.0864)}{.4312}w_7 + \underset{(.0431)}{.1682}w_8 .$$

The coefficient of multiple determination is only .22 but both factor prices positively (and significantly) affect intra costliness. Differences in costliness may arise because of differences in (1) productivity, (2) input efficiency, and (3) high factor prices.

Assume post offices use only labor and floorspace, L and F, and produce mail, M (see Figure 1).

An office's productivity can be measured as the ratio of actual output, M_i, to the output expected from an office of "average" productivity using the set of inputs available to office i. The norm might be derived from a simple production function, such as a single-product Cobb-Douglas estimated by regressing m_i on l_i and f_i. Productivity, then, is

$$P_i = M_i/\hat{M}_i(l_i, f_i) = \hat{e}_i ,$$

the "technical disturbance" in Marschak and Andrews' term. Productivity of individual offices is measured in section C of this chapter.

An office of average productivity can product output M at least cost by choosing labor and floorspace as indicated at point A, incurring

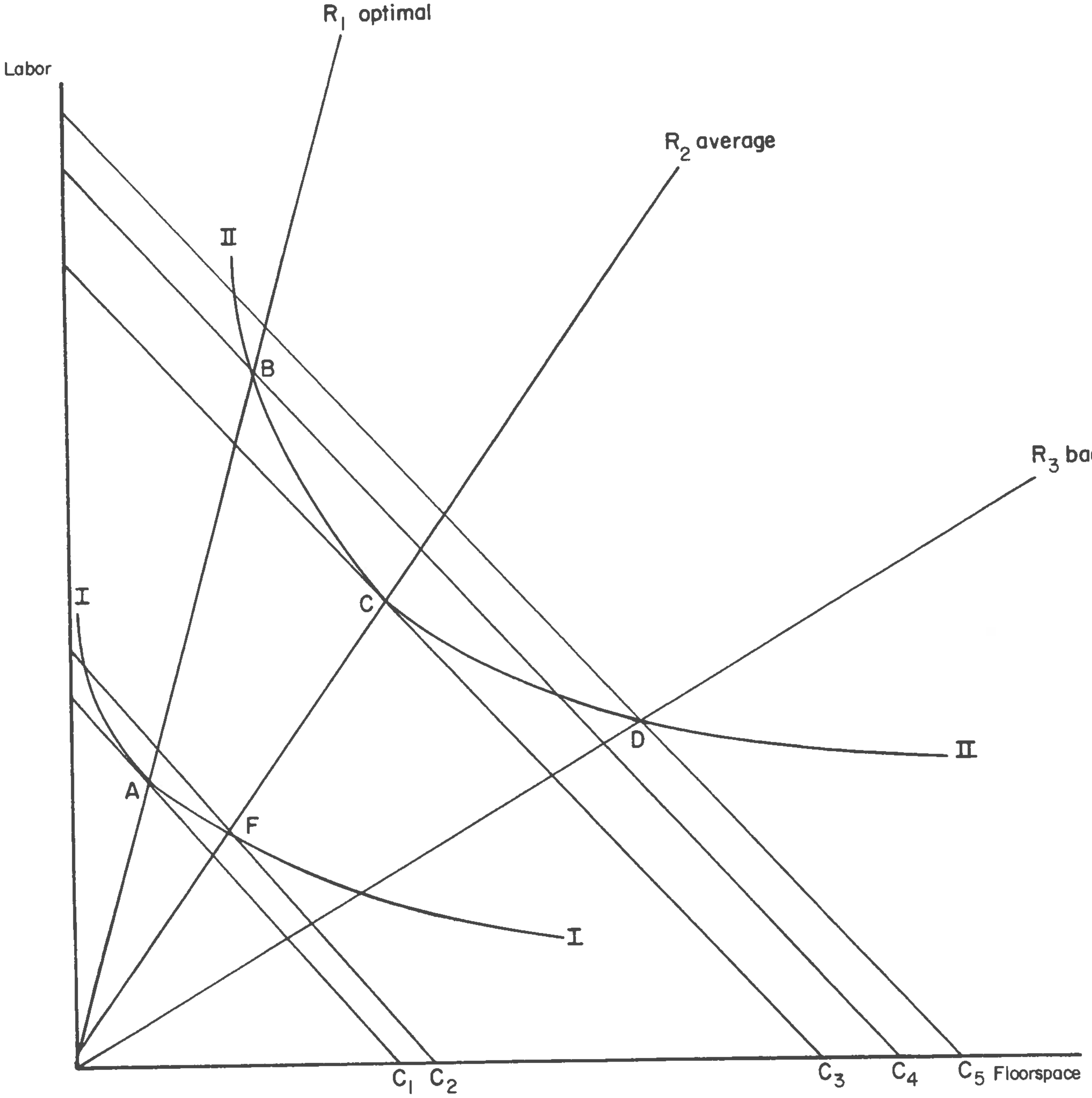

Figure VI-1: COSTLINESS: A COMPOSITE RESULT of PRODUCTIVITY and INPUT EFFICIENCY cost C_1. An office just as productive but only average in its choice of input proportions will produce on ray R_2 at F with costs C_2.[1] If the lower productivity office used these factor proportions, it would produce at C on the less productive higher isoquant. Alternatively, if an "unproductive" (technically inefficient) office chose optimal input proportions at B it would incur C_4, but if it were not only technically inefficient but economically inefficient as well it might produce at D using "bad" factor proportions and incurring costs as high as C_5.

For an office at D, costliness is the ratio of actual cost, C_5, to average cost for an efficient office, C_2.

Productivity is the ratio OF/OC, or C_2/C_3, or the costs of an efficient office to an inefficient one, both with average factor proportions. A measure of the appropriateness of the office's input proportions is C_3/C_5, which holds technical efficiency constant.

So Costliness = C_5/C_2, Productivity = C_2/C_3, and Input Effectiveness = C_3/C_5. Costliness = $[(\text{Productivity}) \cdot (\text{Input Effectiveness})]^{-1}$.

To eliminate the influence of factor prices on costliness we did the following gedankenexperiment. Suppose all offices faced the same mean factor prices. How would their relative costliness appear?

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[1] We are assuming here, for simplicity, that all offices face the same relative factor prices. That is why all the isocost lines are parallel. In the more general case in which factor prices vary cross-sectionally, optimal factor proportions will depend on the factor price ratio facing an individual office.

A. Adjusted Total Costliness

Assume that physical usage of factors remained the same but that each office paid mean factor prices. The wage bill for the gedankenexperiment is labor hours times the mean wage over the sample; the rental bill is floorspace used times the mean rental cost per square foot; and the mechanization bill is the same as before. The sum of these three components would be adjusted total costs, $C(\bar{w},\bar{f})$, a function of the mean wage, $\bar{w}$, and the mean floorspace cost, $\bar{f}$.

Adjusted total costliness is then equal to the ratio of adjusted total cost to expected cost predicted from the estimated cost function, as a function of the outputs actually produced and mean factor prices, $C(\bar{w},\bar{f})/\hat{C}(X_1,\ldots,X_5;\bar{w},\bar{f})$. Adjusted total costliness figures appear in Table VI-1.

B. Technical Efficiency

Using POD factors as a weighting scheme to create a scalar measure of output we may estimate a simple production function. Once that is done, we can compare actual output with output predicted on the basis of the estimated production function and the physical inputs actually present in an office. The ratio of these two is an index of productivity. The estimated equation, an approximation to a CES production function, is given as the first line in Table VI-1. The index of productivity is then

$$P = \frac{\text{Actual Output}}{\text{Predicted Output}}$$

where predicted output is a function of V_7, $V_6 + V_8$, O_9 and SC. Table VI-1

Table VI-1. Indices of intra post-office costliness adjusted for factor prices and productivity.

(1) P.O. No.	(2) Adjusted total costliness	(3) Productivity	(1) P.O. No.	(2) Adjusted total costliness	(3) Productivity
1	.997	.93	40	.752	1.15
2	1.124	1.04	41	1.012	.97
3	.979	1.07	42	1.023	..95
4	.842	1.14	43	1.072	.90
5	.951	.93	44	.885	1.43
6	.526	1.67	45	1.105	.98
7	1.450	.84	46	.979	1.01
8	.971	1.03	47	1.111	1.00
9	.806	1.08	48	.880	1.03
10	.874	1.14	49	1.085	1.03
11	.896	1.04	50	.940	1.02
12	.941	1.03	51	.887	1.27
13	1.130	1.02	52	.984	1.10
14	.901	1.03	53	.842	1.11
15	.998	.98	54	.944	1.03
16	.939	1.16	55	1.061	.91
17	.959	1.18	56	.828	1.11
18	1.126	.92	57	1.113	.83
19	1.038	.91	58	.768	1.05
20	1.047	.92	59	.988	.93
21	1.049	.99	60	.970	.99
22	1.071	.93	61	.885	1.09
23	.830	1.02	62	.872	1.07
24	1.054	1.01	63	.871	1.02
25	.963	1.14	64	.894	1.07
26	1.160	.88	65	.904	1.56
27	1.054	1.01	66	1.111	.87
28	1.057	.95	67	.846	1.11
29	1.081	.99	68	.860	1.12
30	1.070	.92	69	.940	.93
31	.951	1.07	71	1.084	.88
32	.982	1.07	72	1.147	.82
33	.839	1.11	73	.778	1.15
34	.968	1.00	74	.921	1.13
35	1.538	.71	75	1.089	.99
36	.894	1.15	76	1.455	.68
37	1.167	.98	77	1.432	.82
38	1.039	.97	79	.853	1.09
39	1.058	.84	80	.931	1.04

Table VI-1 (continued)

(1) P.O. No.	(2) Adjusted total costliness	(3) Productivity	(1) P.O. No.	(2) Adjusted total costliness	(3) Productivity
81	.972	1.00	120	.904	1.08
82	1.081	1.00	121	1.074	.82
83	1.408	.75	122	.981	.96
84	.896	1.18	123	1.028	1.07
85	1.044	1.05	124	.917	1.03
86	.844	1.15	125	1.108	1.03
87	1.023	1.04	126	1.001	.99
88	1.008	.92	127	1.186	.96
89	1.155	.82	128	.993	.91
90	1.071	1.02	129	.998	1.01
91	.912	1.05	130	.949	1.02
92	1.146	.92	131	1.025	.89
93	1.075	.95	132	.903	1.07
94	1.1321	1.01	133	1.130	.83
95	1.249	.81	134	1.098	.88
96	.966	1.02	135	1.045	.94
97	1.219	.79	136	.933	1.14
98	1.194	.92	137	.892	1.09
99	.857	.74	138	1.005	1.08
100	.857	1.10	139	.923	1.06
101	1.187	.89	140	1.104	.93
102	1.044	1.17	141	1.134	.85
103	1.199	.92	142	.875	1.14
104	1.267	.81	143	1.020	1.04
105	1.018	1.00	144	1.241	.96
106	.962	.91	145	1.038	1.32
107	.984	.95	146	1.439	1.08
108	1.024	1.03	147	.714	1.12
109	1.046	.93	148	1.016	.77
110	.969	1.06	149	.793	.95
111	.982	1.03	150	.797	.87
112	1.144	.89	151	1.182	.80
113	.902	1.09	152	.822	1.11
114	1.159	.91	153	.728	1.29
115	.861	1.24	154	.861	1.01
116	.945	1.02	155	1.528	.79
117	1.100	.98	156	.924	1.13
118	1.170	.84	157	.908	1.08
119	.832	1.14	158	.831	1.19

Table VI-2. Adjusted total costliness, extraordinary offices.

Costly	Non-costly
Long Island City	Little Rock
Pittsburgh	Lubbock
San Juan	Salt Lake City
Seattle	Scranton
Schenectady	South Bend
Staten Island	Terre Haute
Jamaica	Tucson
Portland, Me.	Yonkers
Pensacola	Amarillo
Winston-Salem	Bethlehem
New Haven	Shawnee Mission
Waterbury	Jacksonville
Boston	North Hollywood
Springfield, Mass.	Elizabeth
Providence	Erie
San Francisco	Flint
Oakland	Fort Wayne
Glendale	Fort Worth
Santa Barbara	Jackson
Albany	
Denver	
Detroit	
Flushing	
Harrisburg	

gives the productivity rating of each office in our sample. Table VI-3 displays the names of some extraordinary offices on the criterion of productivity or technical efficiency.

C. Analyses of Variance over Regions

On the criterion of adjusted total costliness we conclude there are significant differences among the fifteen postal regions. Table shows that the F ratio is greater than the tabulated value so that we may reject the null hypothesis of no difference in adjusted total costliness with .01 probability that in making this and similar decisions on such evidence we would be rejecting a true hypothesis. Table VI-4 shows the means for each region. The estimated variance within regions and between regions and results of F-tests are shown in Table VI-5.

Table VI-5. Analyses of variance among regions.

Source	SS	d.f.	M.S.
Adjusted Total Costliness			
Between regions	.87367	14	.062405
Within regions	3.34732	141	.023739
Total about grand mean	4.22099	155	F = 2.63 reject at .01 level

If we do not state hypotheses regarding regional contrasts before estimating regional means, hypotheses suggested by the data come under the heading of "data snooping" [63, p. 80]. As such, Scheffé's method for

Table VI-3. Technical efficiency: extraordinary offices.

Technically Efficient		Technically Inefficient	
6	Little Rock	7	Long Island City
16	Nashville	35	San Juan, P.R.
17	Newark	39	Sioux City
36	Scranton	57	Youngstown
51	Washington	72	Schenectady
65	Garden City	76	Staten Island
73	Shawnee Mission	77	Jamaica
84	Atlanta	83	Portland, Me.
86	Jacksonville	89	Pensacola
102	Los Angeles	95	New Haven
115	Santa Ana	97	Waterbury
145	Des Moines	99	Springfield, Mass.
153	Fort Worth	104	Oakland
		118	Santa Barbara
		121	Las Vegas
		133	Bronx
		155	Harrisburg

Table VI-4. Performance indicators for postal regions.

Region	n	Adjusted total costliness	Productivity	Input efficiency
Boston	10	1.196	.898	.957
New York	18	1.141	.937	.945
Philadelphia	15	1.001	1.016	1.026
Cincinnati	15	.959	1.044	1.036
Washington	6	.969	1.031	1.024
Atlanta	12	1.007	1.016	.976
Chicago	10	.953	1.040	1.096
St. Louis	6	.964	1.155	.922
Minneapolis	4	.982	1.065	.830
Wichita	8	.966	1.009	1.077
Dallas	10	.934	1.021	1.147
San Francisco	23	1.022	.995	.996
Memphis	8	.917	1.079	1.030
Denver	6	1.008	1.000	1.024
Seattle	5	1.035	.972	.998
Overall	156	1.014	1.009	1.003

multiple comparisons should be used. If costliness figures are normally distributed with mean unity and constant variance, then the probability is .90 that simultaneously for any estimable function

$$\hat{\psi} - S\ \mathrm{s.d.}(\hat{\psi}) \le \hat{\psi} \le \hat{\psi} + S\ \mathrm{s.d.}(\hat{\psi})$$

$$\text{where } S^2 = 14\ F(.05;14,141)$$

$$S = 4.96\ .$$

For the contrast between the mean adjusted total costliness in the Boston and Memphis regions (the greatest contrast) we have $\hat{\psi}_1 = .279$ and the estimated standard deviation of this contrast is .072, whence $S\hat{\sigma}_{\hat{\psi}_1} = .357$. We cannot reject the null hypothesis that there is no significant difference between the Boston and Memphis regions. However, there is a significant difference between the Boston and New York regions, on the one hand, versus Washington, Atlanta, St. Louis, Dallas and Memphis, on the other. This is a difference between Northeast and South $\hat{\psi}_2 = .1997$ and its estimated standard error is .0375. Similarly, we might test a final contrast between Northeast and Far West regions and the South and Midwest. Boston, New York, Philadelphia, San Francisco, Seattle and Denver regions would be in the first group and Cincinnati, Washington, Atlanta, Chicago, St. Louis, Minneapolis, Wichita, Dallas and Memphis in the second group. Here the difference in means is .142 and the standard error is estimated at .024, whence .142 ± .119 is a 90% confidence interval for the difference between these groups. So the Northeast and Far West are significantly more costly than the South and Midwest regions even after adjusting for varying factor prices.

Perhaps the reason for the difference is that lower quality labor is available at wage rates the POD pays in the Northeast and Far West than that available in the South and Midwest.

Eighty offices had recently received mechanization in postal fiscal year 1966. Table VI-6 shows a 1 in the RM column for offices recently mechanized; zero otherwise.

It is interesting to ask whether recently mechanized offices perform better than non-mechanized ones. On the criterion of adjusted total costliness there is a difference of .043 in the means, mechanized being the more costly, but this difference is not significant, as the F test in Table VI-7 shows.

Table VI-7. Analysis of variance between mechanized and nonmechanized offices.

Source	SS	d.f.	M.S.
Adjusted Total Costliness			
Between mechanized and nonmechanized	.053	1	.053
Within	4.156	154	.027
Total about grand mean	4.209	155	$F = 1.96$ cannot reject H_o

The indication seems to be that mechanized offices are more costly than nonmechanized, whether or not the difference is significant. This would indeed be a disheartening result: that labor-saving devices increase postal costs. Two observations must be made. Recently mechanized offices

Table VI-6. Candidates for explaining costliness.

No.	ATC	NEFW	RM	EMP	No.	ATC	NEFW	RM	EMP
1	.997	0	0	482	41	1.012	1	1	1131
2	1.124	0	1	5224	42	1.023	1	1	1238
3	.979	0	1	741	43	1.072	1	1	726
4	.842	0	0	572	44	.885	0	0	309
5	.951	0	0	596	45	1.105	0	1	1422
6	.526	0	0	687	46	.979	0	0	479
7	1.450	1	0	1061	47	1.111	1	0	901
8	.971	0	1	2122	48	.880	1	1	675
9	.806	0	0	435	49	1.085	0	1	1233
10	.874	0	0	823	50	.940	1	0	437
11	.896	0	1	2292	51	.887	0	1	10067
12	.941	0	1	4356	52	.984	1	0	618
13	1.130	0	1	4110	53	.842	0	1	994
14	.901	0	1	599	54	.944	1	0	446
15	.998	0	0	480	55	1.061	1	0	858
16	.939	0	1	1511	56	.828	1	0	775
17	.959	1	1	3589	57	1.113	0	0	848
18	1.126	0	1	2841	58	.768	0	0	516
19	1.038	0	0	1147	59	.988	0	0	636
20	1.047	0	1	1747	60	.970	0	0	575
21	1.049	0	1	2060	61	.885	1	0	558
22	1.071	1	0	750	62	.872	0	0	511
23	.830	0	0	651	63	.871	1	0	317
24	1.054	1	1	10239	64	.894	0	0	421
25	.963	1	1	1659	65	.904	1	0	256
26	1.160	1	1	7631	66	1.111	0	0	539
27	1.054	1	1	2712	67	.846	1	0	637
28	1.057	1	0	477	68	.860	0	0	522
29	1.081	0	1	1520	69	.940	0	0	555
30	1.070	1	1	2025	71	1.084	0	0	638
31	.951	0	1	6959	72	1.147	1	0	491
32	.982	0	1	3750	73	.778	0	0	498
33	.839	1	1	1246	74	.921	0	0	573
34	.968	0	1	2053	75	1.089	0	0	396
35	1.538	1	0	943	76	1.455	1	0	554
36	.894	1	0	546	77	1.432	1	1	3239
37	1.167	1	1	3512	79	.853	0	0	592
38	1.039	0	0	682	80	.931	0	1	779
39	1.058	0	0	390	81	.972	0	0	741
40	.752	0	1	440	82	1.081	0	1	1105

Table VI-6 (continued)

No.	ATC	NEFW	RM	EMP	No.	ATC	NEFW	RM	EMP
83	1.408	1	0	827	121	1.074	1	0	588
84	.896	0	1	4786	122	.981	1	0	450
85	1.044	0	1	1256	123	1.028	1	0	704
86	.844	0	1	2061	124	.917	1	0	466
87	1.023	0	1	3989	125	1.108	1	1	38360
88	1.008	0	0	964	126	1.001	0	0	1215
89	1.155	0	0	384	127	1.186	1	0	1229
90	1.071	0	0	605	128	.993	1	1	913
91	.912	0	1	1043	129	.998	0	1	887
92	1.146	0	0	476	130	.949	0	1	5405
93	1.075	1	0	751	131	1.025	1	1	381
94	1.132	1	1	1963	132	.903	0	1	1726
95	1.249	1	1	1676	133	1.130	1	1	3544
96	.966	1	1	443	134	1.098	1	1	8043
97	1.219	1	0	401	135	1.045	1	1	3622
98	1.194	1	1	13537	136	.933	1	0	852
99	1.674	1	1	2135	137	.892	0	0	703
100	.857	1	0	830	138	1.005	0	1	26483
101	1.187	1	1	1886	139	.923	0	1	5381
102	1.044	1	1	12199	140	1.104	0	1	8520
103	1.199	1	1	8241	141	1.134	1	0	501
104	1.267	1	1	2665	142	.875	0	1	2527
105	1.018	1	1	1778	143	1.020	0	1	1578
106	.962	1	1	2107	144	1.241	1	1	3179
107	.984	1	1	1022	145	1.038	0	0	1405
108	1.024	1	1	1281	146	1.439	0	1	8961
109	1.046	1	1	1367	147	.714	1	0	460
110	.969	1	1	823	148	1.016	0	1	855
111	.982	1	0	572	149	.793	1	0	479
112	1.144	1	0	777	150	.797	0	1	746
113	.902	1	1	840	151	1.182	1	1	2501
114	1.159	1	0	540	152	.822	0	0	630
115	.861	1	0	724	153	.728	0	1	1642
116	.945	1	0	469	154	.861	0	1	998
117	1.100	1	0	404	155	1.528	1	1	1207
118	1.170	1	0	382	156	.924	0	1	4424
119	.832	1	0	500	157	.908	0	1	4095
120	.904	1	0	491	158	.831	0	0	552

tend to be the larger cities where wages are higher and the level of economic activity greater where alternatives to POD employment abound. To the extent that the recently mechanized are the tight-labor market cities, this finding is just a repetition of our findings from costliness indicators. Further, since there were diseconomies of scale, the largest offices appear to be least efficient. Second, capital improvements are intended to serve future needs as much as present needs. Capacity utilization is likely to be lower in recently mechanized offices. Our index of capacity utilization does not help us here because it shows literally no difference between the average rate on the eighty mechanized and the seventy-six nonmechanized offices. The reader may recall that our index is labor hours worked divided by full-time hours of the labor complement. This is probably just a reflection on our capacity utilization index in which I have little faith. A McKinsey and Co. study for the POD showed that facer-cancellers in the Providence, R.I., office were used only 16% of the available time and this is the basis of my second caveat.

Gathering results, we have found that in general larger offices have higher costs, as do mechanized offices and offices in the Northeast and Far West. These results may be repetitious observations of the same phenomenon. Large offices (e.g. New York, Los Angeles, and Boston) are located more than proportionately in the costly regions and tend to be mechanized before smaller offices. The solution is to look at the net relationship between costliness and size, region and mechanization by estimating an equation with the last three as regressors. Size will be approximately measured by employee complement, the criterion for stratification which served us best in Chapter 5. Region will be signified by a dummy variable, NEFW, equal to one if the office is either in the Northeast or Far West, zero otherwise. The equation estimated was:

$$\underset{}{ATC} = \underset{(22)}{934.6} + \underset{(.0032)}{.0038EMP} + \underset{(25)}{107.6NEFW} + \underset{(27)}{35.0RM} .$$

The coefficient of multiple determination was small, $R^2 = .13$, so this equation is not very good for prediction purposes, but it can be used for hypothesis testing. Neither size nor mechanization significantly influence costliness. Region is significant, however, offices in the Northeast and Far West being more costly than elsewhere even after adjusting for factor-price variation.

Two explanations are possible for the higher costliness of the Northeast and Far West regions: (1) management is inferior, or (2) labor quality is inferior.

D. Productivity

Productivity was measured as a ratio of actual output to predicted output based on the Taylor's series approximation to a CES production function of Chapter 9 (Table IX-1). Results for the fifteen regions appear in Table VI-4. Table VI-8 shows that productivity differs

Table VI-8. Analysis of variance: productivity.

Source	SS	d.f.	M.S.
Between regions	.4789	14	.0342
Within regions	2.5379	141	.0180
Total about grand mean	3.0168	155	F = 1.90 reject at .05 level

significantly among regions, with the Northeast and Far West significantly less productive than the South and interior.

E. Input Efficiency

Moving to the final column of Table VI-4, input efficiency, the inverse of ATC times productivity, we find (Table VI-9) no significant differences among regions. This performance measure may be taken as an index of management efficiency: choosing the cost-minimizing factor proportions, given factor prices. Apparently, all Regional Offices do this about equally well.

Table VI-9. Analyses of variance of input efficiency.

Source	SS	d.f.	M.S.
Between regions	.1932	14	.0138
Within regions	1.6525	141	.0117
Total about grand mean	1.8457	155	$F = 1.18$ cannot reject H_o
Between mechanized and nonmechanized	.0730	1	.0730
Within regions	1.7727	154	.0115
Total about grand mean	1.8457	155	$F = 6.35$ reject at .05 level

That mechanized offices perform less well than nonmechanized (.983 vs. 1.024) probably indicates excess capacity which may be rational at one point in time in a growing concern.

F. Conclusion on Performance Indicators

What is significantly different among regions is productivity or technical efficiency and it is very likely that labor quality variation is responsible for this. Although the POD pays higher wage rates in the Northeast and Far West, it must accept apparently lower quality labor there than in the South or Midwest. This can be seen from the cost-function results which show that offices use significantly more labor (hours) where the wage is high. Where the nonpostal wage is high and superior opportunities abound, the POD must accept higher turnover, more absenteeism and generally, a lower quality of labor. Postal employment is more attractive in a Southern city where nonpostal wages are considerably lower and fewer alternative employment opportunities are available.

Chapter 7: EXTRA POST-OFFICE ACTIVITY

A. Casting the Problem

Collection and delivery services are so different from mail processing and window services that we have posited a separate production process for them. The resources employed are carrier labor, vehicles and land. The arguments of the extra post-office production correspondence are listed in Table VII-1.

Whereas in the intra study we aggregated incoming and outgoing letters, in the extra study we treat them separately. Outoing cancelled letters usually have to be collected from mailboxes while outoing non-cancelled letters are usually brought to the post office by the sender, so they should not absorb extra post-office resources. Outgoing parcels should similarly absorb few extra post-office resources for the same reason. Finally, window services should use none of these resources. Therefore these outputs are excluded from the regressions and their regression coefficients are assumed to be zero. In preliminary tests such hypotheses were not rejected.

In addition to factor prices, the following environmental variables were used:

(1) postal population per square mile, an estimate of the density of business and residential mail receivers[1]

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[1]Calculated from U.S. POD, Authorized Employee Complements, 1966, and land areas of cities from U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the U.S., 1966.

Table VII-1. Inputs, outputs, prices and notation: extra post-office activity.

Inputs		Prices	
V_7	Outside labor[a] in man-hours	w_7	\$/man-hr
V_8	Outside space, leased and rented, in square feet	w_8	\$/ft^2-yr
O_9	Outlay[b] on vehicles	w_9	(unobserved)

Outputs

XI	Incoming letters: first and third class
XC	Outgoing cancelled letters: virtually all first class
X2	Second class[c]
X4	Fourth class: parcels
XI4	Incoming parcels

[a] Outside labor of the following types: (1) mobile units, (2) city delivery carriers, (3) vehicle service drivers, (4) special delivery messengers, (5) vehicle maintenance.

[b] Composed of straight-line book depreciation plus an imputed interest charge equal to seven percent of the undepreciated book value of capital stock.

[c] .189 outgoing flats + .350 outgoing small parcels and rolls (SPR's) + .193 incoming flats + .259 incoming SPR's. Some third class included in small parcels and some first class among flats. These weights are derived from POD time and motion studies, POD Form 2335, "Operation Analysis," November, 1966.

(2) total precipitation in inches[2]

(3) degree-days,[2] representing the number of days times the number of degrees the mean temperature is below 65°F.

Outlay on vehicles is measured only partially. The value of the stock of vehicles is known. From this annual depreciation plus an imputed interest charge can be calculated. The variable costs of operating vehicles could not be obtained on an office-by-office basis although vehicle service costs were available at the level of the region. For three regions (Dallas, Denver and Wichita), no capital property asset value figures were available. An attempt to "reconstruct" these data by assuming depreciation of asset values in each office was not successful. There were also some missing data under the rubric incoming parcels or SPR's. In some cases offices may have reported incoming parcels and incoming small parcels and rolls together. Offices which had either capital-property or asset-value data missing were excluded from the sample for the extra post-office study. This left a sample of 114 offices on which extra post-office results are based.

B. The Production Model

Let the extra post-office production correspondence be:

$$XI^{\alpha I}\ XC^{\alpha C}\ X2^{\alpha 2}\ X4^{\alpha 4} \;=\; B\ V_7^{\beta_7}\ V_8^{\beta_8}\ \left(\frac{O_9}{w_9}\right)^{\beta_9}$$

and the objective function be:

$$\max \quad -w_7V_7 - w_8V_8 - O_9$$

where w_7 and w_8 are unit prices of labor and floorspace.

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[2] U.S. Department of Commerce, Weather Bureau, Climatological Data, National Summary, Annual, 1950.

TABLE VII 2

EXTRA POST OFFICE INPUTS AND ENVIRONMENTAL VARIABLES

NUMBER	OUTLAB	OUTSPC	VEHCST	DDAYS	RNFL	PPSQM	NUMBER
1	400.21	176.75	33.48	4519	34.07	10.30	1
2	2373.21	272.[illegible]5	147.97	4519	34.07	6.37	2
3	395.84	162.50	44.43	3595	45.27	13.37	3
4	365.04	5[illegible].28	44.76	6937	36.05	9.10	4
5	375.03	30.[illegible]2	25.97	6023	32.66	6.12	5
6	720.54	82.68	34.78	3219	48.66	6.74	6
7	831.31	107.23	194.61	4862	42.37	7.07	7
8	1485.23	525.84	59.06	4289	37.08	10.21	8
9	353.54	7.70	22.09	3787	16.21	2.33	9
10	584.06	72.10	45.02	7764	40.34	4.78	10
11	1327.43	137.53	120.41	3191	49.73	5.36	11
12	2927.78	202.35	125.96	7513	29.51	11.47	12
13	3062.54	255.1[illegible]	220.52	8392	24.78	18.12	13
14	526.37	85.20	45.38	1659	68.13	2.68	14
15	344.81	64.72	20.81	2205	46.80	6.66	15
16	1023.52	106.48	88.15	3578	45.15	14.50	16
17	1248.20	88.32	81.86	4878	39.71	25.00	17
18	1781.12	71.02	107.66	1182	63.25	3.58	18
19	940.11	197.35	50.03	3421	44.94	8.00	19
20	1314.22	353.49	83.01	3844	30.82	1.66	20
21	1077.07	300.59	85.88	6218	27.56	8.42	21
22	552.80	16.40	34.38	4878	39.71	24.79	22
23	525.32	90.48	44.79	6025	34.84	14.19	23
24	5105.12	487.35	264.67	4848	42.48	16.21	24
25	1415.16	274.51	165.55	1598	7.20	3.45	25
26	4999.03	157.12	130.73	5987	36.14	20.72	26
27	1933.33	381.46	124.84	4109	42.37	9.25	27
28	402.62	89.48	30.11	4865	36.84	17.22	28
29	958.15	130.05	96.54	3914	44.21	12.45	29
30	1529.96	96.69	52.14	6822	32.23	14.94	30
31	4623.93	625.16	273.14	4809	35.31	25.09	31
32	2450.38	319.30	137.41	8392	24.78	9.63	32
33	965.81	404.64	73.26	5890	13.90	7.59	33
34	1635.[illegible]8	294.12	109.95	1814	24.50	5.53	34
35	556.13	79.29	34.88	0	60.36	14.89	35
36	414.88	36.71	29.56	6192	34.15	7.08	36
37	2206.14	387.22	175.91	4424	34.10	9.35	37
38	486.82	167.67	46.71	2391	39.02	7.75	38

NUMBER	OUTLAB	OUTSPC	VEHCST	DDAYS	RNFL	PPSQM	NUMBER
39	236.04	33.62	14.78	7073	30.33	1.85	39
40	370.93	21.20	31.37	6532	38.47	7.63	40
41	768.93	171.06	50.50	6762	17.19	5.79	41
42	931.69	139.21	51.68	6750	41.20	11.94	42
43	563.97	122.24	60.89	5168	46.52	6.11	43
44	170.03	28.50	8.41	5699	39.25	4.52	44
45	1172.62	146.35	70.39	6439	37.24	9.88	45
46	350.37	17.60	36.90	5386	27.10	4.07	46
47	600.04	100.58	42.18	4880	41.30	38.89	47
48	551.15	185.86	57.51	1583	9.99	4.64	48
49	985.35	114.21	70.11	3670	49.39	7.03	49
50	290.32	80.80	18.01	6750	41.20	6.71	50
51	5984.93	227.24	264.28	4224	40.78	22.01	51
52	273.14	78.49	25.83	4862	42.37	13.31	52
53	797.91	98.00	53.45	4620	28.41	6.53	53
54	356.74	30.60	27.80	5122	35.62	26.43	54
55	655.89	51.01	46.95	4930	44.56	15.93	55
56	655.24	39.61	20.40	4862	42.37	15.23	56
57	749.95	103.42	50.62	6366	42.39	7.50	57
58	387.61	63.50	28.25	4492	22.81	3.13	58
59	566.80	88.59	27.22	4224	40.78	7.72	59
60	405.05	42.82	33.95	1692	61.54	7.16	60
61	220.30	239.13	49.25	4880	41.30	6.85	61
62	331.96	64.78	22.22	4434	36.40	6.48	62
63	255.70	22.60	21.26	4643	32.94	9.03	63
64	322.14	24.70	13.71	6113	33.18	10.61	64
65	136.59	8.10	5.24	4862	42.37	6.60	65
66	433.11	61.31	29.49	6113	33.18	5.56	66
67	241.77	53.09	14.89	4878	39.71	20.83	67
68	320.86	119.46	40.08	6980	34.87	6.82	68
69	458.06	95.88	35.91	4615	38.57	15.00	69
71	542.94	16.79	20.14	7078	47.97	11.94	71
72	453.96	15.60	17.13	6875	35.08	15.13	72
73	491.76	156.65	41.31	5386	27.10	34.74	73
74	391.90	40.21	23.64	5575	35.98	7.64	74
75	258.53	17.39	17.17	4704	39.80	4.23	75
76	477.23	111.61	23.93	4862	42.37	4.76	76
77	1614.85	295.30	66.42	4862	42.37	20.34	77
79	573.07	36.42	44.25	6546	27.08	15.55	79

NUMBER	OUTLAY	OUTSPC	VEHCST	DDAYS	RNFL	PPSQM	NUMBER
80	410.35	42.31	42.22	2511	66.00	9.64	80
81	658.52	113.63	61.93	214	59.76	11.31	81
82	495.71	471.54	38.36	3808	52.42	3.92	82
83	525.84	53.79	37.45	7511	42.85	6.07	83
84	2413.90	482.99	225.65	2961	47.14	5.70	84
85	863.51	166.67	76.53	3125	43.38	4.75	85
86	1279.21	183.93	104.90	1239	53.36	16.33	86
87	2771.10	437.03	225.43	214	59.76	34.01	87
88	630.81	360.68	74.10	608	63.77	14.82	88
89	286.29	106.06	33.21	1559	79.67	9.47	89
90	357.45	74.07	33.68	3393	43.58	4.72	90
91	[illegible]	145.77	108.64	515	76.57	5.55	91
92	372.41	80.88	38.59	3604	53.01	4.87	92
93	566.59	46.29	59.80	5452	38.10	13.02	93
94	1274.11	189.43	82.76	6235	42.92	23.06	94
95	741.74	184.01	59.38	5731	43.08	16.35	95
96	313.88	17.80	25.79	5452	38.10	2.76	96
97	316.71	53.79	21.69	5731	43.08	4.46	97
98	7863.60	510.81	374.65	5634	42.77	39.10	98
99	1082.47	295.01	57.40	6235	42.92	5.13	99
100	824.68	.50	31.19	6863	57.44	4.99	100
101	1117.67	529.54	36.31	5954	42.13	22.22	101
102	6380.49	265.07	313.25	659	6.44	5.05	102
103	3087.14	100.08	200.94	2177	13.68	16.86	103
104	1571.84	113.30	87.62	2291	13.02	7.73	104
105	1236.45	123.35	95.77	2419	18.02	11.43	105
106	1614.85	75.19	222.29	683	5.88	3.46	106
107	776.27	16.49	89.03	0	21.89	4.76	107
108	996.25	100.18	34.61	897	5.94	9.68	108
109	1195.12	13.00	57.40	2291	13.02	8.84	109
110	598.24	54.71	37.19	659	6.44	8.04	110
111	494.70	12.79	36.78	2291	13.02	18.21	111
112	634.60	160.00	37.71	2148	7.21	10.24	112
113	513.89	149.75	36.60	659	6.44	3.65	113
114	524.27	14.60	14.00	659	6.44	4.41	114
115	483.49	61.01	26.10	897	5.94	9.94	115
116	350.37	75.79	23.29	2291	13.02	4.52	116
117	312.94	15.30	12.90	659	6.44	11.75	117
118	320.54	38.71	25.89	659	6.44	6.61	118

NUMBER	OUTLAY	OUTSPC	VEHCST	DDAYS	RNFL	PPSQM	NUMBER
119	454.86	27.41	12.30	659	6.44	4.30	119
120	330.96	57.23	25.41	659	6.44	6.88	120
121	472.01	86.57	54.88	2251	4.17	8.40	121
122	389.94	72.53	35.91	1691	1.87	13.91	122
123	319.58	56.09	15.10	659	6.44	16.71	123
124	394.65	125.09	26.60	659	6.44	28.00	124
125	12746.35	973.60	560.60	4862	42.37	155.05	125
126	1018.41	108.64	64.78	6546	27.08	6.73	126
127	487.35	60.89	38.86	6875	35.08	10.00	127
128	56.20	113.86	58.56	4303	8.13	6.09	128
129	602.45	82.76	34.09	1950	34.96	5.79	129
130	3763.11	387.61	205.20	4111	44.21	19.67	130
131	200.74	6.30	11.79	6521	37.23	10.07	131
132	1041.07	216.81	94.16	2750	51.69	9.52	132
133	2588.93	22.31	112.06	4862	42.37	33.13	133
134	5361.51	175.39	241.53	4862	42.37	48.38	134
135	2259.73	660.50	114.78	7213	35.65	22.06	135
136	494.23	83.93	24.31	4848	42.48	22.52	136
137	629.55	60.58	42.86	3481	46.75	6.55	137
138	13399.87	687.46	928.90	6113	33.18	18.23	138
139	3703.38	657.21	134.16	4806	39.51	13.48	139
140	6342.32	615.85	242.50	6432	35.35	22.01	140
141	373.16	38.90	45.38	6453	17.41	11.87	141
142	1833.53	218.98	105.43	5444	36.67	8.80	142
143	1164.45	130.06	86.66	5591	40.17	18.24	143
144	2195.14	191.90	161.90	5982	14.81	11.41	144
145	914.15	106.06	66.29	6542	30.37	3.90	145
146	5597.08	437.90	234.63	6275	30.95	14.74	146
147	396.03	18.99	17.39	4878	39.71	14.42	147
148	656.55	228.83	54.82	2578	7.89	3.07	148
149	395.84	5.40	38.17	6334	43.51	10.82	149
150	586.99	240.81	72.82	7335	37.82	7.02	150
151	2223.86	158.38	82.43	4862	42.37	32.62	151
152	511.83	27.99	37.90	6225	41.11	6.44	152
153	1301.15	291.78	74.51	2553	34.14	4.03	153
154	543.43	114.55	54.09	6980	34.87	15.03	154
155	565.10	163.53	38.36	5122	35.62	19.51	155
156	3640.95	818.11	189.81	1278	45.26	4.35	156
157	2907.36	308.28	99.19	5699	39.25	10.86	157
158	387.61	65.10	46.29	2239	49.33	5.53	158

The constraints are:

$$XI \geq \bar{X}I \qquad XC \geq \bar{X}C \qquad X2 \geq \bar{X}2 \qquad X4 \geq \bar{X}4$$

and the structural form is:

$$Gv = Rx$$

$$\begin{bmatrix} \beta_7 & \beta_8 & \beta_9 \\ -1 & 0 & 1 \\ -1 & 1 & 0 \end{bmatrix} \begin{bmatrix} v_7 \\ v_8 \\ o_9 \end{bmatrix} = \begin{bmatrix} (b-\beta_9 W_9) & \alpha I & \alpha C & \alpha 2 & \alpha 4 & 0 & 0 \\ (B_9-B_7) & 0 & 0 & 0 & 0 & 1 & 0 \\ (B_8-B_7) & 0 & 0 & 0 & 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} 1 \\ \bar{x}i \\ \bar{x}c \\ \bar{x}2 \\ \bar{x}4 \\ W_7 \\ W_8 \end{bmatrix}$$

whence the reduced form is:

$$v = G^{-1} Rx$$

$$\begin{bmatrix} v_7 \\ v_8 \\ o_9 \end{bmatrix} = \frac{1}{\Sigma} \begin{bmatrix} C_7 & \alpha I & \alpha C & \alpha 2 & \alpha 4 & -(\beta_8+\beta_9) & \beta_8 \\ C_8 & \alpha I & \alpha C & \alpha 2 & \alpha 4 & \beta_7 & -(\beta_7+\beta_9) \\ C_9 & \alpha I & \alpha C & \alpha 2 & \alpha 4 & \beta_7 & \beta_8 \end{bmatrix} \quad x$$

where $\Sigma = \beta_7 + \beta_8 + \beta_9$

and

$$C_7 = b - \beta_9 W_9 - (\beta_8+\beta_9)\, B_7 + \beta_8 B_8 + \beta_9 B_9$$

$$C_8 = b - \beta_9 W_9 + \beta_7 B_7 - (\beta_7+\beta_9)\, B_8 + \beta_9 B_9$$

$$C_9 = b - \beta_9 W_9 + \beta_7 B_7 + \beta_8 B_8 - (\beta_7+\beta_8)\, B_9 \; .$$

The cost function associated with this model is:

$$c = -\frac{1}{\Sigma}(\beta_7 B_7 + \beta_8 B_8 + \beta_9 B_9 + b) + \sigma + \frac{1}{\Sigma}\sum_{i=I}^{4} \alpha_i \bar{X}_i$$

$$+ (\beta_7/\Sigma)\, W_7 + (\beta_8/\Sigma)\, W_8 \; .$$

C. Returns to Scale

Since we have not posited a fixed factor, the returns to scale statistic, ρ^o, is simpler to interpret.

$$\rho^o = \sum_{j=7}^{9} \beta_j / \sum_k \alpha k \qquad\qquad k = I, C, 2, 4.$$

Again, there is a statistic which is more immediate and the sampling theory for which is more readily available:

$$s^o = \sum_{i=1}^{4} b_i$$

where the $\{b_i\}$ are the regression coefficients of outputs in the extra post-office cost function.

Table VII-3 gives cost functions which show estimates of s^o and its standard error and r^o which is simply the inverse of s^o.

Decreasing returns to size of office is indicated in collection and delivery activities. This is reasonable, for as an office gets larger, with population density held constant, the average trip a carrier must make to reach his route gets lengthier.

In a one-tail test we can reject the hypothesis of constant returns to scale at the .05 level, but we cannot reject constant returns to scale at the .05 level in a two-tail test. When environmental variables such as population density, precipitation and degree-days are measured explicitly and present in the regression, as in Table VII-4, we can reject the constant returns to scale hypothesis and conclude there exist decreasing returns in collection and delivery.

In the group of small offices there was evidence of strongly increasing returns to scale, but the estimates were not very precise. Increasing returns continue through medium offices but slight decreasing returns appear in the group of largest offices.

It is interesting to observe how costs react to more dense population. Presumably, clients closer together should be less costly to serve. That is true as shown by the negative regression coefficients of population per square mile in both equations of Table VII-4.

Degree days, a measure of cold weather, increases extra costs decidedly. Precipitation, however, does not have a predictable impact on collection and delivery costs.

The geographical dummy variable, NEFW, does not behave in the extra post-office cost functions as it did in the intra functions. In the intra equations costs were higher in the Northeast or Far West *ceteris paribus*, presumably because labor quality varied. In the extra equations costs were lower where NEFW was equal to one, although we were not able to measure this effect very precisely. In general our results are less trustworthy for the outside, yet there may be another explanation. Mail delivery routes are arranged through locally developed standards so that a carrier can easily complete the route in his alloted time. The importance of labor quality for costs may not be so great for extra post-office activity as it is for intra post-office activity.

Table VII-3. Extra post-office cost functions.

Independent variable	Group			
	All (114)	Small	Medium	Large
Constant	-5.37	-1.78	-1.70	-4.18
xi	.166 (.161)	.548 (.338)	.410 (.289)	-.202 (.202)
xc	.800 (.154)	.500 (.275)	.220 (.318)	1.11 (.200)
x2	.080 (.048)	-.165 (.090)	-.123 (.091)	.306 (.066)
xi^4 (incoming parcels)	.011 (.071)	-.118 (.135)	.227 (.104)	-.204 (.118)
W_7	1.55 (.510)	.284 (.895)	1.63 (.883)	.921 (.731)
W_8	.041 (.086)	.103 (.126)	.132 (.169)	-.104 (.122)
R^2	.954	.530	.701	.953
SSE	4.80	1.20	1.108	.781
SEE	.212	.196	.189	.159
S^o	1.057 (.026)	.765 (.188)	.734 (.117)	1.009 (.045)

Table VII-4. Extra cost functions with environmental variables.

	5/27/68, p. 44	n=156	4/8/69 p.21	n=114
Constant	-5.27	(.782)	-5.51	(.811)
xi	.297	(.157)	.149	(.165)
xc	.688	(.156)	.886	(.159)
x2	.117	(.067)	.063	(.051)
xi4			-.021	(.076)
x4	-.029	(.058)		
W_7	1.21	(.538)	1.39	(.577)
W_8	.109	(.091)	.054	(.093)
NEFW			-.0059	(.053)
Degree days	1.44×10^{-5}	(1.10×10^{-5})	.00002	(.00001)
Precipitation	.00161	(.00142)	-.00006	(.0015)
Pop./sq. mi.	-.00216	(.00176)	-.0023	(.0015)
SC			.019	(.058)
R^2	.9230		.9567	
SEE	.267		.209	
SSE	10.404165		4.464	

Table VII-5. Returns to scale in extra post-office activity.

Group	n	s^o		t	r^o	Returns
All	114	1.057 (.026)	1.08[a] (.025)	2.19	.946	decreasing
Small	38	.765 (.188)		1.25	1.31	increasing
Medium	38	.734 (.117)		2.27	1.36	increasing
Large	38	1.009 (.045)		.20	.991	constant

[a]With environmental variables included.

D. Derived Demand Functions

As well as cost functions we have estimated derived-demand equations for extra post-office activities. Unlike the cost functions, these were estimated for all 156 offices and $X4$ represents parcels, both incoming and outgoing. Results are available in Tables VII-6 and VII-7.

The labor equation is similar to the cost functions and it indicates slightly decreasing returns to size of office. Again, as in the intra post-office equations, the coefficient of the wage rate has the wrong sign.

The outside space equation is the poorest fitting. It is hard to predict what outside space an office will use and it is not very closely related to the workload. Sometimes parking space will be provided for employees and even patrons. In other situations such space will not be provided by the post office. The POD seems to respond to real estate prices as we would expect cost minimizers to respond. The estimated coefficient of the rental price of outside space is significantly negative. This equation indicates constant returns to scale.

Outlay on mechanization is affected positively by outgoing cancelled letters and parcels. Incoming letters do not use any mechanization nor does second-class mail. Perhaps a better specification would leave out those arguments. This equation indicates roughly constant returns to scale.

Table VII-6. Derived demands for factors extra post-office activity.

Independent Variable	Dependent Variable		
	v_7	v_8	o_9
Constant	-5.30	-3.69	-5.99
xi	.346 (.168)	-.542 (.484)	-.414 (.191)
xc	.605 (.165)	.940 (.476)	1.299 (.187)
x2	.116 (.072)	.503 (.207)	-.047 (.082)
x4	-.011 (.061)	.085 (.175)	.164 (.069)
W_7	.405 (.553)	-1.994 (1.59)	-.431 (.627)
W_8	.117 (.095)	-1.026 (.274)	-.301 (.108)
R^2	.910	.513	.863
SSE	12.254	101.84	15.783
SEE	.287	.827	.325
S^o	1.0557	.986	1.002
n	156	156	156

Source: Calculations done 6/25/68, pp. 32, 35, 38.

Table VII-7. Returns to scale in extra post-office activity inferred from derived-demand equations.

Equation	s^o	r^o	Returns
Labor	1.0557	.947	decreasing
Space	.986	1.014	constant
Vehicle outlay	1.002	.998	constant

E. Structural Estimation

Marginal productivity conditions of cost minimization, when divided one by the other lead to factor share equations of the following form:

$$\frac{w_8 V_8}{w_7 V_7} = \frac{\alpha_8}{\alpha_7}$$

$$\frac{O_9}{w_7 V_7} = \frac{\alpha_9}{\alpha_7}$$

Since the left-hand sides are observable we can estimate

$$\hat{\alpha}_8/\alpha_7 = .00752 \quad \text{and} \quad \hat{\alpha}_9/\alpha_7 = .01868 \; .$$

These "extraneous" estimates can be used to form a new variable representing output capacity:

$$z = v_7 + .00752\, v_8 + .01868\, o_9 \; .$$

Regressing z on the extra post-office products yields:[3]

[3]This equation is taken from computations done 6/24/68, p. 31. x4 represents all parcels, incoming and outgoing. The $R^2 = .91$ and SEE = .288 and the equation was estimated from 156 observations.

$$z = -5.237 + .377xi + .603xc + .130x2 - .018x4 .$$
$$\quad (.359) \ (.165) \quad (.164) \quad (.072) \quad (.061)$$

Letting $\alpha_7 = 1$ to normalize, we have

$$\sum_{j=7}^{9} \alpha_j = 1.0262 \qquad \text{and} \qquad \sum_{k=1}^{4} \hat{\alpha}_k/\alpha_7 = 1.0909 .$$

The estimate of the returns-to-scale parameter becomes

$$r^o = \sum_{i=7}^{9} \alpha_i / \sum_{k=1}^{4} \alpha_k = .9407 .$$

This indicates decreasing returns to size of office in collection and delivery services, thus corroborating our estimates from reduced forms.

F. Conclusion

Several calculations have shown generally diminishing returns to size of office in collection and delivery services although there are increasing returns in small and medium offices.

In cities with severe winters (a large number of degree-days) collection and delivery are significantly more costly. Collection and delivery are less costly where there is a high density of postal population. Such economies of density in distribution costs are similar to those found by Raymond Bressler in a study of milk delivery [9].

Results for extra post-office activity are not so good as those for intra post-office activity. In particular, parcels (whether incoming alone or with outgoing added) appear to have low or negative cost elasticities. This leads us to suspect the output data. It is also true that we do not have complete data on outside costs, especially for the operation of vehicles.

Chapter 8: POSTAL COSTS

A. Factors Important in Explaining Postal Costs

In our sample of 156 offices we observe considerable covariation in office costs and the several services each office produces. By studying this covariation we can seek to identify the factors which appear to account for intra office costs and extra office costs. We shall estimate the marginal costs of the several types of mail.

Two caveats should be kept in mind. The costs reported exclude the cost of intercity transportation and they arise from imperfect data. The piece of mail that an office of final destination sorts to a fine degree is sorted less finely by a Sectional Center through which it passes in transit. Unfortunately, both types of service would count as a "first-handling piece" in our data.

A-1. Intra Post-office Activity

In the overall cost function based on the Cobb-Douglas model of multiproduction regression coefficients of outputs are interpretable as elasticities of cost with respect to outputs. For intra office activity all coefficients are of the expected sign: costs rise with outputs and factor prices. All are significantly different from (s.d.f.) zero at the .05 level save those of third-class mail, GSA space, and the Sectional Center dummy variable.

Cost is most elastic to first- and then to second-class mail. It is not surprising that outgoing noncancelled letters should not influence costs very much. Bulk rate mail must be delivered to the office by the sender presorted by ZIP code so that it takes very little effort on the part of the office of origin. The low-cost elasticity of fourth-class mail is surprising, however, leading us to suspect the reporting of parcel data and some possible confounding with small parcels and rolls.

If an office is a Sectional Center, as nearly all in our sample are, its costs are likely to be lower, although this is not precisely measured. This is likely to be a consequence of the inflated first-handling pieces data for Sectional Centers.

Since labor is the most intensively used factor, its price is of overwhelming importance in determining the intra and extra cost of an office. Its estimated coefficients are five times their standard errors in intra cost functions and twice its standard error in extra.

B. Marginal Costs of Different Post Office Outputs

Marginal costs can be calculated in two distinct ways:

(1) multiply the cost elasticity of a type of service by the ratio of cost to the quantity of that output:

$$\partial C/\partial X_i = C_i \; C/X_i = \partial C/\partial X_i \; \frac{X_i}{C} \; \frac{C}{X_i}$$

where C_i is the elasticity of cost (intra or extra) with respect to output i, or

(2) evaluate the shadow prices.

There is surprising agreement in the results of intra post office marginal costs calculated by the two methods above as shown in columns 1 and 2 of Table VIII-1. Both methods use the results of the same cost function but the shadow prices are functions of all exogenous variables.

Table VIII-1. Marginal costs of selected types of mail.

	MARGINAL		
	From cost function[a]	Shadow price	From amended cost function[b]
Intra			
X_1	.0123	.0125 (.0039)	.0140
X_2[c]	.1240	.1269 (.0319)	.1168
X_3	.0017	.0017 (.0012)	.0023
X_4	.0475	.0461 (.0169)	.0703
X_5	71.30	79.42 (64.65)	32.20

[a]Calculated 7/30/68, pp. 138 ff. and 8/23/68.

[b]With NEFW variable included.

[c]See text for costs of component types of mail.

Shadow prices were calculated for each office and the sample mean and sample standard deviation are given in Table VIII-1.

Estimated shadow prices indicate marginal costs of \$.0125 per piece of first-class mail, \$.0017 for third class, and \$79.42 per thousand dollars of window service business. The marginal cost of second-class mail requires further explanation for X_2 is a weighted average of four different types of mail. The rate of change of costs with respect to X_2 may be .1269 but the rate of change of X_2 with respect to a unit increase in outgoing flats is .189, for example. Multiplying these factors yields the following marginal costs: outgoing flats, \$.0239; outgoing SPR's, .0454; incoming flats, .0245; and incoming SPR's, .0329.

When the cost function is amended to include the geographical variable, NEFW, we obtain different marginal cost estimates. They are given in column 3 of Table VIII-1 and result in the estimates for intra post-office costs per first-handling piece shown in Table VIII-2.

Table VIII-2. Intra post-office marginal costs per first-handling piece.

Classification	Cost
First class	\$ .0140
Outgoing flats	.0221
Outgoing SPR's	.0418
Incoming flats	.0225
Incoming SPR's	.0303
Third class	.0023
Fourth class	.0703
Window service	\$32.20 per \$1,000

The inclusion of the NEFW variable considerably improved these estimates in the sense that they agree more now with common sense, especially the cost of handling the mean parcel.

Extra post-office marginal costs are given in Table VIII-3. They do not agree with intuition because of the high apparent relative cost of outgoing cancelled letters and the low apparent marginal cost of incoming parcels. Outgoing cancelled letters merely need to be collected from boxes. Incoming parcels are delivered to the patron's door or at least an attempt is made to do so. This would seem to use large quantities of

Table VIII-3. Extra post-office marginal costs per FHP.

Classification	Cost
Incoming letters	$ .0040
Outgoing cancelled letters	.0552
Outgoing flats	.0031
Outgoing SPR's	.0059
Incoming flats	.0032
Incoming SPR's	.0042
Incoming parcels	.0167

labor and vehicle services. It is possible that parcels are very heterogeneous and that small advertising samples are present in the parcel data. These should be among small parcels and rolls.

Chapter 9: ALTERNATIVE MODELS

A. The Production Correspondence

Yair Mundlak has discussed the incompatibility of multiproduction, the Cobb-Douglas form of the transformation curve, and profit maximization [48]. He has attempted to rationalize the production of several products and profit maximization by appending an exponential or "transcendental" term to the familiar Cobb-Douglas form of a transformation function [47a]. I intend to (1) show that another familiar functional form has the proper curvature properties for a transformation function; (2) develop a statistical hypothesis test to choose among three functional forms for a transformation function: "Cobb-Douglas," "transcendental" and "CES." Although this theory involves production correspondences, we do not estimate them directly. Instead, we shall be concerned with cost functions, the dual of the production function, in the sense of Uzawa [80], Shephard [65] and McFadden [46a].

A-1. The Cobb-Douglas Form and What is Wrong With It

The Cobb-Douglas function,

$$f(X) = \prod_{i=1} X_i^{\alpha_i} \qquad (1)$$

is a weighted product, where the weights are the exponents $\{\alpha_i\}$. As such, it is a means of aggregating and can be used to aggregate outputs as well as inputs. There are reasons from economic theory, however, which argue against using a weighted product as a means of aggregating outputs.

As indicated by Klein [37] (and amended by Nerlove [52] p. 82, fn.3), if a multiproduction function be Cobb-Douglas in outputs, then the first-order conditions for profit maximization lead to a saddle point and not a maximum of profits. On the other hand, for a transformation curve concave in product space like Figure 4, a profit-maximizer will be in equilibrium at an interior point with positive production of all outputs. The trouble with the Cobb-Douglas form is that it is convex and hence appropriate for a production function but not a transformation function.

A-2. <u>The CES Form</u>

Another aggregation function which, like the Cobb-Douglas, is a "mean value function" and has come to be known in the economics literature as the "constant-elasticity-of-substitution" (CES) production function [1]. Typically, its arguments have been inputs but mathematically, they may just as well be outputs, in which case we call it a transformation function. In general, the function is:

$$g(X) \;=\; A\Big[\sum_{i=1}^{n} B_i\, X_i^{\rho}\Big]^{\mu/\rho} \tag{2}$$

$$\text{where} \quad \sum_{i=1}^{n} B_i \;=\; 1 \qquad\qquad A,\ \{B_i\} \;>\; 0. \tag{2a}$$

Let $\mu = 1$ for the time being and let us discuss some properties of this function by examining the case of two arguments. Let

$$Y \;=\; A[B_1X_1^{\rho} \;+\; B_2X_2^{\rho}\,]^{1/\rho}\,. \tag{3}$$

Let Y_i denote partial derivative with respect to X_i. Then:

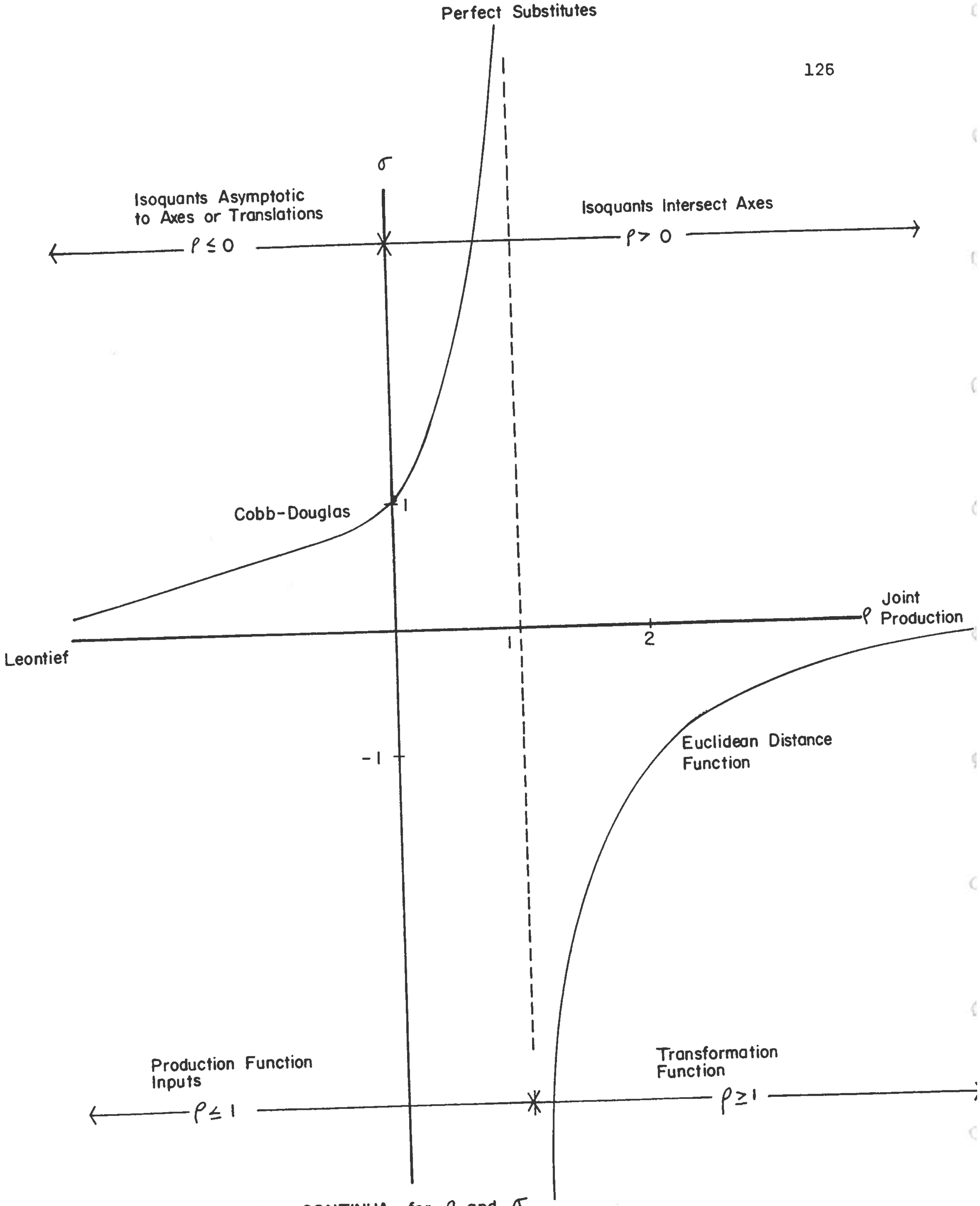

Figure IX-1: CONTINUA for ρ and σ

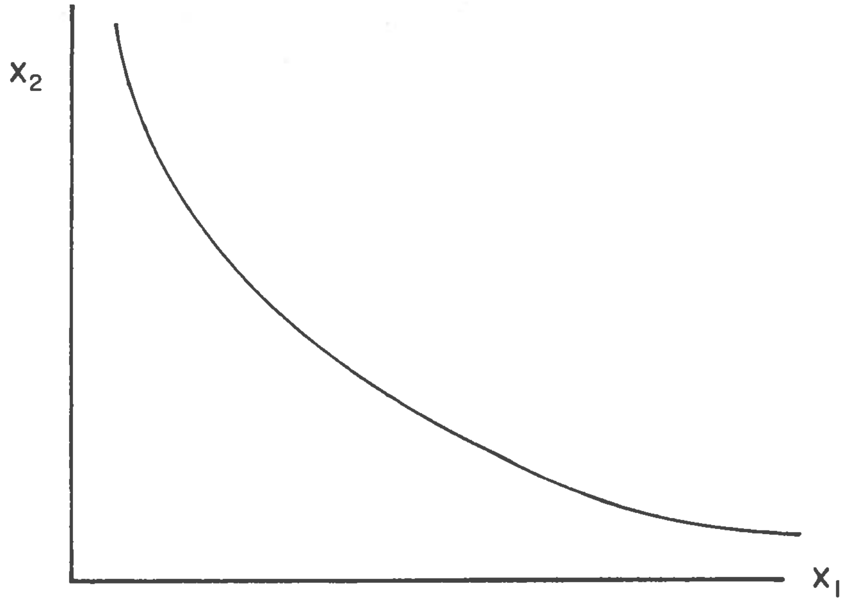

Figure IX - 2: ISOQUANT, CONVEX in INPUT SPACE, $\sigma = 1$: COBB-DOUGLAS CASE

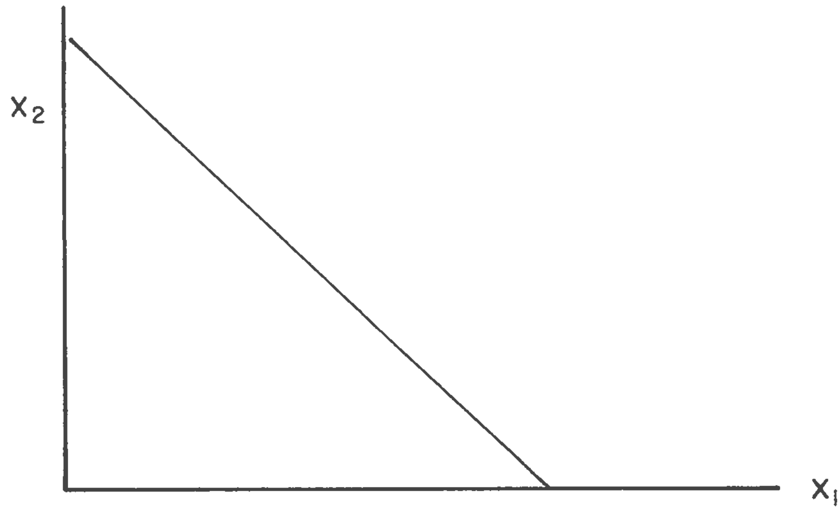

Figure IX - 3: PERFECT SUBSTITUTES and NONESSENTIAL FACTORS in PRODUCTION or CONSTANT-COST TRANSFORMATION CURVE: $\sigma = \infty$

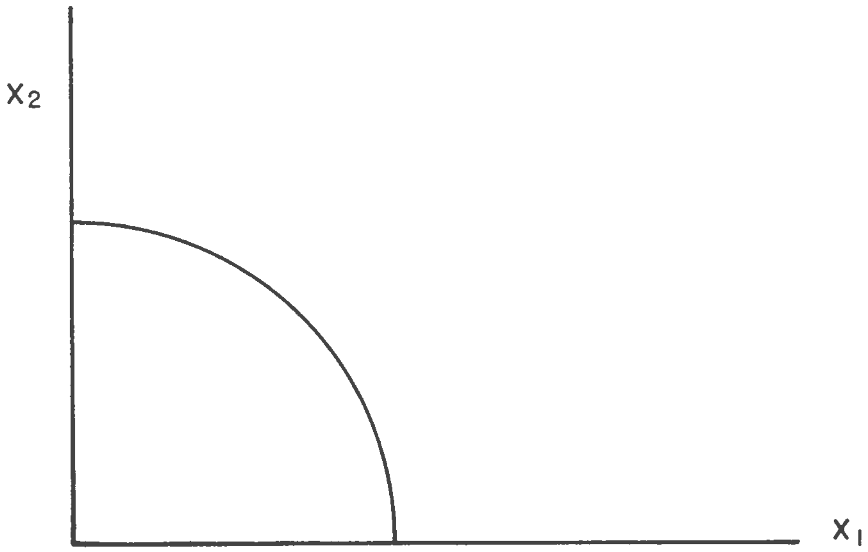

Figure IX - 4: TRANSFORMATION CURVE, CONCAVE in OUTPUT SPACE: $\sigma < 0$

$$Y_i = \left(\frac{Y}{X_i}\right)^{1-\rho} A^{-\rho} B_i \ . \tag{4}$$

For constant Y, we have

$$dY = Y_1 \, dX_1 + Y_2 \, dX_2 = 0 \tag{5}$$

whence

$$\frac{dX_2}{dX_1} = \frac{-Y_1}{Y_2} = \frac{-B_1}{B_2} \left(\frac{X_1}{X_2}\right)^{\rho-1} , \tag{6}$$

and
$$\frac{d^2X_2}{dX_1^2} = \frac{-B_1}{B_2} \frac{(\rho-1)}{X_2} \left(\frac{X_1}{X_2}\right)^{\rho-2} \left[1 + \frac{B_1}{B_2} \left(\frac{X_1}{X_2}\right)^{\rho}\right] . \tag{7}$$

Equations (2a) and (6) imply that in $\{X_i\}$ space the slope is negative. This is proper either for an isoquant or a transformation curve. The second derivative is what distinguishes the two. If the $\{X_i\}$ are inputs and (3) a production function, we require the isoquant to be convex in input space, i.e. $\frac{d^2X_2}{dX_1^2} \geq 0$ as in Figures 2 or 3. If the $\{X_i\}$ are outputs and (3) a transformation function, we require it to be concave, i.e. $\frac{d^2X_2}{dX_1^2} \leq 0$ as in Figures 3 and 4 for the strict inequality or Figure 3 for the equality. Equation (7) shows that convexity or concavity is determined by ρ and the critical value is 1. The curve will be concave for $\rho \geq 1$ and convex for $\rho \leq 1$.

The elasticity of substitution, σ, is given by:[1]

$$\sigma = 1/1-\rho \ . \tag{8}$$

---

[1]This differs from the formula in [1] because their analogue of (2) involved $(-\rho)$ in place of my ρ.

In Figure 1 we have the graph of equation (8) which shows the domains appropriate when the arguments of (2) are outputs and when they are inputs. From (7) we see that (2) is a production function for $\rho \leq 1$ and a transformation function for $\rho \geq 1$. This explains the "outputs" and "inputs" domains for ρ at the bottom of Figure 1. The line of demarcation is $\rho = 1$.

For a production function, isoquants asymptotic to the axes[2] imply that positive quantities of both factors are necessary for production; neither factor can be "substituted out" completely by application of another factor. Figure 2, the Cobb-Douglas, is an example of this essential factor case.[3]

In the domain $0 < \rho \leq 1$ isoquants intersect the axes and neither factor is essential. As $\rho \to 1$, $\sigma \to \infty$, we approach the "perfect substitutes and non-essential factor" case of Figure 3.

In all forms of (2) appropriate for outputs as arguments the isoquants intersect the axes. If this were not the case the implication would be that an unlimited amount of one output could be achieved by letting the second output approach zero. This is one reason why (1) is unacceptable as a scheme for aggregating outputs.

For $\rho > 1$, $\sigma < 0$, we have the multiproduct case with diminishing marginal rate of transformation as in Figure 4.

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[2]Or translations of the axes.

[3]A "translated Cobb-Douglas" $Y = A\,(X_1 - a)^{a_1}\,(X_2 - b)^{a_2}$ would be a case in which the origin was translated to point (a,b) and both factors were essential.

As $\rho \to \infty$, $\sigma \to 0$ from below, we approach the joint production case in which outputs are produced strictly in fixed proportions (as in eggs and eggshells or mutton and wool) as along the ray OP in Figure 5. The more familiar case is the diametrically opposed Leontief production function in which inputs must be combined in fixed proportions for technically efficient production. The expansion path is the ray OQ in Figure 6 connecting successive levels of greater output. This case is approached as $\rho \to -\infty$, at the left of Figure 1.

One final analogue: the Euclidean distance function (measured from the origin) is

$$d = (X^2 + Y^2)^{1/2} \tag{9}$$

which is a special case of (2) with $A = \sqrt{2}$ $B_i = 1/2$ $i=1,2$ and $\rho=2$. This is the locus of points equidistant from the origin, a typical "guns-butter" curve in the first quadrant, the "mirror image" of a Cobb-Douglas.

Thus the CES functional form can be employed fruitfully with outputs as well as inputs as arguments.

Consider a production correspondence CES in outputs, X_i, and Cobb-Douglas in inputs, V_j, of the form:

$$[a_1 X_1^{\rho} + a_2 X_2^{\rho}]^{\mu/\rho} = A\, V_3^{\alpha_3}\, V_4^{\alpha_4}\, V_5^{\alpha_5} \tag{10}$$

where $a_1 + a_2 = 1$ and V_5 is a fixed factor.

From a cost-minimization exercise we obtain the other structural equation of the model

$$\frac{w_4 V_4}{w_3 V_3} = \frac{\alpha_4}{\alpha_3}$$

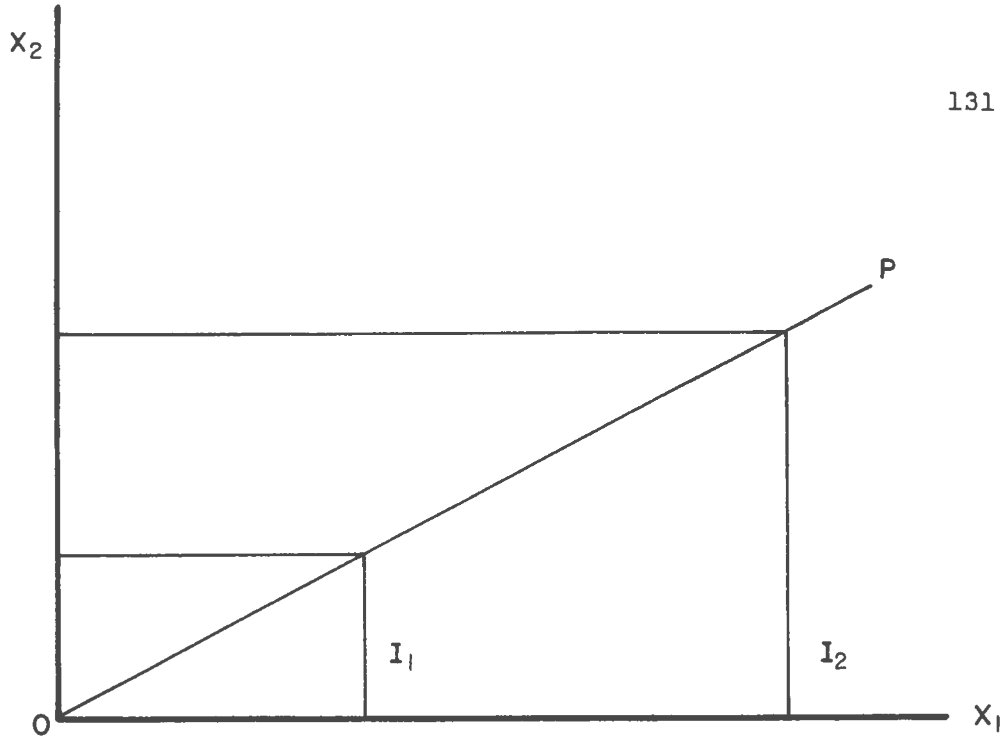

Figure IX - 5 : TRUE JOINT PRODUCTION : $\sigma = 0$ for OUTPUTS

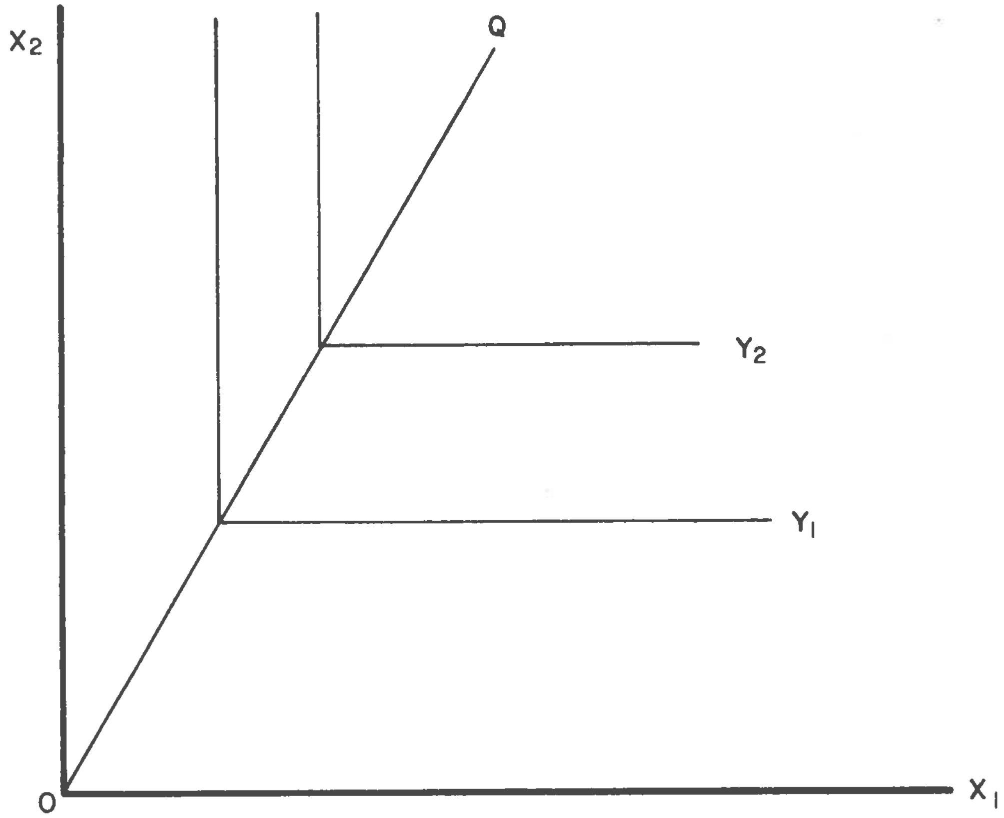

Figure IX - 6: LEONTIEF FIXED PROPORTIONS AMONG INPUTS $\sigma = 0$ for INPUTS (where $\{w_i\}$ are the factor prices),

whence the reduced form is the pair of derived demands for factors:

$$V_3 = A^{-1/\Sigma}\left(\frac{\alpha_3}{\alpha_4}\right)^{\alpha_4/\Sigma} V_5^{-\alpha_5/\Sigma}\left[a_1X_1^{\rho} + a_2X_2^{\rho}\right]^{\mu/\rho\Sigma}\left(\frac{w_4}{w_3}\right)^{\alpha_4/\Sigma}$$
$$V_4 = A^{-1/\Sigma}\left(\frac{\alpha_4}{\alpha_3}\right)^{\alpha_3/\Sigma} V_5^{-\alpha_5/\Sigma}\left[a_1X_1^{\rho} + a_2X_2^{\rho}\right]^{\mu/\rho\Sigma}\left(\frac{w_3}{w_4}\right)^{\alpha_3/\Sigma} \qquad (11)$$

where $\Sigma = \alpha_3 + \alpha_4$.

Equations (11) are not linear in their parameters. Taking logarithms and observing the "case logarithm" convention (lower case letters represent natural logs of upper-case counterparts and <u>vice versa</u>):

$$v_3 = -\frac{1}{\Sigma}a + \frac{\alpha_4}{\Sigma}\frac{A_3}{A_4} + \frac{\mu}{\rho\Sigma}\ln[a_1X_1^{\rho} + a_2X_2^{\rho}] + \frac{\alpha_4}{\Sigma}(W_4 - W_3) - \frac{\alpha_5}{\Sigma}v_5 \;. \qquad (12)$$

The part nonlinear in parameters is

$$g(\rho) = \ln(a_1X_1^{\rho} + a_2X_2^{\rho}). \qquad (13)$$

This can be approximated by a Maclaurin's series about $\rho = 0$, the Cobb-Douglas case, which will be valid for small departures from that form [38].

For a more general form with more than two factors, we have,[4]

---

[4]If there are p products,

$$f(o) = \ln\sum_{i=1}^{p} a_i = \ln 1 = 0$$

$$f'(o) = \sum_{i=1}^{p} a_i x_i \qquad f''(o) = \sum_{i<j} a_i a_j (x_i - x_j)^2$$

which, in the case of three factors is

for $$f(\rho) = \ln (a_1 X_1^\rho + a_2 X_2^\rho + a_3 X_3^\rho)$$

$$f(\rho) \cong \rho\{a_1 x_1 + a_2 x_2 + a_3 x_3 + \frac{\rho\, a_1 a_2}{2\Sigma} (x_1 - x_2)^2$$

$$+ \frac{\rho\, a_1 a_3}{2\Sigma} (x_1 - x_3)^2 + \frac{\rho\, a_2 a_3}{2\Sigma} (x_2 - x_3)^2 \ . \qquad (14)$$

Thus, our approximation to (12) is

$$v_3 = (-1/\Sigma)\, a + \frac{\alpha_4}{\Sigma} \frac{A_3}{A_4} + \frac{\mu\, a_1}{\Sigma} x_1 + \frac{\mu\, a_2}{\Sigma} x_2 + \frac{\mu\, a_3}{\Sigma} x_3 + \frac{\mu\rho}{2\Sigma} a_1 a_2 (x_1 - x_2)^2$$

$$+ \frac{\mu\rho}{2\Sigma} a_1 a_3 (x_1 - x_3)^2 + \frac{\mu\rho}{2\Sigma} a_2 a_3 (x_2 - x_3)^2 + \frac{\alpha_4}{\Sigma} (W_4 - W_3) - \frac{\alpha_5}{\Sigma} v_5 \ . \qquad (12')$$

The approximation is needed for the cost function as well:

$$c = k^* + \frac{\mu}{\Sigma} \sum_{i=1}^{P} a_i x_i + \frac{\mu\rho}{2\Sigma} \sum_{i<j} a_i a_j (x_i - x_j)^2 + \frac{\alpha_4}{\Sigma} W_4 + \frac{\alpha_3}{\Sigma} W_3 - \frac{\alpha_5}{\Sigma} v_5 . \qquad (15)$$

A-3. <u>Mundlak's Transcendental Form</u>

Mundlak [47a, 48] suggests a transcendental production correspondence:

$$F(X;V) = X_1^{\alpha_1} X_2^{\alpha_2} \exp(\beta_1 X_1 + \beta_2 X_2) - A\, V_3^{\alpha_3} V_4^{\alpha_4} = 0 \ . \qquad (16)$$

$$f''(0) = a_1 a_2 (x_1 - x_2)^2 + a_1 a_3 (x_1 - x_3)^2 + a_2 a_3 (x_2 - x_3)^2$$

and Taylor's formula (without remainder) is

$$f(\rho) \cong f(0) + \rho\, f'(0) + \frac{\rho^2}{2} f''(0) \ .$$

Taking logarithms we have

$$\alpha_1 x_1 + \alpha_2 x_2 + \beta_1 X_1 + \beta_2 X_2 = a + \alpha_3 v_3 + \alpha_4 v_4 \ . \tag{17}$$

This is a linear-logarithmic equation save for the $\{X_i\}$. The derived-demand equations implied by (16) are:

$$\begin{bmatrix} v_3 \\ 4_4 \end{bmatrix} = \begin{bmatrix} c_3 \\ c_4 \end{bmatrix} + \frac{1}{\Sigma} \begin{bmatrix} \alpha_1 & \alpha_2 & \beta_1 & \beta_2 & -\alpha_4 & \alpha_4 \\ \alpha_1 & \alpha_2 & \beta_1 & \beta_2 & \alpha_3 & -\alpha_3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ X_1 \\ X_2 \\ W_3 \\ W_4 \end{bmatrix} \tag{18}$$

where $\Sigma = \alpha_3 + \alpha_4$.

The cost function is:

$$c = k + \frac{\alpha_1}{\Sigma} x_1 + \frac{\alpha_2}{\Sigma} x_2 + \frac{\beta_1}{\Sigma} X_1 + \frac{\beta_2}{\Sigma} X_2 + \frac{\alpha_3}{\Sigma} W_3 + \frac{\alpha_4}{\Sigma} W_4 \tag{19}$$

where c = ln total costs, k is a constant, and the case-logarithm convention is observed.

In each case we shall test a general model, CES or transcendental, against a simpler model, the Cobb-Douglas. The general model will be the maintained hypothesis and the Cobb-Douglas will be the null hypothesis to be tested.

The models have more variables but are similar to those in sections A-1 through A-3 above. In general, the CES model is not linear in parameters. Because of that we have approximated the CES with the first two terms of the Maclaurin's series as suggested by Kmenta [38].

The criterion for testing each hypothesis will be Snedecor's F statistic essentially comparing the error variance from estimated cost functions under a Cobb-Douglas hypothesis with the error variance of the more general model.

1. Transcendental vs. Cobb-Douglas

(a) Maintained hypothesis Ω:

(i) Production correspondence:

$$\prod_{i=1}^{5} X_i^{\alpha_i} \exp\left(\sum_{i=1}^{5} \beta_i X_i\right) = \prod_{j=6}^{8} V_j^{\alpha_j} \left(\frac{O_9}{w_9}\right)^{\alpha_9}$$

(ii) Cost function:

$$c = k' + \sum_{i=1}^{5} \frac{\alpha_i}{\Sigma} x_i + \sum_{j=1}^{5} \beta_j X_j + \frac{\alpha_7}{\Sigma} W_7 + \frac{\alpha_8}{\Sigma} W_8 - \frac{\alpha_6}{\Sigma} v_6$$

where $\Sigma = \alpha_7 + \alpha_8 + \alpha_9$.

(b) Cobb-Douglas hypothesis: $H_o : \beta_1 = \beta_2 = \ldots = \beta_5 = 0$.

Under Ω we fit 15 parameters and the sum of squared residuals (SSE) was 3.193352.[5]

Under $\omega = \Omega \cap H$ we fit 10 parameters and SSE = 3.234223.[6]

Snedecor's F = .361 and we cannot reject the Cobb-Douglas null hypothesis in favor of Mundlak's transcendental.

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[5]Computations performed May 31, 1968, p. 41.

[6]Computations performed May 27, 1968, p. 40.

2. CES vs. Cobb-Douglas

(a) Maintained hypothesis Ω:

(i) Production correspondence:

$$[\sum_{i=1}^{5} \alpha_i X_i^{\rho}]^{\mu/\rho} = A' \prod_{j=6}^{8} V_j^{\alpha_j} \left(\frac{O_9}{w_9}\right)^{\alpha_9}$$

(ii) Cost function approximation:

$$c = k'' + \frac{\mu}{\Sigma} \sum_{i=1}^{5} \alpha_i x_i + \frac{\mu\rho}{2\Sigma} \sum_{i<j} a_i a_j (x_i - x_j)^2 - \frac{\alpha_6}{\Sigma} v_6 + \frac{\alpha_7}{\Sigma} W_7$$

$$+ \frac{\alpha_8}{\Sigma} W_8 + b_{19}\ SC$$

where $\Sigma = \alpha_7 + \alpha_8 + \alpha_9$ and SC denotes Sectional Center dummy variable.

(b) Cobb-Douglas hypothesis : H_o:

$$c = k''' + \frac{\mu}{\Sigma} \sum_{i=1}^{5} a_i x_i + \frac{\alpha_7}{\Sigma} W_7 + \frac{\alpha_8}{\Sigma} W_8 - \frac{\alpha_6}{\Sigma} v_6 + b_{19}'\ SC\ .$$

Under Ω we fit 20 parameters.[7]

Under ω we fit 10.

$$F = \frac{(S_{10} - S_{20})/10}{S_{20}/136} = 3.24$$ which implies reject the Cobb-Douglas hypothesis in favor of the CES at the .01 level.

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[7] Computations performed June 11, 1968, p. 30.

We conclude that there is insufficient evidence to reject the Cobb-Douglas model when the alternative is Mundlak's transcendental production correspondence, although there is evidence to support the production correspondence with CES aggregation of outputs as an improvement over the Cobb-Douglas form. The trouble with CES aggregation of outputs is that it is more cumbersome to work with. Even in a Maclaurin's series approximation with five outputs we have to estimate ten extra parameters. So we have used a Cobb-Douglas transformation function in the body of this study. Let us see whether substantive results on returns to scale are different under that simplification.

The CES form is homothetic so that it yields a cost function homogeneous in outputs. The coefficients of the five outputs should be of the form $\mu\, a_i/\Sigma$. Adding over all five outputs gives an estimate of μ/Σ, the returns-to-scale parameter because $\sum_{i=1}^{5} a_i = 1$. The estimate[8] we obtained was

$m = 1.117$ and the estimate of b_6 was $-.002$ so that the overall returns-to-scale parameter with all factors including GSA space variable is $r = \frac{1.002}{1.117} = .8970$, indicating decreasing returns to scale as in the Cobb-Douglas case. Our estimate of $s = \sum_{i=1}^{6} b_i = 1.1137$ with a standard error of .0669 so that Student's t-statistic is about 1.7, which would not be sufficient to reject a null hypothesis of constant returns to scale at the .05 level.

Maddala and Kadane [43] have done a Monte Carlo study that suggests that estimating the degree of returns to scale in this way following Kmenta [38] gives a negligible bias.

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[8]Computations of June 11, 1968, p. 30.

B. The Production Function

Paying more attention to the production function than to the scheme of aggregating outputs, we may test the Cobb-Douglas production function against a CES alternative. Using a Kmenta Taylor's series approximation about the Cobb-Douglas case we can test whether three coefficients of variables representing departure from Cobb-Douglas will simultaneously vanish.

Assume the production function is of the following form:

$$Y = A[a_7V_7^{\rho} + a_8(V_6 + V_8)^{\rho} + a_9O_9^{\rho}]^{\mu/\rho} \tag{20}$$

where μ is the degree of returns to scale, Y is a scalar measure of output and the elasticity of substitution between inputs is $\sigma = 1/1-\rho$. Taking logarithms of both sides of (20) and observing the case-logarithm convention, we have

$$y = a + \frac{\mu}{\rho} \ln [a_7V_7^{\rho} + a_8(V_6 + V_8)^{\rho} + a_9O_9^{\rho}] \quad . \tag{21}$$

The last term is not linear in the parameters. Expanding it by Taylor's series about ρ=0 yields

$$\begin{aligned} y = {} & a + \mu\, a_7v_7 + \mu\, a_8 \ln (V_6 + V_8) + \mu\, a_9o_9 + \frac{\mu\rho}{2} a_7a_8 \\ & [v_7 - \ln (V_6 + V_8)]^2 + \frac{\mu\rho}{2} a_7a_9\, [v_7 - o_9]^2 \\ & + \frac{\mu\rho}{2} a_8a_9\, [\, \ln (V_6 + V_8) - o_9]^2 \; . \end{aligned} \tag{22}$$

The estimate of this equation by least-squares is given in Table IX-1.

An estimate of the returns-to-scale parameter, μ, is obtained by using the identity $a_7 + a_8 + a_9 \equiv 1$, as reported in Chapter 7. There is

Table IX-1. CES and Cobb-Douglas production function for intra post-office activity.

	K	v_7	$\ln(V_6+V_8)$	o_9	$[v_7-\ln(V_6+V_8)]^2$	$[v_7-o_9]^2$	$[\ln(V_6+V_8)-o_9]^2$	SC	R^2/SSE
CES 8/27/68, p. 39	7.83 (.41)	.328 (.359)	.510 (.260)	.035 (.141)	.120 (.055)	.018 (.037)	-.013 (.041)	.072 (.028)	.978 2.819626
Cobb-Douglas 8/27/68, p. 47	7.27 (.11)	.884 (.032)	.030 (.032)	-.036 (.025)				.078 (.029)	.977 2.929470

no unique estimate of σ. Furthermore, estimates of σ are affected by units of measurement but can be had if we first calculate the sample mean of $(x_i - x_j)$.[9]

An F-test that the coefficients of the variables in brackets vanish yields F = 1.919 with 3 and 148 degrees of freedom. This is not sufficient to reject the null hypothesis at the .05 or even the .10 level, yet the coefficient of $[v_7 - \ln(V_6 + V_8)]^2$ is s.d.f. 0 at the .05 level.

Shall we reject the Cobb-Douglas form? A strict F-test says no, but there is evidence of some divergence from the Cobb-Douglas form. A very significant labor coefficient becomes insignificant on its entry in a quadratic form so that the Cobb-Douglas form is not robust to slight changes in the specification.

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[9] [86, p. 7] and personal correspondence between Zarembka and Kmenta kindly shown me by Professor Zarembka.

Chapter 10: CONCLUSIONS

This thesis was a pilot study in analyzing the efficiency of public expenditure when similar services are performed at many remote locations. The pilot study was done on post-office data because that was reasonably well developed in uniform accounting categories. In the course of doing the study we reached some conclusions about post offices and the postal system, but I also hope that we have shown that production functions and cost functions are useful tools for analyzing such problems. Let us first discuss the conclusions we were able to reach regarding post offices and then judge the method and give a prognosis for its usefulness in other applications which might be intrinsically more interesting.

The statistical study of 156 offices began with a demarcation between intra and extra post-office activities. In general, our results pertaining to intra post-office activity are superior to those for extra post-office activity. They are both more reasonable and more convincing.

When the entire sample of 156 offices was examined it was found that intra post-office services are produced subject to decreasing returns to scale. Extra post-office activities are also produced subject to decreasing returns. These results were consistent whatever the form specified for production or transformation functions. We suggested two alternatives to the Cobb-Douglas transformation function. These had the proper shape: concave in output space: the "transcendental" and the "CES." We did not have enough evidence to reject the Cobb-Douglas in favor of the transcendental, but we could reject it in favor of CES aggregation of outputs.

When the sample was stratified into groups of small, medium, and large offices, we found increasing returns to scale in the small and medium groups and decreasing returns to scale in the large group. At first these stratified results were not very precise in the sense that large standard errors were attached to estimates of returns to scale. Eventually, when a geographic variable was included which we discovered important in the course of the analysis, we returned to the U-shaped pattern of increasing returns through the medium offices and finally decreasing returns in the largest offices.

All these results refer to scale economies at the level of the post office. This is analogous to firm size economies and has implications with respect to the optimal size of post offices and to whether we should agglomerate where possible or decentralize operations at the office level. The policy conclusion from these results is that offices smaller than the hundred largest in the country ought to be merged where possible. The largest fifty offices might profitably be decentralized.

It is well known that most of the 33,624 post offices in the country are maintained for political purposes to generate salaries and rents. Since increasing returns obtain in our small and medium sized offices with the returns parameter monotonically decreasing, offices smaller than those in our sample should be consolidated where possible. This class is the overwhelming majority of all offices, 33,500. In some cases geographical separation prevents consolidation, but it ought to be done wherever there is demographic continuity among areas.

Increasing returns to scale are also prevalent in extra post-office activity through the medium group of offices. Thus consolidation of offices does not imply longer mean hauls because an office can consist of many stations dispersed throughout a metropolitan area.

There exist nodal distribution economies: those of mass or bulk in the volume passing through any node [4a]. The Post Office has one national grid. For every destination there exists a single normal transportation path. Several firms operating nationally would be more costly than a single firm.

Admittedly, we have little experience on what results competition would yield in the Post Office. Milton Friedman suggests trying competition.

> If the delivery of mail is a technical monopoly, no one will be able to succeed in competition with the government. If not, there is no reason why the government should be engaged in it [24, p. 29].

Competition has been tried in a very analogous service: milk delivery. Raymond Bressler, after studying that industry, bemoaned wasteful competition among milk deliverers. Referring to other forms of distribution, he says:

> . . . inefficiency will persist until and unless a considerable degree of local monopoly is established, for the underlying factors are similar to those in milk distribution [9, p. 344].
>
> . . . duplications of routes, excess route and plant capacity and the multiplication of agencies and competitive services. Zoning or allocating cities into exclusive delivery territories for each dealer would permit cost reductions ranging from 0.7 to 1.9 cents per quart. The consolidation of all milk distribution in a single public or private agency would bring important additional savings in plant costs so that total distribution costs might be reduced 2.3 to 4.0 cents per quart. Total costs under such a system would be about half as high as characterized daily delivery under the . . . system [of competition he observed] [9, p. 340].

We did not investigate scale economies at two other possible levels: that of the station and that of the entire POD. Economies of scale in the POD bear on whether there should be competition or monopoly in the provision of postal services and whether decreasing costs coupled with marginal cost pricing require a subsidy to the POD to cover total costs. I believe that there exist economies of scale at the level of the POD and that therefore the Post Office should remain a monopoly.

This is not to say that the status quo is the best policy. While the Post Office should be a monopoly, it need not be in the government. Between 1953 and 1962 output per man-hour increased at an average rate of one-third of one percent, while the average rate of increase in four federal government organizations studied was 3.9 percent per year [21, p. 14], and the average rate of increase in the economy as a whole was 2.9 percent per year [21a, p. 97, Table 17]. Postal production is not different; it is amenable to technological change. If the Post Office were outside the federal government, while yet a monopoly, I believe it would perform better. It would be able to finance a rational capital expansion program, to choose factor proportions without the likely biases of congressmen and to set its own rates under the purview of a regulatory commission.

Factor prices are important in accounting for the different costs experienced at different offices. The outputs an office produces affect costs as well and the mix of mail differs considerably from office to office. Outputs are not produced in (even roughly) fixed proportions so that our contention that multiproduction rather than joint production characterizes post offices is supported. Not all outputs affect costs as regularly as we might expect. Third-class mail and parcels appear to be less costly than other studies and laymen's conversation would indicate.

Costly offices were identified as well as those which did not experience high costs relative to the mix of mail they faced. Costly offices were generally in cities with high factor prices: large cities not in the Southeast. Extra post-office costliness was only slightly related to factor prices.

Extra costs were significantly influenced by degree days, thus modifying the Post Office motto "Neither snow, nor rain, nor heat, nor gloom of night, stays these couriers from the swift completion of their appointed rounds."[1]

Since factor prices play such a crucial role in postal costs we created "adjusted" indices of intra post-office costliness which adjusted for varying factor prices.

Analyses of variance by postal regions indicated significant differences among regions on criteria of adjusted costliness. The Northeast and Far West Regions were significantly more costly than the South and Midwest even after accounting for factor prices.

There is no significant difference among regions in input efficiency, suggesting that management efficiency is roughly constant.

The West Coast and Northeast are significantly less productive than the South and interior of the country. My feeling is that this occurs because of inferior inputs and diseconomies of scale.

When recently mechanized offices were compared with offices which had not been involved in recent mechanization there was no significant

[1]Inscription on the Main Post Office, New York City. The original author of these lines never saw a U.S. mail carrier: "The Persian messengers travel with a velocity which nothing human can equal. . . . Neither snow, nor rain, nor heat, nor darkness are permitted to obstruct their speed" [28a].

difference in adjusted total costliness. Thus there is no proof that more mechanization is more efficient. In one case an elaborate system for handling mail had to be scrapped because the post office was better off without it. Not all changes are improvements!

The dummy variable representing geographic location, NEFW, proved to be a significant factor affecting intra post-office costs. The re-estimated cost function including it is:

$$c = \underset{(.51)}{-5.42} + \underset{(.04)}{.52}x_1 + \underset{(.05)}{.40}x_2 + \underset{(.03)}{.04}x_3 + \underset{(.03)}{.11}x_4 + \underset{(.03)}{.06}x_5 - \underset{(.01)}{.01}v_6 + \underset{(.30)}{1.57}W_7$$

$$+ \underset{(.05)}{.12}W_8 - \underset{(.04)}{.02}SC + \underset{(.03)}{.08}NEFW \qquad R^2 = .981 \quad SSE = 3.07$$

Now the returns to scale test statistic, s = 1.12, with a standard error of .015. Real improvement in precision of estimation comes in the stratified sample. Now we have a pattern of increasing returns to scale in small offices, persisting in the medium range and finally decreasing returns in the largest 52 offices. Table X-1 gives results on returns to scale with and without the regional adjustment. That the precision of estimating returns to scale has been improved is shown by the fact that although point estimates of returns to scale have not changed qualitatively, an hypothesis of constant returns to scale could not have been rejected in medium or large offices before the adjustment. With the geographical adjustment we can reject constant returns in favor of decreasing returns in large offices. Thus, with the regional adjustment we have a textbook case of a U-shaped cost curve.

These regional differences in the quality of labor make it advisable to re-estimate marginal costs of the several types of mail using

Table X-1. Returns to scale in post offices.

Group	Without Regional Adjustment[a] s (S.E.)	t	r	Returns	With Regional Adjustment[b] s (S.E.)	t	r	Returns
All	1.106 (.015)	7.1	.905	decreasing	1.122 (.015)	8.0	.892	decreasing
Small	.773 (.095)	-2.4	1.293	increasing	.774 (.093)	-2.4	1.292	increasing
Medium	.857 (.103)	-1.4	1.164	increasing	.918 (.107)	- .8	1.088	increasing
Large	1.045 (.035)	1.3	.957	decreasing	1.082 (.028)	2.9	.924	decreasing

[a]Source: Table V-2 above.

[b]Source: Cost functions estimated January 15 and 18, 1969.

new estimated cost elasticities. This has been done and the estimated marginal costs listed in column 4 of Table VIII-2. Table X-2 shows our best estimates of marginal intra post-office costs of each handling of the several types of output we have defined.

Table X-2. Marginal cost per first-handling piece.

Classification	Cost
First class	$ .0140
Outgoing flats	.0221
Outgoing SPR's	.0418
Incoming flats	.0225
Incoming SPR's	.0303
Third class	.0023
Fourth class	.0703
Window service	32.20 per $1,000

The inclusion of the NEFW considerably improved these estimates in the sense that they agree more now with common sense, especially the cost of handling the mean parcel.

I think it has been shown that production functions are a useful tool for the analysis of public services. On the basis of estimated cost functions remote locations can be ranked on several criteria: costliness, productivity, and input efficiency. The factors responsible for varying performance can be isolated. Those which can be controlled, such as size of office, may be altered. Those which cannot, such as environmental variables, can be taken into account so that units in difficult environments are not unduly penalized.

No significant differences were found in postal management over the country. The Post Office is run uniformly with a high degree of centralization. Not all agents in the public sector are, however. Hospitals, for example, are considerably decentralized, being run by boards of directors composed largely of local medical doctors. In many cases hospitals may be considered to be in the private sector. Given the diversity among hospitals, it would appear fruitful to find efficient hospitals by applying a method such as the one I have used on post offices. A by-product of such a study would be norms for costs for various activities of hospitals analogous to the costs we have derived for types of mail services. These could be very useful to third parties like governments and insurance companies who pay for an increasing share of hospital costs. A study like this has been done on the National Health Service in England by Martin Feldstein [22]. Factor prices do not vary cross-sectionally there because, again, that system is managed nationally. In this country a great service could be done by using cost functions to study hospitals. Efficient producers could be identified and methods of third-party cost reimbursement could be designed which would reward them and thus encourage economic behavior.

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