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FORMULATION AND TESTING OF THE
TARGET RETURN PRICING HYPOTHESIS

by

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Table of Contents

Chapter I

Introduction

For at least thirty years numerous economists have contended that the neoclassical economic theory of the firm provides an inadequate frame of reference for the analysis of price, output, and investment behavior in modern industry.[1] Several of the critics have centered their arguments around interview evidence which is claimed to show that businesses typically set prices according to "full cost" principles rather than in the profit maximizing fashion postulated by neoclassical theory.[2] Supporters of the latter have counterattacked with charges that the critics do not properly understand neoclassical theory and that the evidence cited is unreliable by its nature and, in any case, is consistent with the postulate of profit maximization.[3]

The debate between full cost and neoclassical theorists has periodically burst into print but has apparently failed to settle the issues. This failure has been due in part to a lack of preciseness on the part of the full cost theorists: their hypotheses have not been framed clearly. The failure to reach agreement has also been partially due to the reluctance of many economists to accept as meaningful empirical evidence of the interview type.

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[1] Examples include Baumol [8], Boulding [9], and Cyert and March [13]. It should perhaps be made explicit that we do not refer to the debate over the theory of monopolistic competition which is largely distinct from our concern, the neoclassical vs. "full cost" disagreement.

[2] See Hall and Hitch [27], Andrews [2], and Kaplan, Dirlam, and Lanzillotti [37].

[3] See Machlup [53] and Friedman [23].

This study attempts to advance this debate both by formulating a full cost hypothesis precisely enough to permit statistical testing and by carrying out tests, for two industries, of a type which should be acceptable to most economists.

The target return pricing hypothesis is chosen to represent the more plausible elements of the full cost views. It asserts that sellers of a product charge prices equal to average variable cost at standard output plus a margin designed to yield (at standard output) a certain net rate of return on the firms' assets. It is distinguished from other full cost views by its focus upon costs at standard, as opposed to actual, output rates. One implication of the hypothesis is that commodity price levels are determined by costs alone, with demand conditions playing no direct role. Our statistical test will be based upon this implication.[4]

Many of the full cost proponents have been hostile to the neo-classical profit maximization postulate, and have seemed to suggest that notions of "fair" profit rates are useful in explaining industrial behavior. This study is not sympathetic to such a view. On the contrary it sees the source of target return behavior in attempts by firms in concentrated industries to prevent entry of new rivals.[5] The putative mechanism involves implicit partial collusion designed to keep prices

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[4] One unusual and desirable feature of the statistical testing procedure is that both the hypothesis under test and the alternative possess economic meaning. This is in contrast to the usual case in which the only alternative to a hypothesis is that it is not true. (In much econometric work, in fact, hypotheses are not explicitly stated and the search is simply for "significant" regression coefficients.)

[5] Our empirical test, however, can distinguish only between price behavior consistent with and inconsistent with the target return hypothesis: it cannot show whether behavior consistent with the hypothesis stems from entry prevention or "fair profit" motives.

just barely below the level which will make entry appear profitable. The motive then is not incompatible in spirit with near-maximum "long run profits," i.e., near-maximum net worth. But the proximate goal of preventing entry neither implies, nor is implied by, maximum net worth under all conditions. Whatever its relation to profit maximization, target return pricing should on this view be expected to prevail only in highly concentrated industries.

Most of the theoretical ideas discussed in this study have been proposed by previous writers, though not all by any single writer. While some theoretical clarification is here attempted, it should be stressed that the work is intended primarily as a study in applied econometrics, rather than economic theory. The main products are (1) a well-defined technique for testing the target return hypothesis and (2) empirical applications of the proposed test to the cement and lumber industries. Only two industries are studied because each application requires an extensive amount of data collection and processing while the primary intellectual task lies in the design of the testing procedure. With the latter developed, application to specific industries becomes an arduous but highly programmed undertaking.

The two applications included are nevertheless of considerable importance. The industries were chosen with care so that the empirical results provide something of a test of the testing procedure itself, as well as a test of the target return hypothesis in each case. Specifically, the lumber industry was chosen because its unusually competitive structure implies that target return pricing should not be expected to prevail. The rejection of the hypothesis which in fact occurs in lumber demonstrates the ability of our procedure to detect deviations from target return behavior.

The other application is to the cement industry, one in which target pricing appears more plausible. Cement has an oligopolistic structure and a history of collusive attempts to avoid price competition. Thus a believer in the prevalence of target return type behavior should expect to find it in the cement industry. While our empirical results do not of course show that such behavior does in fact exist, they are highly consistent with the hypothesis.

Development of the testing procedure required excursions which yielded secondary products. These are concerned *inter alia* with the economic theory of optimal inventory holdings and the statistical theory of estimation of nonlinear structural relationships in simultaneous equation systems. In each case the discussion contributes, hopefully, to fuller understanding of the topics.

The outline of the work is as follows. In Chapter 2 the target return hypothesis is stated. Then several of the more significant papers and monographs promoting or attacking "full cost" views are reviewed in order to see how the ideas have developed. Criticism and synthesis of the writings is attempted. Implications of the resulting theory of importance for both recognition and evaluation of target return behavior are briefly discussed. Finally a review of the major relevant statistical studies is presented.

Chapter 3 is devoted to formulation and explanation of the statistical version of the hypothesis. Also the nature of the alternative hypothesis is explored. Examination of the interrelationships of various variables indicates that the parameters of a demand function should be estimated simultaneously with the pricing equation. A rather generalized demand function, suitable for the purpose, is accordingly specified.

One of the explanatory variables in the target return pricing equation is manhours usage at standard output. This variable is not directly observable but its values can be "predicted" on the basis of a function which describes labor usage in a target return pricing industry. Such a behavioral function is then developed in Chapter 4 together with an equation designed to describe output or inventory behavior. The relationships adopted are modified generalizations of ones used in recent econometric studies.

In Chapter 5 the stochastic assumptions underlying the testing procedure are specified and problems concerning statistical testing-estimation are raised. The presence of parameter nonlinearity in the crucial pricing equation implies that non-standard estimation techniques should be utilized. The technique chosen is a version of the two-stage least squares method, modified to take account of the nonlinearity. A discussion of this procedure is necessary since no published version exists; most of this discussion is, however, reserved for Appendix C.

The data utilized in the empirical applications is presented and its sources discussed in Chapter 6. In addition, brief descriptions of the structural characteristics of the lumber and cement industries are included.

Numerical estimates of parameters of the various behavioral equations are given and discussed in Chapter 7. Results (of the two versions) of the statistical test of the target return hypothesis are presented in some detail. The results are strong, i.e., not borderline, in each case.

Chapter 8 contains a brief summary of the study, a very brief discussion of its conclusions, and a few suggestions for further research.

Five appendices conclude the dissertation. These contain explorations of particular topics which are important but somewhat technical. Appendix A is a lengthy theoretical development of one element of the output model of Chapter 4. Appendices B and C are concerned with statistical estimation in single-equation and multiple-equation models which are nonlinear in the parameters. In the latter the nonlinear TSLS procedure is explained more completely than in Chapter 5 and an argument is developed showing that its parameter estimators possess the desirable property of consistency. Appendices D and E discuss the treatment of seasonality and the effects of including "extra" variables in regression studies.

Notational conventions are as follows. Chapters 2-8 each consist of sections which are numbered serially within each chapter (e.g., Sections 2.1, 2.2, ..., 2.4). Some sections are divided into subsections which are numbered serially within each section (e.g., Subsections 2.2.1, 2.2.2, ..., 2.2.10). Equations are referred to by numbers which occur serially within each chapter. Not all equations are numbered. Tables and figures are given Roman numbers. They are each numbered serially. References to the books and articles of the bibliography is by the placement of the reference number in a square bracket. Usually the author's name will be used (e.g., Malinvaud [55]).

Chapter 2

The Hypothesis and its Development

2.1 Introduction

Chapter 1 presented a brief statement of the target return pricing hypothesis; this chapter elaborates on that statement. It begins in Section 2.2, however, with a review of some of the important writings which have contributed to the development of the hypothesis. Section 2.3 then presents our version of the hypothesis, discusses some issues which arise, and points to significant implications. Finally Section 2.4 is devoted to criticism of existing statistical studies which bear on our topic.

2.2 Survey of Previous Writings

2.2.1 Introduction

The survey of this section is intended as a straightforward historical review, criticism and synthesis being reserved for the following section. Only a small number of the more important writings on "full cost"[1] pricing are surveyed. As the American Economic Association's Index of Economic Journals lists 48 entries under "Full Cost Pricing" (2.1334), complete coverage would be impractical, especially since many more relevant articles appear under other captions such as "Price Flexibility", "Profit Maximization and Business Behavior", and "Oligopoly [and] Bilateral Monopoly." The selections explicitly covered include some items critical of full cost theories since these have played an important role in the development of the version of the hypothesis which appears most plausible. The author's comments on certain points are inserted to smooth the transition between selections.

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[1] We shall use this as a generic term referring to any average cost pricing hypothesis which ignores demand influences because of its early use by Hall and Hitch [27] and its adoption by the A.E.A.'s Index of Economic Journals. Target return pricing is a special case of full cost pricing.

2.2.2 Hall and Hitch (1939)

The discussion began with the famous 1939 article of R.L. Hall and C.J. Hitch [27] who reported on findings of an Oxford University research group which interviewed British businessmen. The Oxford group was struck by the businessmen's ignorance of marginal cost and revenue functions and by their insistence that prices were based on average costs (including fixed costs) plus a conventional allowance for "profit". Hall and Hitch summarized their findings as follows [27, pp. 32-3]:

> (i) A large proportion of businesses make no attempt to equate marginal revenue and marginal cost in the sense in which economists have asserted that this is typical behavior.
>
> (ii) An element of oligopoly is extremely common in markets for manufactured products; most businesses take into account in their pricing the probable reaction of competitors and potential competitors to their prices.
>
> (iii) Where this element of oligopoly is present, and in many cases where it is absent, there is a strong tendency among businessmen to fix prices directly at a level which they regard as their "full cost".
>
> (iv) Prices so fixed have a tendency to be stable. They will be changed if there is a significant change in wage or raw material costs, but not in response to moderate or temporary shifts in demand.
>
> (v) There is usually some element in the prices ruling at any time which can only be explained in the light of the history of the industry.

2.2.3 Machlup (1946)

An early and constructive criticism was provided by Machlup in his well-known article "Marginal Analysis and Empirical Research" [53]. Machlup argued that little if any of the evidence presented by Hall and Hitch was necessarily inconsistent with profit maximization or marginalist behavior, especially if long term considerations were taken into account. "Do these findings support the theory of the average-cost principle of pricing? I submit that they give little or no support to it. The margins above average cost are different from firm to firm and, within firms, from period to period and from product to product. These differences and variations strongly suggest that the firms consult other data besides or instead of their average costs" [53, p. 545]. He went on to argue that the evidence positively suggested that businessmen did pay attention to demand elasticity. Also he pointed out that full cost pricing could serve as a useful device for effecting implicit collusion [53, pp. 542-3].[2]

2.2.4 Comment

On the basis of these two articles alone one could have formulated a proposition that full cost pricing of some sort would occur in certain markets in which this form of implicit collusion might be profitable. Such a proposition was not formulated, however. One disturbing aspect

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[2] Machlup also stressed the elementary point that ignorance of marginal cost and revenue schedules does not invalidate the marginalist theory which requires only a striving by businesses for maximum profits.

of this sort of view might have been the apparent implication that prices would fall during cyclical expansions and rise during contractions. Price movements of this sort, which are of course inconsistent with empirical evidence, would be implied by full cost price formulas if (a) actual current costs were considered the relevant ones and (b) average costs were higher for low levels of output than for high, a situation believed to exist by many economists. The next step in the development of the target return hypothesis was the specification that costs evaluated (hypothetically) at "standard", rather than actual, output rates were the basis for price determination.

2.2.5 Andrews (1949)

An early expression of the idea of basing a full cost price on standard average cost appeared in P.W.S. Andrews' Manufacturing Business [2], a book representing "... an attempt to re-write the theory of pricing in the light of inquiries which the author has conducted into the behavior of manufacturing firms" [71, p. 771]. The standard cost notions can be seen in Andrews' summary of his pricing theory: "...the price ... will equal the estimated direct costs of production plus a costing margin ... [which] will tend to remain at a constant level, whatever the output which is being produced, given the prices of the direct-cost factors of production ...; [also]... the costing-margin will normally tend to cover the costs of the indirect factors of production and provide a normal level of net profit ... but will remain constant, given the organization of the individual business, whatever the level of its output; ... [and] given the prices of the direct factors of production, price will tend to remain unchanged, whatever the level of output" [2, p. 184].

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Andrews' full statement does not follow the current standard cost formulation exactly. The discrepancy arises from his view that average variable cost is typically constant over the whole range of output levels (up to some capacity limit). Thus his elaboration of the standard cost idea refers only to the spreading of fixed costs over the "budgeted" output: "If output falls, the businessman will not revise his prices so as to charge a higher allowance for average overheads -- that would be absurd, as causing the charging of a higher price in a falling market. In such cases, then, he will continue to make the same costing allowance for average overheads, and will get a price which would have come out right only if he, in fact, had got his budgeted output" [2, p. 164].

2.2.6 Robinson (1950)

E.A.G. Robinson's review article [71] criticized Manufacturing Business on several grounds. For one thing, the book apparently intended to present a theory applicable to all manufacturing on the basis of a detailed empirical study of only two industries. Also the theory was apparently designed to replace standard neoclassical views. Yet, as Robinson says, may not the behavior described by Andrews be a "reasonable account of rational action for long-term profit maximization in industries possessing certain characteristics?" [71, p. 774]. Indeed Andrews failed to indicate how the type of behavior he postulated is inconsistent with net worth maximization. Also, as Robinson noted, Andrews did not publish the empirical basis for his generalizations.

2.2.7 Kaplan, Dirlam, and Lanzillotti (1958)

A major study of pricing in 20 large American businesses, sponsored by the Brookings Institution, was authored in 1958 by Kaplan, Dirlam, and Lanzillotti [37]. The study utilized questionnaires and corporate memoranda but relied principally upon lengthy interviews with corporate officials, followed up with a second set of interviews several years later.

A useful distillation of the study findings concerning pricing objectives was provided by Lanzillotti [45]. Conclusions from his summary of 20 case studies are difficult to draw, but some points can be made. Lanzillotti apparently believed that cost-oriented pricing was widespread in American manufacturing and that the neoclassical profit maximization assumption was thus an inappropriate building block in economic analysis: "... no single motivational hypothesis such as profit maximization ... will provide a satisfactory basis for valid and useful predictions of price behavior" [45, pp. 938-9]. The profit maximization assumption, in his view, was also undermined by managers' tendencies to think of their firms as "... part of a socially integrated group, with responsibilities for the whole pipeline ..." [45, p. 936] and by the tendency of target return minded companies "... to behave more and more like public utilities" [45, p. 940].

In the process of summarizing the findings of the Brookings study, Lanzillotti produced a rather clear statement of target return pricing and its standard cost basis: "Under this pricing system both costs and profit goals are based not upon the volume level which is necessarily expected over a short period, but rather on standard volume; and the margins added to standard costs are designed to produce the target profit rate on investment, assuming standard volume to be the long-run average rate of plant utilization" [45, p. 923]. The Kaplan, Dirlam, and Lanzillotti volume linked the standard cost notion to accounting practices [37, p. 14-15].

2.2.8 Kahn (1959)

Kahn assailed Lanzillotti (and his colleagues) severely, claiming that, contrary to Lanzillotti's conclusions, the Brookings evidence "lends support to [the]... conclusion: that these large corporations typically price to maximize monetary profits--not day-to-day, to be sure, but to a large extent year-by-year and certainly over a fairly brief period of years" [36, p. 671]. His argument was based on (1) "the differences between the targets set by the various companies," (2) "...the widely varying investment-return components of these companies' prices on different products," and (3) "...the divergencies of actual company returns from their respective targets-- above it for extended periods of time, where the market permits, below it where the market requires" [36, p. 671-3]. Kahn also mentioned the important distinction between procedures and goals.

Lanzillotti, in his reply, capitulated on the "public utilities" analogy [46, p. 686] but did not commit a general surrender. He suggested that Kahn's version of the profit maximization hypothesis (over a fairly brief period of years) was imprecise, and that "... whatever profits maximization may be construed to mean, it does not prove helpful in understanding pricing policies of large corporations" [46, p. 682]. He also said that, "... while Kahn is correct in stating that the subject of my article is pricing objectives and not procedures, objectives and procedures are very closely interrelated, and in some companies, in fact, procedures to a large extent determine price policy" [46, p. 684]. He claimed, "... the essential strength of the target-return thesis is that it has a much higher degree of plausibility and realism in a world where large firms have (a) such strong asset positions; (b) limited knowledge ... (c) wide diversity of product lines ...; (d) uncertainty ...; plus (e) strongly entrenched market position, with all this entails by way of oligopolistic interdependence, antitrust pressures, and Congressional inquiry. Under these circumstances the short-run price will, I believe, be determined by some feasible long-run objective such as a predetermined target rate of return on invested capital and/or target market share" [46, p. 685].

2.2.9 Sylos-Modigliani (1957-58)

One obvious weakness of the cost oriented pricing theories mentioned thus far is their failure to explain the level of the profit margin which is supposedly added to standard cost. This omission is not adequately remedied by vague references to "long run profit maximization." Sylos addressed himself to this question in a 1957 monograph [81]. His analysis was not only presented to the English reading audience but also further developed by Modigliani in a well-known article [62].[3]

[3] Modigliani also discussed the influential analysis of Bain [6]. While Bain apparently developed the theory of entry-preventing or "limit" pricing before Sylos, we here focus attention upon Sylos and Modigliani because (unlike Bain) these writers showed explicitly how the analysis ties in with full cost pricing [81, pp. 57-61] [62, pp. 225-6].

The main relevant proposition of the Sylos-Modigliani analysis is that in an oligopoly the price will tend to be just below the lowest level that will attract entry of new firms. The motivation is clear; the fewer the firms, the larger the possible monopoly returns for each. As Modigliani stressed, however, the above idea alone does not lead to a clearly defined price because it depends upon the beliefs of possible entrants concerning the response of existing firms to entry attempts. A well defined price does emerge, though, under "Sylos' postulate": potential entrants behave as though they expected existing firms to adopt "... the policy of maintaining output while reducing the price (or accepting reductions) to the extent required to enforce such an output policy" [62, p. 217].

With this assumption,[4] it is possible to specify a well-defined price, above the competitive level, which the oligopolists can charge without attracting new firms. The discrepancy between this entry-preventing price and the competitive equilibrium price is positively related to the "strength" of economies of scale and inversely related to market demand elasticity and the number of firms which would remain in the industry if price were held at its competitive level.

Modigliani introduced a graph which illustrates the ideas very simply. (It is slightly modified here). Let D in Figure I be the market demand curve and LAC be the long run average cost curve for a

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[4]The assumption is admittedly complex. It concerns belief by existing firms about potential entrants' beliefs about behavior of existing firms. But in highly concentrated industries it seems likely a priori that managers of existing firms would in fact engage in such speculation. In any case, the appropriate way to test the theory is to compare its predictions with reality.

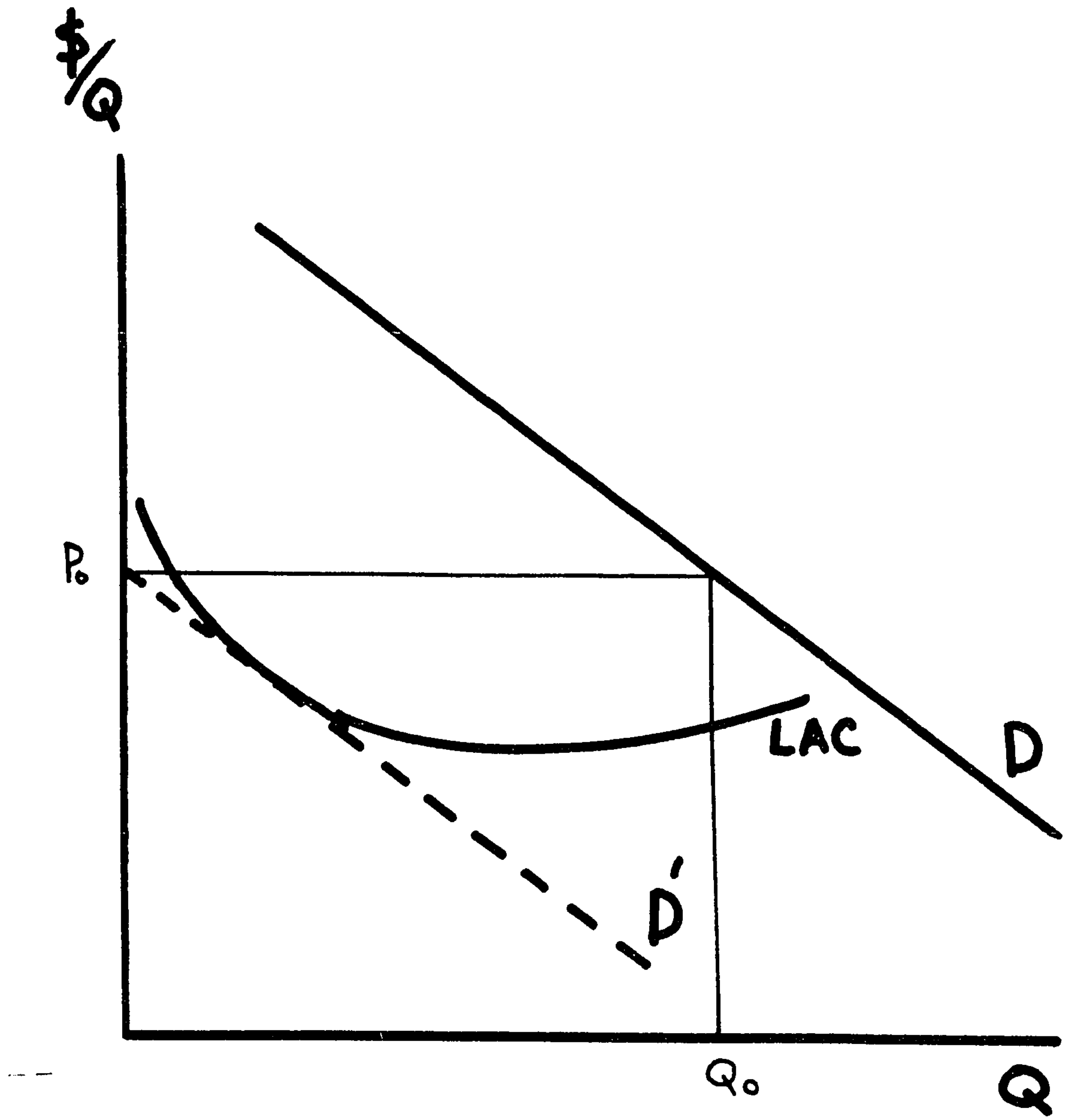

Figure I

potential entrant. If the existing firms together produce Q_o and the market price is P_o, then under Sylos' Postulate it will not pay to enter, for if these firms maintain a joint output of Q_o in response to entry, the new firm will face the residual demand curve D', which is obtained by sliding D to the left until it is tangent to LAC. Thus the new firm can earn no excess profits and will have no incentive to enter if the price is P_o or slightly lower.

A crucial point to note is that if the market demand curve D shifts out or in, the entry preventing price P_o will not change. If D tilts or is not linear then there will be some change in P_o, but usually very little. If technology or factor prices alter, however, LAC will move up or down and so will P_o. While it is obvious that P_o will usually not change by <u>precisely</u> the same fraction as the standard average costs of the existing firms, it is equally obvious that a constant fraction markup rule would permit oligopolists facing roughly the same factor prices and technology to keep their prices very close to P_o while costs change, without any explicit collusion taking place. Changes in demand would leave unchanged the prices of markup or target return pricers, just as the latter would desire if their immediate goal were to prevent entry at the highest possible price.[5]

Thus the Sylos-Modigliani analysis ties full cost pricing to the objective of preventing entry and thereby "explains" the level of the

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[5]Similar results, in a rather different setting, are obtained by Henderson [31],p. 576-9].

markup figure which is adopted by full cost pricers. Should behavior of this type be considered as designed to maximize profits? Sylos himself says "The object is to maximize profits in the long run ..." [81], p. 83]. This issue is somewhat controversial and will be left for a fairly lengthy treatment in Subsection 2.3.2.

2.2.10 Eckstein (1964)

In 1964 Eckstein presented "A Theory of the Wage-Price Process in Modern Industry" [18] containing an algebraic formulation of a target-return pricing formula which specifies clearly a standard cost concept and which is of a form suitable as a basis for econometric investigations. His statement is as follows: "Target-return pricing calls for a price sufficient to earn the company its target rate of return on capital when it operates at its standard rate of operation. It can be expressed formally:

$$(1) \qquad p = \frac{\bar{\pi} K}{\bar{x}} + w \frac{L(\bar{x})}{\bar{x}} + m, \text{ where}$$

P is product price, $\bar{\pi}$ is the target rate of return, $\bar{x}$ is the standard rate of output, and m is the unit material cost" [18, p. 269]. Also K is capital stock and $L(\bar{x})$ is labor usage at standard output.

It should perhaps be mentioned that Eckstein's definition of standard cost may not correspond exactly to the accounting definition. While there is doubtless no unique version of accounting standard cost, if $\bar{w}$ were a standard wage, then $\bar{w}L(\bar{x})$ would probably be more widely accepted by accountants as a "standard" labor cost than would $\bar{w}L(\bar{x})$.[6]

Eckstein also presents a model, developed earlier with T. Wilson [86], of labor usage which can serve as an operational basis for standard labor cost determination (see Chapter 4 below) and he usefully contrasts target return with "crude full-cost" pricing: "Target return pricing differs from crude full-cost (or cost-plus) pricing by relating price not to actual cost but to standard cost. Given the behavior of productivity, actual costs fall as output rises over the cycle, and full-cost pricing would thus require that prices be lowered with rising prosperity and increased with falling prosperity. This clearly flies in the face of all evidence" [18, p. 269].

Although he provided several useful insights and discussed target return pricing behavior at length, Eckstein did not formulate a testable hypothesis concerning the latter. In fact his final theory rendered the notion virtually irrefutable (empty) as an empirical proposition by making price changes dependent upon two "mechanisms," target return behavior and "... the more competitive demand elements..." [18, p. 270]. It is difficult to see how a "combination of the two mechanisms" could be operationally distinguished from purely marginalist behavior without much more refined empirical procedures than are presently available to the economist.

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[6] The total "variance," $wL(x) - \bar{w}L(\bar{x})$, between actual and standard labor costs would usually be split into a "price variance," $(\bar{w}-w)L(x)$, and an "efficiency variance," $\bar{w}[L(\bar{x})-L(x)]$, presumably for the purpose of evaluating operating performance. See, e.g., Anthony [3, pp. 373, 408-9].

2.3 Formulation of the Target Return Hypothesis

2.3.1 Statement and Discussion

We now turn to consideration of our version of the target return pricing hypothesis which we shall specify and discuss in this section. The statement of the hypothesis is as follows. The sellers of a particular product in a highly concentrated industry charge prices equal to average variable cost at standard output plus a margin designed to yield (net) a target rate of return on the firms' assets, this rate remaining constant over time. Standard output is a constant fraction of productive capacity. The target rate of return figure, r, is the highest which in the view of existing firms can be obtained, given demand and cost conditions, without attracting new firms into the industry. This mode of behavior, which amounts to implicit collusion, is adopted (perhaps unconsciously) by the firms of the industry to avoid price competition which is attractive to each individually but which leads to undesirable results for them when pursued by all.

Our version of the hypothesis represents a synthesis of several of the ideas surveyed in the previous section. The particular choice of features is intended to yield a hypothesis which is in keeping with the spirit of full cost views yet which possesses some plausibility and also yields implications differing from neoclassical hypotheses. The origins of some of the ingredients chosen are as follows. The general full cost principle itself stems from Hall and Hitch. We incorporate the standard cost aspect, developed mainly by Andrews, Lanzillotti, and Eckstein, in order to avoid the implication of countercyclical price movements. The view of full cost pricing as a form of implicit collusion, suggested by Machlup, is accepted as useful even if the firms do not explicitly think in terms of collusion. Finally we feel that the Sylos-Modigliani explanation of the target return margin, as the one which will just exclude entry, is an important possibility. It accordingly appears in our statement of the hypothesis. Yet, as we will discuss below, our test for the presence of target return pricing in a given industry does not depend upon the validity of this particular feature.

We now turn to discussion of several issues raised by our statement. The reader will note that the hypothesis asserts that target return pricing will prevail in highly concentrated industries, not in all industries. Thus it should be considered not as a rival to the theory of competitive markets, but as a complementary theory designed to provide better explanation and prediction in industries where structures are far from competitive. Most full cost adherents (including Sylos and Modigliani) have apparently intended their analyses for oligopolies. But it should be equally applicable to a monopolist which wishes to remain a monopolist.[7,8] The essential features of the analysis are (1) a small enough number of firms such that at least some of them are not price takers, (2) the technical possibility of entry by more firms, and (3) the existence of economies of scale. These features combine to make entry-preventing pricing attractive. The latter is not attractive where entry of new firms is infeasible

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[7] Entry-preventing or "limit" pricing has been hypothesized for both monopolies and collusive oligopolies by Bain [5].

[8] Two passages in the textbook by Weiss [84] are of interest here. On pages 189-90 Weiss quotes a past president of the "classic monopoly,

due to patents, scarce resources, or other strict barriers. Target return pricing might occur in such industries (which are few in number) but it is not predicted by the Sylos-Modigliani line of reasoning.

Since the highest rate of return which will fail to attract entry depends in magnitude upon demand and cost conditions, our version of the hypothesis does not suggest that target return rates should be the same for all products or for all sellers of a given product. With respect to multiproduct firms, further, the hypothesis does not suggest that the target rate should be the same for all products sold by a particular firm. Thus the penetrating comments of Robinson [71, p. 776] and Kahn [36, pp. 671-2] are not damaging to the version of the hypothesis which we are considering. Also it is apparent that cost differences among firms in an industry should not seriously hamper the workings of the target return scheme of implicit collusion.[9]

Various proponents of full cost views have claimed that short run marginal and average variable cost curves are horizontal, i.e., that these costs are independent of output rates. In particular, Andrews [2] and Sylos [81, pp. 26-32] have assumed that cost curves are of this type. In our view this assumption is unnecessary to the argument and therefore objectionable. The entry-preventing price is

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8,cont'd) Alcoa, as testifying that Alcoa priced in a target return fashion. On pages 200-4 Weiss shows that Alcoa's profit levels during 1920-40 were below those which would be expected on the basis of its market power and the expanding demand for aluminum.

[9] The nature of the hypothesis is such that costs are defined to include "normal profits."

determined by the position and shape of the residual demand curve D' and the long run average cost curve LAC as in Figure I above. Then the standard cost notion provides the needed link between long run average cost and (short run) average variable cost. For a given plant a firm will have standard and capacity output rates as shown by Q^s and C in Figure II. SAC is the short run average cost curve and AVC the average variable cost curve. Suppose P^s is the entry-preventing price. Then the target rate of return r is determined by the relation

$$(2) \qquad P^s = r K^s + AVC^s ,$$

where K^s is the value of assets divided by Q^s and AVC^s is average variable cost evaluated at Q^s. Actual AVC levels, which may vary with output rates, do not appear in the target return formula (2). Thus the assumption that AVC is flat is unnecessary.

The hypothetical pricing process works as follows. The firms in a given industry determine, from their knowledge of demand and cost conditions and also perhaps by trial and error, a price P^s which will just prevent entry of new firms. Then they determine the rate of return r which satisfies (2) given P^s and their costs.[10] Having once determined the target rate r, they treat it as a long-term constant and in future periods calculate the prices to be charged from (2), using r and costs.[11] If variable costs rise then the formula will

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[10] As mentioned above, r may vary from firm to firm.

[11] Of course, the fruitfulness of this hypothesis does not depend upon whether firms actually follow such procedures any more than the fruitfulness of standard neoclassical analysis depends upon firms actually calculating marginal cost and revenue curves.

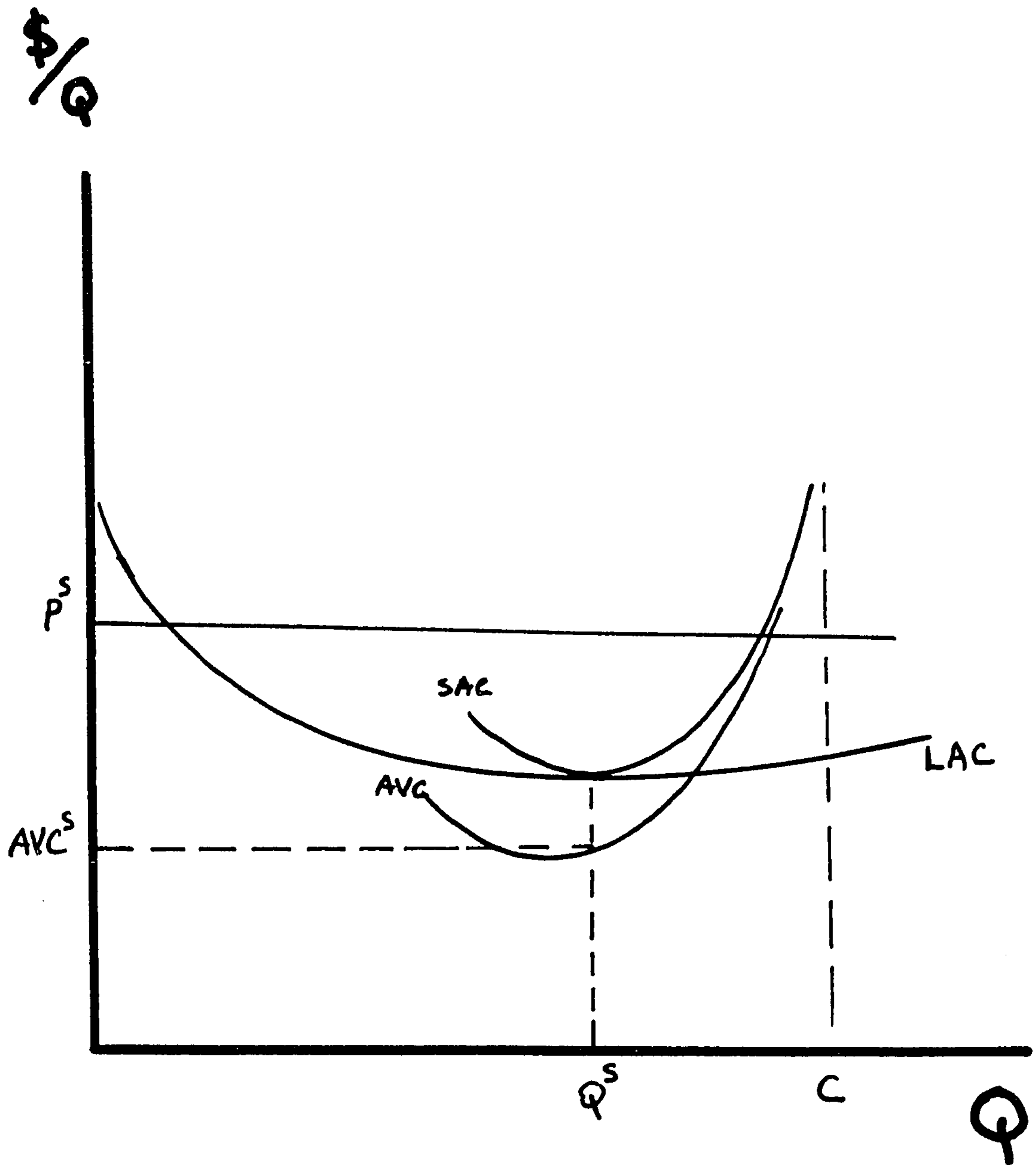

Figure II

call for a price increase, and so on. As discussed above in Subsection 2.2.9, this process will lead to approximate attainment of the entry-preventing price at all times.

A comment may be in order concerning our assumption as to the behavior of the target rate r over the business cycle. Most full cost theorists have held that r (or its counterpart in "markup" formulations) will vary somewhat over the cycle: see, for instance, Sylos [81, pp.67-74] and Hall and Hitch [27, p. 19]. Our formulation, however, specifies that r is strictly constant over time. We adopt this more stringent requirement to insure that an operational version of the hypothesis can be formulated. Permitting variations of r over time would open the door to all sorts of price movements and would tend to make the hypothesis irrefutable and thus devoid of operational meaningfulness [73].[12]

In this context it should be noted that some business executives have claimed that their corporations base prices on target return (or markup) formulas but that their actual prices may differ from the formula levels because of "competition" or "market conditions".[13] In our view this sort of behavior should not be considered target return pricing, for appropriate deviations from formula levels could produce instantaneous profit maximizing price levels. The essence of the target return notion is intentional abstention from price changes which, due to shifts in

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[12] Occasional discrete shifts in r might be considered by some economists to be consistent with target return behavior. If this viewwere accepted then the hypothesis should be expanded to predict conditions under which such shifts would occur. As the author knows of no compelling reasons why discrete shifts in r should have occurred in cement or lumber during the period 1948-64, strict constancy is assumed in the empirical work reported in Chapter 7.

[13] See Weiss [84, p. 355] and Hall and Hitch [27, pp. 25-27].

demand, would apparently be profitable in the short run but would tend to induce entry or price rivalry among existing firms. It is for this reason that we require a constant target rate r in our formulation; that requirement assures us that our formula will not "predict" prices which would maximize short run profits (except by sheer accident).

A question could arise as to the base for the rate of return used in the target return formula (2): should the base be total assets (as in our statement of the hypothesis) or net worth? Chamberlain, who believes target return pricing to be widespread,[14] has discussed this question [11, pp. 55-65]. He states that "...return on net worth is more in keeping with traditional economic assumptions of profit maximizing, but [that in practice] return on total assets seems to be the measure preferred by a number of major business firms" [11, p. 65]. For our purpose the latter criterion would seem to be more important, since we are concerned with actual business behavior. In addition Stigler has argued that the total asset base has advantages even from the point of view of neoclassical theory [79, pp. 123-5]. We shall therefore adopt the total asset base. Since conclusions from our empirical studies depend only on the constancy of the target rate, and not its level, they should be relatively insensitive to the choice of base.

We should perhaps call attention to the important role played by economies of scale in versions of the target return hypothesis which are based on the Sylos-Modigliani reasoning. In Figure I it can readily be

[14]"In general, then, price policy is designed to set the general level of company prices at a sufficient margin over costs, at an assumed volume of sales, to yield that profit which the target calls for" [11, p. 191].

seen that a horizontal LAC curve would not define an entry-preventing price above the LAC level.[15] Thus economies of scale must exist, at least for low output rates, or entry of new firms will take place and drive the price down to the competitive level. Furthermore it would appear that these economies must be of such a magnitude that a few firms could produce, at the minimum possible cost, the entire market output, for with larger numbers of firms collusion (implicit as well as explicit) is more difficult to maintain. Do Bain's findings "...that the most important barrier to entry ... is probably product differentiation..." [6, p. 216] rather than economies of scale in production, then imply that entry-preventing pricing is not of widespread importance? The answer would seem to be no, for both Sylos [81, p. 53-6] and Modigliani [62, p. 232] have pointed out that economies of scale <u>in marketing</u>, which are significant, have the same type of effect as economies in production.

One aspect of the price behavior hypothesized for concentrated industries has not yet been discussed: why do prices not tend to levels <u>below</u> those which will prevent entry? While the Sylos-Modigliani reasoning shows how target return pricing could be an effective instrument for implicit collusion, one that keeps prices down to entry-preventing levels, it does not discuss forces which would keep individual firms from deviating from this sort of cooperative behavior. It does not show, that is, why firms do not cut prices slightly in attempts to improve their profit positions at the expense of the other existing firms in the industry.

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[15] But if the (flat) LAC curve were higher for the potential entrant, entry would leave existing firms with above-normal profits.

The forces at work can be conveniently represented, for a duopoly, in terms of the well known "Prisoner's Dilemma" of game theory. Representation of duopoly behavior in terms of two-person games has become rather standard textbook fare. If the two strategies open to each player are "hold the price" and "cut the price" then the (profit) payoff matrix is of the Prisoner's Dilemma type. For an analysis which utilizes this formulation and extends it to more than two players, the reader is referred to Nutter [68].[16] The n-person generalization of the Prisoner's Dilemma is discussed more formally by Weil [83].

Let us refer to the two strategies mentioned above as cooperative and non-cooperative, respectively. If a Prisoner's Dilemma game is played only once, the non-cooperative (price cutting) strategy is dominant and is therefore likely to be chosen by both players.[17] But a duopoly model must recognize that the "game" is not played once but is repeated indefinitely. In such cases the conclusion is reversed: if the Prisoner's Dilemma game is repeated numerous times the cooperative (hold the price) outcome is likely. This has been shown using mathematical analysis for the case of indefinitely repeated games with discounted payoffs, and also for repeated games of an unknown number.[18]

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[16] It should be noted that Nutter does not conclude that implicit collusion is likely.

[17] See Luce and Raiffa [52, p. 94-6].

[18] See Luce and Raiffa [52, p. 102].

In addition, there is experimental, as opposed to theoretical, evidence that a large fraction of players choose the cooperative strategy in repeated plays even when the finite number is known.[19]

Lave has related the implicit collusion tendency to a measure of the attractiveness of collusion, formed in terms of the specific entries in the payoff matrix [48]. His results appear to be consistent with the widely held belief that oligopolists are more likely to rule out price competition than, say, competition by means of advertising.

In this subsection we have stated our version of the target return hypothesis and have discussed issues concerning both its nature and its range of applicability. Hopefully this discussion has convinced the reader that the hypothesis is not inconsistent with what little is known about price behavior in concentrated industries and that the hypothesis is thus worthy of empirical testing. Implications of the model, one of which suggests a method of testing, will be pointed out in 2.3.3. But before considering implications we feel compelled to discuss a question which has apparently produced considerable disagreement among economists: is target return pricing inconsistent with the profit maximizing postulate of the neoclassical theory of the firm?

2.3.2 Full Cost Pricing and "Long Run Profit Maximization"

A recurrent theme in the full cost pricing debate is disagreement over the relation between full cost[20] pricing and profit maximization. The line of disagreement does not find full cost advocates on one side

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[19] See Lave [47] and Rapoport and Chammah [70].

[20] The comments of this section refer to all variants of full cost pricing, including target return pricing.

and critics on the other. In the process of proclaiming the prevalence of full cost pricing, Hall and Hitch [27, p. 18-22] and Lanzillotti [45, p. 938-9] also attacked the profit maximizing assumption. Sylos, on the other hand, claimed that "... the object [of full cost pricing] is to maximize profits in the long run ..." [81, p. 83]. It thus appears desirable that we comment on this question.

The notion behind Sylos' assertion is that the prevention of entry may maximize the net worth[21] of the existing firms, taken in the aggregate. But as Bain has shown, such is not always the case: the expected price after entry could be so close to the entry-preventing price that it would pay existing firms to charge higher prices as long as possible [5]. Another case in which prevention of entry does not maximize net worth of existing firms is when the entry-preventing output (Q_o in Figure I) is not divided among firms in a manner which minimizes total costs. Modigliani [62, p. 221-2] has recognized this possibility. Finally, even if net worth is maximized for the aggregate of existing firms, each firm could only in a limited sense be said to be maximizing its profits. Thus while full cost pricing could in certain circumstances imply behavior which would lead to net worth maximization, and while the spirit of entry prevention has something in common with that of maximum income, we must conclude that there exists no clear link between full

[21] The term "long run profits" is unfortunate as it suggests that a firm with an objective of maximum "long run" profits would charge, at each point in time, the price which would maximize profits in a long run equilibrium situation; such is of course not the case. Stigler declares the objective is "... maximizing the present value of the firm" [78, p. 149], i.e., the discounted value of future net income. We shall use the term "net worth maximization."

cost pricing and "long run" profit maximization.[22]

It should be stressed that our position results from the above reasoning and not from the claims of Lanzillotti or Hall and Hitch. We tend to agree with Kahn [36] that these writers may have placed too much emphasis on pricing policies, objectives, and/or procedures. These are the concern of the managerial economist or business advisor. Economists generally are concerned with market prices and quantities, and thus with firms' internal operations only so far as necessary for the explanation of market phenomena. The views of Friedman [23] and Machlup [54] on this point are well known. But it is perhaps not as widely recognized that this view is also held by economists who contend strongly that study of internal operations is in fact needed.[23] There is room for disagreement as to whether knowledge of firms' pricing policies, etc., is necessary for prediction of market price responses to external stimuli. But economists such as Hall and Hitch and Lanzillotti, who are concerned with public rather than business policy, have notdemonstrated that the conventional profit maximization assumption fails to explain adequately actual patterns of resource allocation and market prices. The discussion of the next subsection will touch upon this matter.

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[22] This conclusion is perhaps not accurate with respect to Sylos. His discussion [81, p. 41-50] of equilibrium attainment utilizes profit comparisons as the ultimate criterion. But his discussion relies upon specific numerical examples which cannot be generalized. In modigliani's treatment, which we adopt because of its generality, entry prevention is itself the final criterion.

[23] Cyert and March, for example, have stated clearly that the conventional theory of the firm "... is primarily a theory of markets [which] purports to explain at a general level the way resources are allocated by a price system" [13, p. 15].

2.3.3 Implications of the Hypothesis

The above discussion concerning the relation between full cost pricing and net worth (or "long run" profit) maximization is primarily of doctrinal interest. But the relation between our version of the target return hypothesis and short run profit maximization is more crucial. As net worth maximization is not a concept easily made operational, the neoclassical theory in practice relies upon short run profit maximization as the basis for prediction of price movements. In particular, neoclassical theorists utilize almost exclusively models of short run profit maximization under conditions of pure competition or pure monopoly in their applied price analysis.[24] Thus target return pricing should be treated as a distinct hypothesis concerning price behavior if and only if its implications differ from those of competitive or monopoly pricing models which assume maximization of short run profits.

It is immediately apparent from our equation (2) that the target return hypothesis does in fact imply price behavior different from the neoclassical models. This equation contains no reference to demand conditions; it thus implies that demand changes affect prices only through their effects on standard costs, in strong contrast to neoclassical orthodoxy.[25] It is on this implication that we shall base our test of the target return hypothesis.[26]

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[24] See Stigler [77] and Friedman [23].

[25] Demand changes may have indirect effects by bringing about changes in standard costs, but have no direct effects.

[26] The test is developed in Chapter 3.

In focusing upon this implication our test will not be sensitive to the entry-preventing objective postulated by Sylos and Modigliani. If firms in an industry priced according to (2) because of religious beliefs (for example) our test result would be the same as it would be if these firms were concerned with entry prevention. It should be possible to develop other tests which focus upon the relations between entry-preventing price and minimum long run average cost.[27] Such tests would provide evidence relevant to the view that target return pricing stems from attempts to prevent entry. These would require different data and techniques than the one developed in this study, however, so we must here be content to test for the presence of target return pricing without direct reference to the entry prevention aspect of our version of the hypothesis.

Let us now conclude this section by briefly mentioning implications of the hypothesis which are of importance for evaluation, rather than recognition, of target return behavior. First, resource allocation effects occur if entry-preventing pricing is successful, for the object is to keep price above the competitive level. Thus an industry which prevents entry will utilize fewer resources and produce less output than would be required for Pareto optimality if all other industries were competitive. Second, the presence of some sort of cost determined pricing is usually assumed in cost-push theories of inflation. While it

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[27] See Subsection 2.2.9 above.

has not been shown that cost oriented pricing is a sufficient condition for continuing inflationary pressures at under-full employment levels, it may be a necessary condition. Finally, it is apparent that the imposition of a lump sum or profits tax would shift upward the LAC curve in Figure 1 and thus bring about a higher price, a result which is not forthcoming in either monopoly or competitive models.[28]

2.4 Previous Statistical Studies

2.4.1 General

The only empirical evidence mentioned thus far is that based on interviews with business managers. The dangers of reliance on such evidence are obvious and were cataloged long ago by Machlup [53]. Probably most economists would concur with Friedman's opinion concerning interview findings: "They may be extremely valuable in suggesting ... new hypotheses... [but] ... they seem to me almost entirely useless as a means of testing the validity of economic hypotheses" [23, p. 31].

Our empirical work accordingly will utilize published statistics concerning prices, quantities, and other variables. It will be econometric in nature, that is, it will employ the tools of formal statistical inference which have been specifically designed for analysis of economic phenomena. Before turning to our work we must then survey previous econometric studies. While none has been designed specifically to test a full cost pricing hypothesis, several have been of relevance.

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[28] This implication is potentially useful for recognition as well as for evaluation. In the discussion which follows we do not take explicit consideration of taxes of any kind.

The two main points which have been studied are (1) the relative usefulness in "explaining" prices of standard costs as compared to actual costs and (2) the significance of demand conditions as a direct determinant of prices.

2.4.2 Schultze and Tryon (1965)

The most extensive statistical study of pricing to date is that of Schultze and Tryon, Chapter 9 of The Brookings Quarterly Economic Model of the United States [75]. Using quarterly time series for 1948-60, they studied two aggregates (durable and non-durable manufacturing) and fifteen SIC two-digit industries (as well as some non-manufacturing aggregates). Their main findings were that "normal" costs are more important than current deviations from normal in explaining prices and that demand influences were insignificant or of the wrong sign in many industries. The main weakness of their study lies in the specification of the equation estimated. They regressed price on normal unit labor costs, deviation of current from normal unit labor costs, a materials price index, and the deviation of current from trend capacity utilization. The latter variable was supposed to represent demand influences. It would be more appropriate, however, to relate price changes, rather than levels, to the capacity utilization variable. The latter is an indicator of supply-demand disequilibrium, as recognized by Schultze and Tryon [75, pp. 285-291]. Thus a high but unchanging value should lead to repeated rises in prices which are not implied by the Schultze-Tryon specification. Their formulation is analogous to making a price, rather than its rate of change, a function of excess demand. It therefore involves a serious misspecification.

In addition one could point out that the 12 quarter moving average construction used for labor man-hours per unit of output does not exactly duplicate the standard cost formulation suggested (e.g.) by Eckstein. In practice, however, the Schultze and Tryon figures probably differ very little from those which would be calculated for standard man-hours using an explicit labor usage equation. A more serious objection to the results would concern the level of aggregation employed: two-digit industries are much too broad to correspond adequately to the "industries" of economic theory or industrial organization. Also test statistics indicative of the presence or absence of autocorrelation were not published.

2.4.3 Yordan (1961)

W.J. Yordan studied 14 industries at a more disaggregated level in an attempt "to test the hypothesis that inflationary pressures are transmitted through concentrated industries at a different rate than through unconcentrated industries" [87, p. 287]. He regressed monthly price changes on monthly changes in labor and materials cost per unit of output, using various lags, and found little difference between the two groups of industries.

More relevant to our survey was Yordan's attempt to relate concentration and price sensitivity to demand conditions, especially his findings that "the insensitivity of price to demand change in concentrated industries is striking" [87, p. 291]. Also his results suggested "that insensitivity to demand change is not confined to highly concentrated industries, but is typical of industrial prices" [87, p. 292].

Again, however, the conclusions regarding demand are vitiated by improper specification of the pricing equation. Yordan made change in price a function of the change in the deviation of a length-of-work-week variable from its average. Thus, in effect, he related rates of change in prices to changes in excess demand, rather than to the more appropriate levels of excess demand. In addition, the length of work week is but a proxy for excess demand in product markets.

2.4.4. Wilson (1959)

Wilson [85] regressed quarterly changes in prices on changes in wages, deviations of GNP from its trend, unfilled orders and new orders minus sales. The latter two variables were both lagged and standardized by sales. Wilson's coverage was steel and machinery industries for 1953-III to 1959-II.

In the machinery study three subsectors were recognized and pooled to obtain more degrees of freedom, dummy variables being inserted to absorb differences in reactions into constant terms. The deviation of GNP from trend variable and the new orders minus sales variable both had positive and statistically significant coefficients, suggesting that demand influences were important in machinery sectors. No variable representing materials costs was included, however. Since such a variable would probably be highly correlated with the demand variables utilized, the coefficients of the latter were subject to misspecification bias (due to omitted variables[29]).

[29] See Appendix E.

Wilson also estimated parameters for a similar equation using steel industry data. The GNP variable had a positive and significant coefficient but both of the industry-specific demand variables had insignificant negative coefficients. Since no material cost variable was included, it is difficult to draw any useful conclusions regarding the results.

2.4.5 Eckstein and Fromm (1967)

At the December 1967 American Economic Association meetings, Eckstein presented a progress report on a study, "The Price Equation," being conducted with Gary Fromm [19]. This research represents the natural extension of Eckstein's 1964 article [18] and as such looks upon pricing as a blend of target return and competitive "mechanisms."[30]

Eckstein and Fromm report estimates for ten different specifications of pricing equations. In each, two demand variables are included, capacity utilization and change in unfilled orders over sales (lagged). Both of these variables are indicators of excess demand and are thus misplaced in the four equations using a price level as the dependent variable. Explanatory variables are included in these equations, as well as in the six explaining price changes, which should be treated as endogenous.

The other major objection to the Eckstein and Fromm results stems from the excessively aggregative nature of the sectors studied: all manufacturing, durable manufacturing and non-durable manufacturing [19].

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[30] See Subsection 2.2.10 above.

The announced intention was also to obtain estimates for two digit manufacturing industries which are still extremely non-homogeneous and not usually thought to correspond at all closely to the "industries" of microeconomic theory or industrial organization.

2.4.6 Neild (1963)

In an influential British study, Neild studied U. K. manufacturing as an aggregate using quarterly data, 1950-60 [64]. Although it used a different formulation, his study yielded results similar to those of Schultze and Tryon in that "normal" labor costs appeared to be more useful than actual labor costs in explaining price levels.

Neild examined the influence of demand on prices by introducing an index of excess demand based on labor market conditions, into his pricing equation. "It was found, however, that this added nothing useful to the explanation of prices" [64, p. 20]. He concluded that "the pricing results seem to be consistent with the view that manufacturers' prices are set by reference to costs when operating at some normal level of capacity and that they are not sensitive to moderate fluctuations in demand" [64, p. 51].

These results are inadequate for our purposes for several reasons. First, Neild studied all manufacturing as an aggregate whereas tests of pricing behavior should be conducted on an industry basis. Second, the excess demand variable is actually a proxy for conditions in the labor market rather than "the" product market. Even if conditions in these markets are closely related, time lags should be of considerable importance. Finally, Neild reported "marked serial correlation" of the regression residuals [64, p. 20]. Since his estimating equation contained a lagged dependent variable, his estimators were thus biased and inconsistent.

2.4.7 Conclusion

Our foregoing survey of relevant econometric studies has not been exhaustive, but the five items discussed are felt to be the most important attempts to date to examine evidence in a manner which could shed light on the validity of the target return pricing hypothesis. The studies surveyed have provided some evidence favorable to the notion that standard costs, rather than actual, are relevant in price determination, at least in some segments of manufacturing industry. Our critique has shown, however, that results intended to convey information concerning the sensitivity of price levels to conditions of demand have been of very little value. The main reason for this failure has been misspecification of the regression models, but use of inadequate proxies for demand intensity and overly aggregative data have also contributed.

Since the main testable implication of target return pricing hypothesis is that prices are not directly responsive to demand shifts, but are responsive only through influences on (standard) costs, we conclude that no adequate framework for testing the hypothesis has been previously developed. It is then this task to which we turn in the next chapter.

Chapter 3

Operational Formulation of the Hypothesis

3.1 A Preview of the Model

The purpose of this chapter is to present the target return pricing hypothesis in an operational form suitable for statistical testing. In order to accomplish this aim we shall express the hypothesis as an assertion concerning the value of a parameter of an econometric (statistical) model. We begin with a summary sketch of the final product and then discuss its derivation. The econometric model to be used contains two structural equations, the two jointly dependent variables being price, P, and quantity demanded, D. These equations may be generally represented as follows:

$$(1) \quad P_t = f_1(D_t, P_{t-1}, D_{t-1}, D_{t-2}, K^s{}_t, K^s{}_{t-1}, W_t, W_{t-1}, u_{1t})$$

$$(2) \quad D_t = f_2(P_t, D_{t-1}, B_t, P_{ct}, u_{2t})$$

The symbols are defined in Table I. This list also includes symbols for variables which do not appear in equations (1) or (2). The main exogenous variables in the system (1)-(2) are K^s = assets per standard unit of output, W = standard per unit cost of labor and materials, B = output or income of purchasing sector, and P_c = price used to deflate P. u_1 and u_2 are stochastic disturbance terms. Our test of the target return hypothesis will be based on statistical estimates of the parameters of equation (1).

As will be seen in the sequel, equations (1) and (2) give an incomplete picture of our model, but they should provide the reader with some orientation. This orientation may prove helpful in the reading of this chapter, most of which will be concerned with derivation of and elaboration upon equations (1) and (2).

Symbols

Endogenous Variables

P	actual price
D	actual quantity demanded

Exogenous Variables

I	end-of-period stock of finished goods inventory
M	labor manhours
K^s	value of assets per (physical) unit of product, at standard output rate
L^s	labor manhours per unit, at standard output
w	wage rate
F^s	salaries per unit, at standard output
m	cost of materials per unit of actual (or standard) output
B	output of purchasing sector
C	productive capacity
P_c	price used to deflate P
W	non-capital cost per unit of output, at standard output ($W=wL^s + F^s + m$)

Other Variables

A	anticipated quantity demanded (at P^s)
P^s	"standard" price ($P^s = rK^s + W$)
Q	actual output
Q^P	planned output
Q^s	standard output ($Q^s = kC$)
M^s	labor manhours at standard output ($M^s = L^s W^s$)
$I*$	"desired" inventory level
u	stochastic disturbance variable

Table I

3.2 The Pricing Equation

In this section we shall begin development of the pricing relationship presented above as equation (1). The target return formula, equation (2) of Chapter 2, provides a basis for our formulation. We now rewrite it, using the symbols of Table I.

$$(3) \qquad P^s_t = r\,K^s_t + w_t\,L^s_t + F^s_t + m_t$$

Here P^s is the "standard" price indicated by the target return pricing formula. K^s is the net value of assets divided by standard output. Since r is the constant target rate of return, rK^s provides the margin which is added to non-capital costs to yield the target return. The wage rate is w and L^s is the number of manhours per unit which would be employed if output were at the standard level, so wL^s is standard labor costs per unit. F^s is per unit expenditure on salaries at standard output. Finally, m is materials cost per unit of actual output. We assume that this does not vary with output and so m is also materials cost per unit at standard output. The t subscript stands for time periods. The formula is taken to refer to a single-product industry.

The essence of the target return hypothesis is that (3) provides a complete explanation of prices over time for the commodity in question. In particular the hypothesis asserts that r is constant over time and denies that any additional variable reflecting demand conditions will contribute usefully to the explanation of price movements.

The version of the hypothesis implied by (3), however, is overly strict. Specifically it postulates that full adjustments to changes in costs occur in each time period. We shall therefore slightly relax this version to reflect non-instantaneous adjustment of actual prices toward the levels specified by (3). We assume that the adjustment of actual prices, P, is of the type introduced by Nerlove [65]:[1]

$$(4) \qquad P_t - P_{t-1} = \lambda(\alpha P^s{}_t - P_{t-1}) \qquad 0 < \alpha,\ 0 < \lambda \mid .$$

This adjustment process specifies that the change in the actual price between two periods is a constant fraction, λ, of the difference between α multiplied by the standard price of the later period and the actual price of the earlier period. Equation (4) thus specifies a tendency for the actual price to approach αP^s over time, if the latter is unchanging. The constant α would normally be close to 1.0, but might slightly exceed that figure if the secular trend of prices were upward. With an upward price trend α would have to exceed 1.0 to prevent P from being below P^s on the average.

Equation (4) may equivalently be written as

$$(5) \qquad P_t = \alpha\lambda\ P^s_t + (1-\lambda)\ P_{t-1} \quad .$$

This form suggests a second interpretation of our posited relation between actual and standard prices. Suppose P equals α times a distributed lag of current and previous values of P^s, with the weights declining geometrically.[2] Then we would have

$$(6) \qquad P_t = \alpha\lambda\ [P^s_t + (1-\lambda)\ P^s_{t-1} + (1-\lambda)^2 P^s_{t-2} + \dots] \quad .$$

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[1] This adjustment model has been utilized fruitfully in a variety of contexts. See, for instance, the studies edited by Harberger [28].

[2] This lag form was introduced by Koyck [42].

Equations (5) and (6) are equivalent as can be seen by deriving the latter from the former. This is accomplished by repeatedly lagging (5) and substituting the results back into (5).

Combining equations (3) and (5) leads to

$$(7) \qquad P_t = \alpha\lambda\ rK_t^s + \alpha\lambda w_t L_t^s + \alpha\lambda F_t^s + \alpha\lambda m_t + (1-\lambda)P_{t-1} ,$$

which is operational and will be used in our empirical work.[3] It is convenient in the following discussion, nevertheless, to refer to (5) as the target return equation, thus using P^s to stand for the terms on the right hand side of (3).

It should be noted that version (5) of the hypothesis, like the stricter version $P_t = P_t^s$, asserts that r is constant over time and that demand conditions do not directly affect price. As suggested above, it is on this latter implication that we base our test.

How might price behavior differ from that specified by equation (5)? A more neoclassical view would suggest that prices deviate from the pattern implied by (5) in the following way. Firms alleged to practice target return pricing would be tempted by profit opportunities to set prices above the target level of (5) in a period in which the actual quantity of product demanded, D, exceeds the demand quantity anticipated, A.[4] To represent this view we then specify an alternative

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[3] It would be easy to impose the constraint $\alpha=1$, but we shall not do so because the estimates of α can be useful in interpretation of the empirical results.

[4] We elaborate upon this reasoning below.

to the target return hypothesis according to which the actual price exceeds the target return level by the amount $\phi\ (D_t - A_t)$, where ϕ is a positive constant.

There are two relatively straight-forward ways in which the term $\phi\ (D_t - A_t)$ can be made to have such an affect. First, we could add it directly to (5), obtaining

$$(8) \qquad P_t = \alpha\lambda\ P_t^s + (1-\lambda)\ P_{t-1} + \phi\ (D_t - A_t)\ .$$

Second,[5] we could add the term to the distributed lag equation (6), obtaining

$$(9) \qquad P_t = \alpha\lambda\ [P_t^s + (1-\lambda)P_{t-1}^s + (1-\lambda)^2 P_{t-2}^s + \dots] + \phi(D_t - A_t).$$

The price response patterns implied by (8) and (9) are somewhat different, as the latter is equivalent to

$$(10) \qquad P_t = \alpha\lambda P_t^s + (1-\lambda)P_{t-1} + \phi(D_t - A_t) - \phi(1-\lambda)\ (D_{t-1} - A_{t-1})\ .$$

The responses differ as follows: equation (10) specifies that the effect of D exceeding A does not carry over into succeeding periods whereas (8) specifies that the stimulus wears off gradually. As an example, suppose that P_t^s equals 100 in periods t=0, 1, 2, ..., 10 while $(D_t - A_t)$ is zero in all these periods except 3, in which it is 20. Then if α=1, λ =0.7, and ϕ=0.5, the prices specified by (8) and (10) are as follows:

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[5] I am indebted to Professor Levy for suggesting this second variant.

Period, t	Equation (8)	Equation (10)
1	100.000	100
2	100.000	100
3	110.000	110
4	103.000	100
5	100.900	100
6	100.270	100
7	100.081	100
8	100.024	100
9	100.007	100
10	100.002	100

It is not entirely clear whether (8) or (10) is the more appropriate specification for firms which deviate from target return pricing. Neither type of response can be positively ruled out by economists' meager knowledge of dynamic behavior. Formulation (8), however, seems somewhat more plausible than (10) except for cases with λ very close to 1.0, for values of λ less than 1.0 imply that price responses to changes in costs are spread over a number of periods.[6] In such cases it seems reasonable to expect that restoration of prices, altered from target return levels to take advantage of deviations of actual demand levels from those anticipated, will likewise be spread over a number of periods. Of course the price alterations from target return levels must occur promptly or no advantage will be gained. But pressures for restoration to target return levels do not require immediate action. Thus slow restoration or readjustment of prices would seem natural in cases in which adjustments to cost changes are slow. On these grounds specification (10) seems

[6] Note that specifications (8) and (10) are equivalent when $\lambda = 1$; i.e., when price responses are prompt.

slightly less satisfactory than (8). Nevertheless we shall investigate both formulations, devoting somewhat more attention to (8).

We can now state the target return hypothesis in fairly precise terms. It is

(11) $H : \phi = 0.$

To test this hypothesis statistically we must add a stochastic disturbance term to (8) or (10) and make specifications concerning its probability distribution.[7] Then we consider the alternative hypothesis,

(12) $H_A : \phi > 0,$

estimate the parameters of (8) and (10), and reject the target return hypothesis if the empirical data indicates that ϕ is in fact positive.

A desirable feature of this test as compared with many found in econometric studies is that both the "null" and the alternative hypotheses are economically meaningful. In this case, in fact, the alternative postulates a result that neoclassical economic theorists would expect, i.e., that demand directly influences price levels.

The test (11) based solely on the estimated value of ϕ illustrates clearly the general strategy of our testing procedure but in practice a second test formulation should also be considered. This second formulation, which constitutes a more stringent test of the target return hypothesis, will be outlined below in Section 3.4.

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[7] See Chapter 5 below.

The use of two slightly different tests each with two slightly different pricing equations opens the door to possible ambiguity. What conclusion should be reached if some test results for a given industry imply rejection and some acceptance of the target return hypothesis? Since data inconsistent with a hypothesis shows it to be false while consistent data does not imply its truth, we apparently must reject the hypothesis if any of the four results call for rejection. While broadly accepting this rule we shall add the proviso that the stochastic specifications underlying the test appear to be met for a result which calls for rejection, if it disagrees with other results. Of course there are no problems in cases where the four test results lead to the same conclusion.

The above discussion is incomplete in that it has not specified a mechanism for the formation of anticipations nor taken recognition of other behavior equations which should, perhaps, be estimated simultaneously with (8) or (10). In addition the nature of the alternative hypothesis could be discussed more fully. Let us therefore turn to these topics, beginning with the last-mentioned.

3.3 The Alternative Hypothesis

In order to understand more fully the nature of our alternative hypothesis, consider an imaginary cartel of n firms (assumed for simplicity to be identical). Suppose n firms form the cartel and agree to price on a target return basis (say to prevent entry and price competition) and to forecast demand collectively (to avoid duplication of effort). The cartel manager then determines the target return price P^s and at the start of each period announces A, the total demand which is anticipated at P^s. It is agreed that each firm will then plan to sell, during the period, A/n units from production or inventory stocks. Sale of these units takes place at the end of the period.

Now consider what happens if demand turns out to be greater than anticipated (curve D2 rather than D1 in figure III) so that the quantity demanded at P^s, which we denote D^s, exceeds A. If inventory holdings were impossible then A would be sold during the period and the price would have to be above P^s for the market to clear. Strict adherence to the target price P^s -- or to any price below P' -- would require rationing. Thus there would be extreme pressure on the cartel as a whole and on the firms separately to raise the price above P^s.

Typically, however, inventory holdings will in fact exist. In this situation the pressure for a price increase when demand exceeds the anticipated level would still exist although it would not be as strong. More than A units would be sold, inventory stocks being drawn down. The quantity sold, D, would still typically be below D^s and the price above P^s. If the firms entered the period with the level of inventories desired, then there would be a cost of drawing down the stock and this cost would lead the firms to prefer a price-quantity combination such as (P,D) to the combination (P^s,D^s). If the beginning stock were less than desired the tendency for price to exceed P^s would be even greater. If the beginning stock were greater than the desired level, then it is conceivable that firms would prefer (P^s,D^s) to any combination with price above P^s but this case is unlikely.

Thus we see that when demand is greater than that anticipated, the firms of our target return cartel will be motivated to raise their

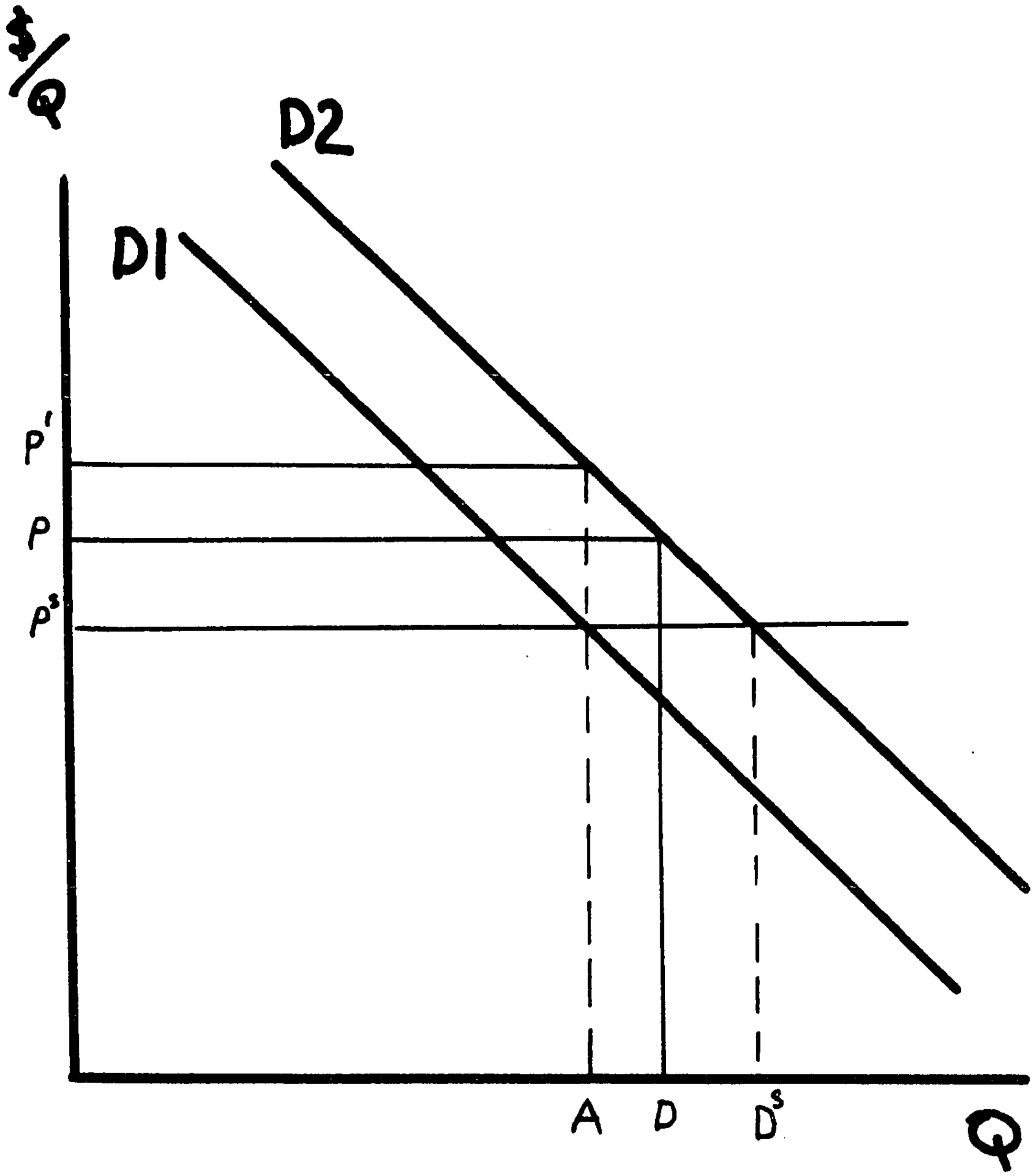

Figure III

prices above the target return level. Actual price P will exceed P^s and D will exceed A. Similarly when demand is less than anticipated they will wish to lower prices below P^s. The firms will then exert pressure on the cartel manager to permit deviations from the target return price. Such deviations would constitute divergences from target return behavior. Of course we would expect deviations to be the rule, rather than the exception, in industries with many firms.[8] The target return hypothesis, in other words, does not apply to competitively structured industries.

A critic of this test could argue that the alternative hypothesis entertained does not exhaust the possibilities of deviations from target return behavior and could accordingly contend that failure to reject the hypothesis does not establish the presence of target return pricing. He would be correct but this conclusion does not, we think, render our test either uninteresting or unimportant. In the first place, a similar situation always exists in scientific research. As Hempel puts it, "... the fact that a test implication inferred from a hypothesis is found to be true, does not prove the hypothesis to be true" [30, p. 8]. In other words, as mentioned above, empirical evidence can show a hypothesis to be untrue; it can never show it to be true. Also, we believe that the implications chosen come close to providing a "crucial test" [30, pp. 25-28] between target return and neoclassical views. The main implication of the former view, as we have said, is the absence of any direct demand influence on price while the latter implies

[8]Actually we would expect that the hypothesized cartel would not exist.

(under most circumstances) demand effects which in turn suggest that $\phi > 0$.

3.4 Demand Anticipations

In order to render equations (8) and (10) operational, we must specify how expectations or anticipations concerning quantity demanded are formed. Here we utilize a well-known model, apparently first used by Cagan [10]. The "adaptive expectations" model,

$$(13) \qquad A_t - A_{t-1} = \delta(D_{t-1} - A_{t-1}), \qquad \delta > 0 ,$$

posits that anticipation adjustments are proportional to the previous period's error. This scheme has been utilized, with apparent success, in a very wide variety of contexts.[9]

We now use (13) to eliminate the unobservable A term from equation (8). t-subscripts are suppressed for neatness. First (13) is inserted into (8) to yield

$$(14) \qquad P = \alpha\lambda P^s + (1-\lambda)P_{-1} + \phi D - \phi\delta D_{-1} - \phi(1-\delta)A_{-1} .$$

Next (8) is lagged one period and solved for $-\phi A_{-1}$:

$$(15) \qquad -\phi A_{-1} = P_{-1} - \alpha\lambda P^s_{-1} - (1-\lambda)P_{-2} - \phi D_{-1}.$$

Finally (15) is inserted into (14) and the result simplified:

$$(16) \qquad P = \alpha\lambda P^s - (1-\delta)\alpha\lambda P^s{}_{-1} + (2-\lambda-\delta)P_{-1} - (1-\delta)(1-\lambda)P_{-2} + \phi(D-D_{-1})$$

The unobservable variable A has been eliminated.

[9] These include studies of inflation, demand, consumption functions, and the term structure of interest rates. See, respectively, Cagan [10], Nerlove [66], Zellner, Huang, and Chau [88], and Meiselman [59].

A similar procedure can be used to eliminate A from equation (10). The result is

$$(17)\quad P = \alpha\lambda P^s - (1-\delta)\,\alpha\lambda P^s_{-1} + (2-\lambda-\delta)\,P_{-1} - (1-\delta)(1-\lambda)\,P_{-2}$$
$$+ \phi D - \phi(2-\lambda)\,D_{-1} + \phi(1-\lambda)\,D_{-2}$$

When expression (3) for P^s is inserted into (16) and (17), all the terms are operational. It is convenient, when performing this step, to utilize the definition

$$(18)\qquad W = wL^s + F^s + m.$$

The resulting equations, with stochastic disturbance terms added, are as follows.

$$(19)\qquad P = \alpha\lambda rK^s - \alpha\lambda r(1-\delta)\,K^s_{-1} + \alpha\lambda W - \alpha\lambda(1-\delta)\,W_{-1}$$
$$+ (2-\lambda-\delta)P_{-1} - (1-\delta)(1-\lambda)P_{-2} + \phi\,(D-D_{-1}) + u_1$$

$$(20)\qquad P = \alpha\lambda\, rK^s - \alpha\lambda rK^s_{-1} + \alpha\lambda\, W - \alpha\lambda(1-\delta)W_{-1} + (2-\lambda-\delta)\,P_{-1}$$
$$- (1-\delta)(1-\lambda)P_{-2} + \phi D - \phi(2-\lambda)D_{-1} + \phi(1-\lambda)D_{-2} + u_1$$

Estimates of the parameters of equations (19) and (20) provide the basis for formal hypothesis testing. It was mentioned above that one test of the target return hypothesis could be conducted by means of the statistical hypothesis $\phi = 0$, tested against the alternative $\phi > 0$. If the stochastic disturbance u_1 has a normal distribution this test is based on the t distribution possessed under the hypothesis by the estimator of ϕ.

As was also mentioned above, there exists a second way of testing the target return hypothesis which is perhaps more stringent in the sense of being more likely to lead to rejection. This second test recognizes that the terms of (19) and (20) involving $(1-\delta)$ should not be present in the pricing equation if the target return hypothesis is true. Thus target return pricing implies that $(1-\delta)$, as well as ϕ, equals zero. The second method is then to test the two-dimensional statistical hypothesis

$$(11') \qquad \phi = (1-\delta) = 0.$$

In this case it is difficult to formulate a one-sided alternative. The standard procedure for testing (11') is to use a generalized alternative, $\phi \neq 0$ and/or $(1-\delta) \neq 0$. Then if the u_1 terms are normally distributed, a test statistic with an F distribution under the hypothesis provides the basis for a test.[10]

In the sequel we shall refer to the tests described in the preceding two paragraphs as a "t test" and an "F test", respectively. This usage is intended to serve as a useful shorthand way of referring to the different tests and is not itself intended to suggest any fundamental distributional distinction.[11] Both the "t test" and the

---

[10] The test statistic is described below in Section 7.2. The general idea of the test can be put as follows: the target return hypothesis is apparently incorrect and should be rejected if the R^2 statistic for the equation (19) or (20) representing the alternative hypothesis is large relative to the R^2 for the target return equation (7). Standard references for the F test are Scheffe [74, pp. 31-7], Johnston [34, p. 126], Goldberger [25, p. 177] and Malinvaud [55, pp. 201-3].

[11] Our first test, the "t test", is a one-sided, one-dimensional test. Our second test, the "F test", is a two-sided, two-dimensional test. Since a two-sided t test is simply a special case of an F test (which is inherently two-sided in this context) the dimensionality of the tests seems less "fundamental" a distinction than the other. Both tests are likelihood ratio tests.

"F test" will be carried out using both specifications (19) and (20) for each industry studied.[12]

It should now be noted that in both (19) and (20) the number of explanatory variables, and thus of regression coefficients in a linear regression, exceeds the number of distinct parameters. In the case of (19) there are seven regressors and but five parameters, α, r, λ, δ, and ϕ. Equation (20) contains nine regressors and only the same five parameters. In the latter case several estimates for ϕ would be implied by the nine coefficients obtained via linear regression and serious ambiguity would therefore be introduced into the "t test" procedure. The situation with respect to equation (19) is less serious since ϕ itself appears as a regression coefficient.

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[12] A word may be in order concerning the validity of the test results if the u_1 disturbances are not normally distributed. The question is, how are significance levels and power curves affected by deviations from normality? Numerous studies of the question have been carried out utilizing sampling experiments, theoretical asymptotic results, and moment comparisons. Convenient summaries of the findings have been provided by Keeping [38], Malinvaud [55, pp. 251-4], and Scheffe [74, pp. 331-50]. In general it appears that F tests (including two-sided t tests) are very robust to deviations from normality but one-sided t tests are affected considerably by skewness in the distribution of the disturbances. The following results taken from Malinvaud [55, p. 252] illustrate the insensitivity of an F test (with 4 and 20 degrees of freedom) to deviations from normality characterized by the classical coefficients of skewness, $\beta_1 = \mu_3^2/\sigma^6$, and kurtosis, $\beta_2 = \mu_4/\sigma^2$. (Here μ_3 and μ_4 are the third and fourth moments about the mean. These have the values 0 and 3, respectively, for normal distributions.) The significance level when normality obtains is .05, as is shown in the third row. That row gives the probability of the test statistic exceeding the critical value which would be correct for a .05 significance level if the distribution were normal.

β_1	0	0	0	0	2
β_2	2	3	4	5.5	3
$P[F > 2.866]$	.052	.050	.048	.044	.052

In both cases, however, the ordinary linear regression[13] technique of estimation has undesirable effects on the "t test" because of failure to utilize exact known relations among the parameters, a failure which presumably[14] involves a loss in estimating efficiency. It is preferable that these known (nonlinear) constraints be utilized. The effect on the "F test" of ignoring the known nonlinear restrictions is even more serious, for it implies testing the "significance" of adding [to the target return equation (7)] either four or six additional parameters (depending upon whether formulation (19) or (20) is considered) instead of the correct two. It is therefore highly desirable that the non-linear restrictions implied by equations (19) and (20) be imposed during estimation. This is accomplished by the use of nonlinear regression. For more discussion see Chapter 5 and Appendices B and C.

3.5 Simultaneity

Statistical estimation of parameters of behavioral equations usually proceeds by means of least squares regression, linear or non-linear. Ordinary least squares estimators of an equation's parameters are, however, not only biased but also inconsistent if the equation contains more than one simultaneously determined variable. To be sure of avoiding this "least square bias" we must accordingly consider

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[13] At this point we abstract from the "simultaneous equations" problem. See Section 3.5.

[14] Goldberger [25, p. 255-8] shows that failure to impose known linear constraints leads to unnecessarily large sampling variances of parameter estimators. It is my conjecture that a similar situation applies when the restrictions are nonlinear.

whether any of the variables appearing on the right hand side of equation (20) are jointly determined with P.[15]

It is immediately apparent that quantity demanded, D, is determined jointly with P, for the market demand function for the commodity assures us that there is feedback from price to quantity demanded; i.e., that the line of "causality" does not flow solely from D to P. Simultaneity does not hold under the target return hypothesis (11) as it specifies that D does not enter into the determination of P. But the raison d'etre of the study is to test this hypothesis. Thus the parameters of (20) should be estimated jointly with those of a demand function, some "simultaneous equation" procedure such as two-stage least squares being utilized.

Are there other jointly determined variables on the right hand side of (20)? The only others which are not lagged are K^s and W. But W is simply a shorthand notation for $wL^s + F^s + m$, so we must consider K^s, w, L^s, F^s, and m to see if each can be considered exogenous. K^s is the value of the firms' assets divided by standard output. The latter is by definition a constant fraction of capacity and thus a long-run variable, a "given" as far as pricing decisions are concerned. Also corporate assets may be considered as virtually fixed for the time periods (quarters) which we shall be using. Thus K^s is exogenous and so not jointly dependent with P and D. Similar reasoning holds for L^s; it is a function only of capacity and time[16], both of which are exogenous. This point should become clearer in the next chapter.

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[15] Since (20) includes all variables appearing in (19) we shall here explicitly discuss only the former.

[16] Time serves as a proxy for technical change.

The case for classifying w, F^s, and m as exogenous is somewhat less strong but we shall do so nevertheless. Our justifications are two in number. (1) Feedback effects on wages, salaries, and materials prices probably do not take place until after a lag of a quarter or two, in the case of wages partly due to the length of union-firm contracts.[17] (2) Our model is intended for units which correspond at least approximately to theoretical industries. Since these are relatively small units, the impact of their changes in derived demand on prices in factor markets will tend to be small.[18]

Our simultaneous structural equation system thus includes only the pricing or "supply" function (20) and a demand function. Specification of the latter will be the subject matter of the next section.[19]

3.6 Demand Function

In developing our demand function it is important that its role in the analysis be kept in mind. We are concerned with this relation because its neglect can impair our estimates of the parameters of the pricing equation, not because of interest in product demand functions *per se*. In principle we would like our test procedure to be applicable to numerous different industries and the results to be comparable. Thus the relations of our model should be applicable to all these industries.

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[17] This reasoning has been utilized by Neild [64] and Wilson [85].

[18] Exceptions could be handled by treating the appropriate factor price as endogenous and expanding the system. See the next to last paragraph of Subsection 7.3.4.

[19] The calculation of L^s, which requires estimation of two more equations, is discussed in Chapter 4.

Consequently our goal is to specify a general purpose demand function, adequate for many commodities, rather than a specialized relation which embodies features appropriate for only one or a few goods.

The economic theory of consumer demand shows the rate of purchase by a consumer of a given commodity to be dependent upon the prices of all goods and the consumer's income. The function is supposed to be homogeneous of degree zero in prices and money income; this feature is usually incorporated by deflating all prices and money income by some consumer price index.[20] In empirical studies the number of prices actually found significantly to influence consumption rates of a commodity is typically very small. In many cases, in fact, even the own-price is apparently of little importance.[21] If we used only the deflated own-price of a commodity and the price-deflated income in a linearized market[22] demand function, our equilibrium quantity demanded would be given by

$$(21) \qquad D^e_t = b_o + b_1 (Y/P_c)_t + b_2 (P/P_c)_t \,,$$

where Y is money income and P_c the price used as a deflator.

If the commodity in question is an intermediate good, rather than a consumers' good, then relation (21) is not appropriate. The demand

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[20] See, for instance, Klein [40, p. 21].

[21] See, for example, the recent studies of Houthakker and Taylor [33]. This result would probably not occur if the observed range of prices were greater.

[22] We here ignore aggregation problems which can arise if persons' tastes differ (as they do) and individual demand functions are not approximately linear. For an introductory discussion of aggregation problems in this context see Klein [40, p. 24-8].

for an intermediate good is a derived demand reflecting firms' purchases of productive inputs. Cost minimization theory makes the quantity demanded of an input a function of all input prices and the rate of output. Instead of the real income variable, Y/Pc, in this case we should utilize the real output of the purchasing sector of the economy, denoted B. The deflated own-price P/Pc should appear as before, but the appropriate deflator becomes either the price of a rival input or a price index for several other inputs. In our empirical studies it will be convenient to use the difference, P-Pc, rather than the ratio P/Pc, because Pc appears linearly in the former. As an expression for equilibrium quantity demanded of an intermediate good we then adopt the following:

$$D^e = b_o + b_1 B + b_2 (P-Pc) \tag{22}$$

where t subscripts are suppressed.

Since actual market quantities are usually not equilibrium values, we must incorporate some adjustment mechanism. The partial adjustment model,

$$D - D_{-1} = \xi (D^e - D_{-1}), \qquad 0 < \xi \leq 1 , \tag{23}$$

has been utilized successfully by Nerlove [66] and others. We adopt this scheme, substitute (22) into (23), add a stochastic disturbance term, and obtain

$$D = \xi b_o + \xi b_1 B + \xi b_2 (P-Pc) + (1-\xi) D_{-1} + u_2 \tag{24}$$

as an operational demand function. With appropriate choices of variables B and Pc, this function should be suitable for a wide variety of intermediate goods. For application in the case of a consumers' good, (24) should contain Y/Pc in place of B, as is apparent from comparison of (21) and (22).

3.7 Summary

Our proposed test of the target return pricing hypothesis is based on the implication that demand factors do not cause deviations of prices from the levels specified by the generalized target return formula (7). If such deviations do in fact occur because firms behave more neoclassically than the hypothesis supposes, then the parameters ϕ and $(1-\delta)$ will be positive in equations (19) and (20). If estimation of the pricing equation, in either form, produces an estimate of ϕ which is significantly greater than zero, then the target return hypothesis should be rejected for the industry in question. The target return hypothesis should likewise be rejected for an industry in which the R^2 for either equation (19) or (20) is significantly greater than the R^2 for equation (7), since the latter is descriptive of target return pricing.

Price and quantity demanded are determined simultaneously, in our model, by the pricing ("supply") equation (19) or (20) and the demand equation (24). Our econometric model consists of those two equations together with requisite stochastic specifications. The latter will be discussed in Chapter 5.

Chapter 4

Manhour Usage and Output Functions

4.1 Introduction

In the previous chapter the variable L^S, manhours per unit at standard output, was specified as exogenous in the two-equation econometric model there developed for testing the target return hypothesis. The argument was that L^S depends only upon productive capacity C and time t, the latter serving as a proxy for technical change. In this chapter we elaborate upon this argument and indicate how values of L^S can be obtained.

The general argument is as follows. The number of manhours employed in a given period depends upon planned output and capacity as well as actual output. The state of technology is also important. Symbolically we have

(1) $$M_t = f\ (Q_t, Q^P{}_t, C_t, t)$$

where M = manhours, Q = output, Q^P = planned output, C = capacity, and t = time. If in period t both planned and actual output levels were to coincide with the standard output level, $Q^S{}_t = k\ C_t$, then the number of manhours utilized would be

(2) $$M^S{}_t = f(kC_t, kC_t, C_t, t)$$

where f is the same function as in (1). Manhours per unit at standard output is given by $L^S{}_t = M^S{}_t/Q^S{}_t$ so from (2) we have

(3) $$L^S{}_t = f(kC_t, kC_t, C_t, t)/kC_t\ .$$

Thus we see that L^s is a function only of C and t which are exogenous.

Now in order to be able to determine numerical values of L^s for a given time period, with known C, the function f of equations (1) - (3) must be known. The functional form is chosen on the basis of theoretical considerations while specific parameter values are estimated empirically. The latter step requires that planned output be related to observable variables. This in turn requires specification and estimation of an output behavior equation. In the following sections we discuss more fully these two functions designed to represent manhour and output behavior.

4.2 Manhour Usage Function

Our model of manhour determination is a modification of one developed by Wilson and Eckstein [86]. Several "short run labor productivity" models have been proposed in recent years; the one of Wilson and Eckstein is desirable because it is more firmly based in traditional microeconomic theory than the others.[1]

Wilson and Eckstein posit a "maladjustment period" which amounts to a planning period shorter than the short run (fixed plant size) of traditional theory. Just as a firm's long run total cost curve (LRTC) is an envelope of all possible short run cost curves (SRTC), so each of the latter is an envelope of planning period maladjustment cost curves (MALTC). One short run and one maladjustment curve are shown in Figure IV. Plant capacity is designated by C,

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[1]Compare Wilson and Eckstein's discussion with, for instance, that of Kuh in the Brookings Model Volume [44].

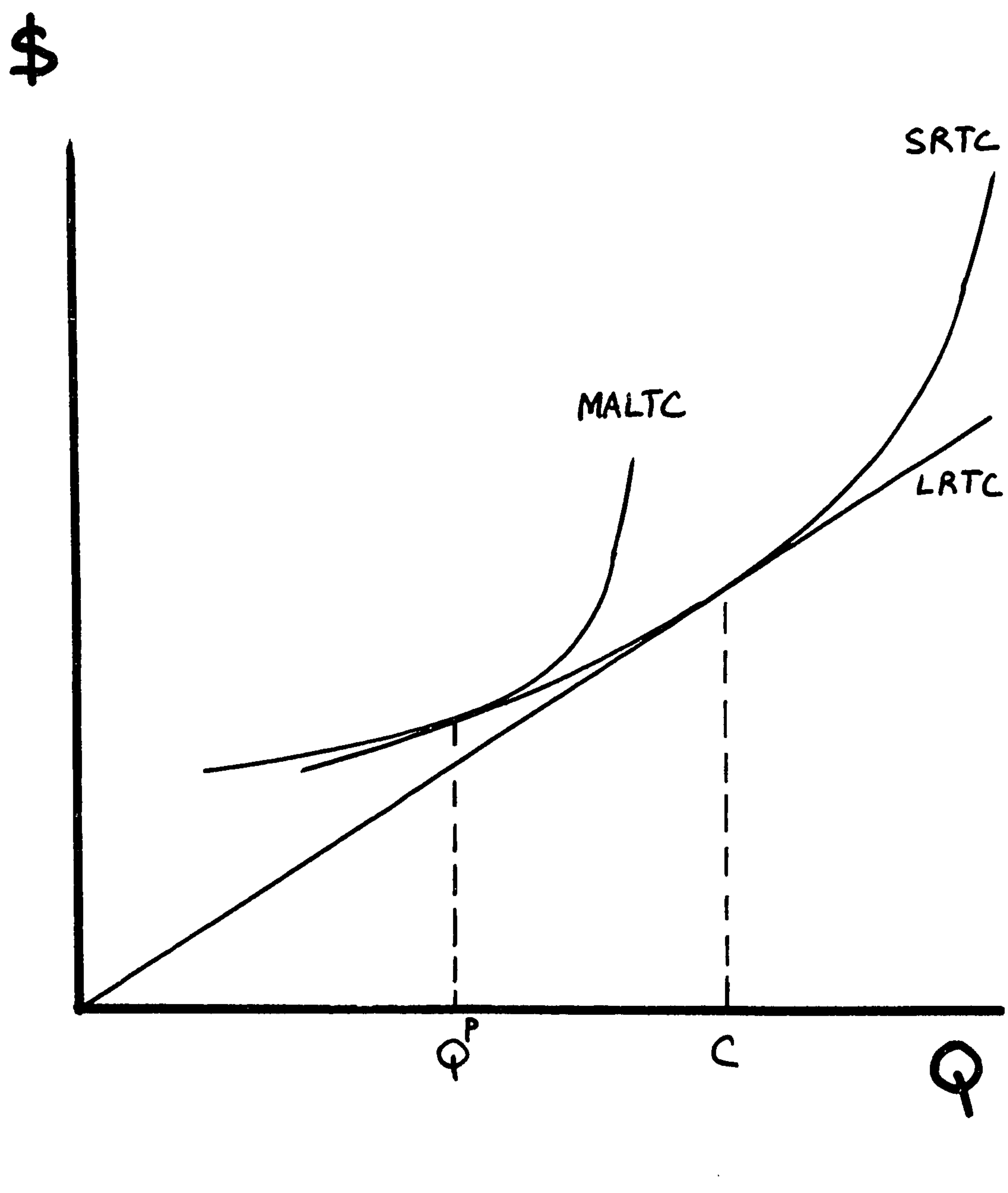

Figure IV

planned output by Q^P, and actual output by Q. Thus actual costs are greater than those specified by the short run (plant) cost curve if $Q \neq Q^P$.

The corresponding manhour usage curves will be similar for $Q^P < C$ and for $Q < Q^P$, since firms are slow to lay off workers when output is less than anticipated. As Wilson and Eckstein point out, though, an asymmetry exists for the manhour curves since "much of the high cost of operating above capacity or above the level planned at the start of the period may result from using expensive labor (especially overtime labor), from sacrificing maintenance work, and from more intensive use of machinery" [86, p. 42].

Thus they formulate a linearized model (ignoring, at first, technical progress) of the form

$$(4) \quad M_t = \alpha C_t + \beta(Q_t^P - C_t) + \gamma(Q_t - Q_t^P) \qquad \alpha > \beta > \gamma > 0$$

which, graphically, appears in Figure V.

Let us now rewrite (4) as follows, adding a constant term and dropping t subscripts:

$$(5) \quad M = a_0 + a_1 C + a_2 Q^P + a_3 Q \ .$$

Now $a_1 = \alpha - \beta$, $a_2 = \beta - \gamma$, and $a_3 = \gamma$ so the Wilson-Eckstein hypothesis $\alpha > \beta > \gamma > 0$ is equivalent to $a_1 > 0$, $a_2 > 0$, $a_3 > 0$.

Technical progress is introduced by making the coefficients functions of time. While more complicated versions could be handled, we make only a_1 a function of time, linear for simplicity:

$$(6) \quad a_1 = a_{10} + a_{11} t \qquad a_{11} < 0.$$

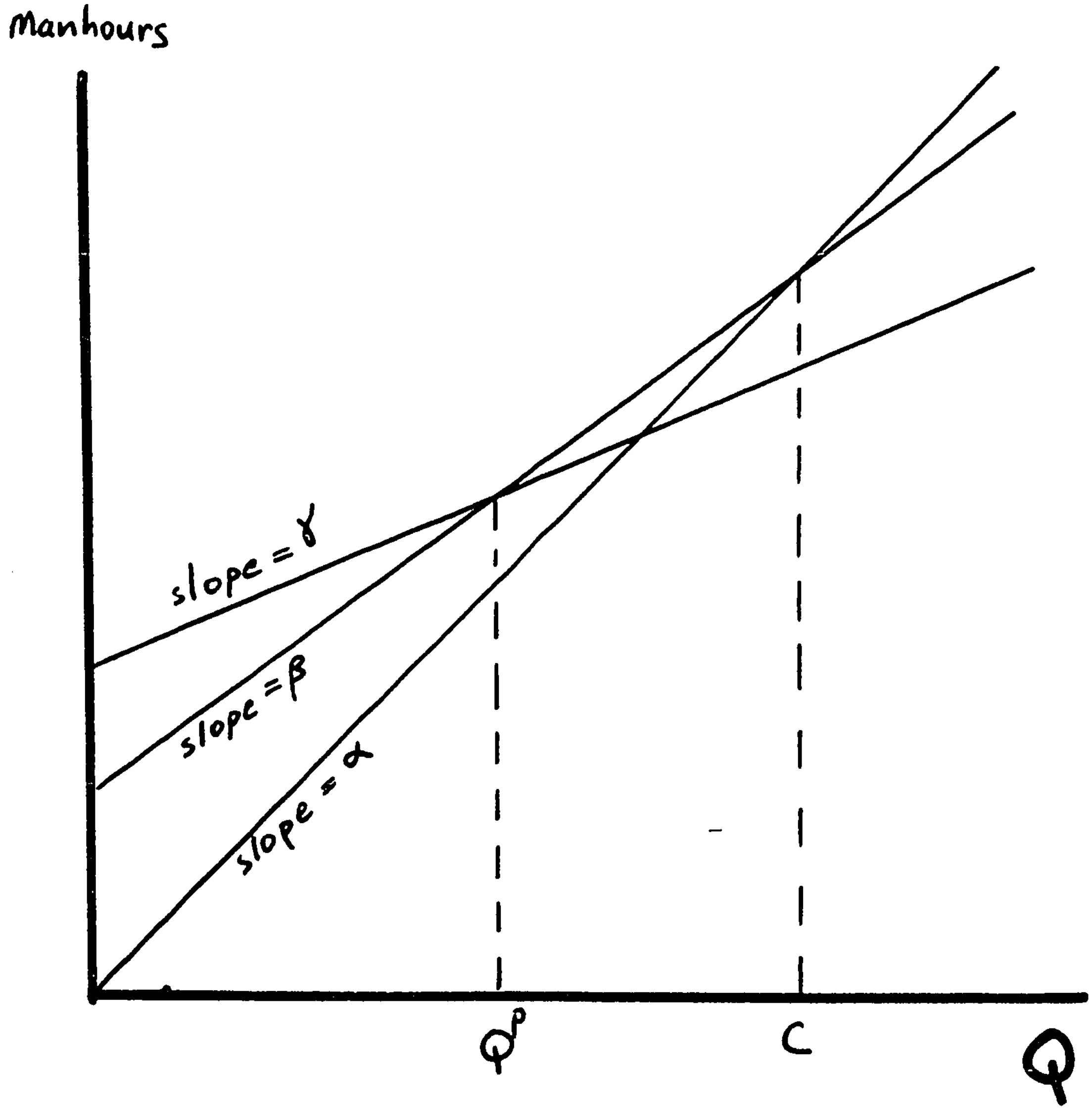

Figure V

Planned output is of course unobservable. According to the output model developed in the next section, though, it is related to actual output, quantity demanded, and anticipated demand by the following expression:

$$(7)\quad Q^P = Q + (1-\nu)\ [A-D].$$

An estimate of the parameter $(1-\nu)$ is obtained from the output equation. Anticipated demand A is also unobservable, but we have already specified, in equation (13) of Chapter 3, that

$$(8)\ A = (1-\delta)\ A_{-1} + \delta D_{-1}.$$

If (6), (7), and (8) are then substituted into (5), and A_{-1} eliminated by a procedure like that of Section 3.4, the following expression is obtained:

$$(9)\quad M = a_0 + (1-\delta)M_{-1} + a_{10}C + a_{11}(tC) - a_{10}(1-\delta)C_{-1}$$

$$- a_{11}(1-\delta)(tC)_{-1} + \beta Q - \beta(1-\delta)Q_{-1} - a_2(1-\nu)(D-D_{-1})$$

Equation (9) represents our operational model of manhour usage. It differs from the original Wilson-Eckstein version in its treatment of planned output. Whereas we utilize well-specified behavioral relations (7) and (8) to describe the generation of output plans, Wilson and Eckstein simply used the expression

$$0.500\ Q_{t-1} + 0.333\ Q_{t-2} + 0.167\ Q_{t-3}$$

for Q^P_t.

It may be noted that the definition of capacity implicit in Figures III and IV differs from that of Figure II of Chapter 2. To be consistent with our earlier analysis we should replace C with $Q^s = kC$ in the Wilson-Eckstein model and thus in equation (9). This step has no operational significance, however: it simply alters the interpretation of the parameters a_{10} and a_{11} .

The operational procedure for developing the standard manhours series should now be clear. Numerical estimates for the parameters of (9) are obtained first.[2] The number of manhours which would be used at times t can then be "predicted" for any hypothetical level of output. In particular, manhours at standard output is predicted by setting Q and Q^p equal to kC. The resulting standard manhours figures are then divided by the standard output figures, kC, to yield the numbers L^s for use in the pricing equation. The constant k is the average, over the time period studied, of Q/C.

It is apparent that the modified Wilson-Eckstein procedure requires data on productive capacity. For some industries (e.g., cement) there are published capacity figures, collected typically by trade organizations. In such cases these figures are used in estimating (9). In very unconcentrated industries (e.g., lumber) capacity series are non-existent and some alternative manhours model is required. In these cases we resort to the simple trend equation,

(10) $$M/Q = c_o + c_1\, t + c_2\, t^2 + \text{seasonal terms.}$$

The smoothed M/Q series "predicted" by the estimated equation is then used for L^s in the pricing equation. Some evidence that this does not seriously affect the pricing equation estimates is presented in Section 7.2.

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[2] Note that a nonlinear regression technique should be used here.

4.3 Output Function

A firm which follows target return pricing will base its production plans on the anticipated quantity demanded at price P^s. At the industry level this quantity is represented by A. As suggested above, in Section 3.3, the firm will not produce exactly A/n units unless its beginning inventory[3] is the same magnitude as it wishes to have at the close of the coming period. If the beginning inventory I_{t-1} exceeds the "desired" closing level I^*_t, then the firms together will plan to produce less than A units of output during the period, moving actual inventory toward the desired level. Similarly, if I^*_t is greater than I_{t-1}, then Q^P_t will exceed A_t. Formally we specify the relation

$$(11) \qquad Q^P_t - A_t = (1-\mu)[I^*_t - I_{t-1}]$$

where μ is a constant between zero and unity. Equation (11) asserts that the firms of an industry plan each period to eliminate the fraction $(1-\mu)$ of the discrepancy between desired and actual inventory levels.[4]

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[3] Throughout this study "inventory" means stock of finished goods. Thus we do not include stocks of raw materials or goods in process in "inventories". While our terminology (adopted for convenience) is somewhat unusual, the practice of treating finished goods inventories separately is not. See, e.g., Lovell [49] and references cited therein.

[4] Equation (11) shows our output-inventory model to be of the "stock adjustment" variety utilized in several recent econometric studies (such as Jorgensen's analysis of investment in fixed capital [35]). Stock adjustment models consist primarily of (a) an equation specifying "desired" or "equilibrium" values of some variable and (b) an equation describing the dynamics of adjustment of actual toward desired values. We are here concerned with (b); element (a) is discussed in Appendix A.

Demand anticipations will normally turn out to be somewhat incorrect. When actual demand exceeds A we presume that firms will revise their output rates somewhat from those planned. Specifically, we assume that actual industry output deviates from the planned magnitude in proportion to the deviation of actual demand from anticipated:

$$(12) \qquad Q_t - Q^P{}_t = (1-\nu)[D_t - A_t] \qquad \nu > 0.$$

If equation (12) is used to eliminate Q^P from (11), the result is

$$(13) \qquad Q - D = (1-\mu)[I^* - I_{-1}] + \nu[A - D]$$

where t subscripts have been suppressed.

As it is convenient to work in terms of inventory levels, the identity

$$(14) \qquad I - I_{-1} = Q - D$$

is used to rewrite (13) as

$$(15) \qquad I - I_{-1} = (1-\mu)[I^* - I_{-1}] + \nu[A - D].$$

For (15) to be made operational, anticipated demand A and the desired level of inventory I* must be related to observable variables. The theoretical discussion of Appendix A suggests that desired inventory can be approximated by a linear function of anticipated demand,[5] as

$$(16) \qquad I^* = \theta_o + \theta_1 A.$$

[5]Theoretical justification of equation (16) is placed in Appendix A because it is lengthy and somewhat peripheral to the main theme of this study. The analysis is nevertheless interesting on its own and should, of course, be considered as part of this study.

Substitution of (16) into (15) gives

$$(17) \qquad I - I_{-1} = (1-\mu)[\theta_o + \theta_1 A - I_{-1}] + \nu[A - D].$$

As in Chapter 3, anticipations are assumed to conform to the "adaptive expectations" model,

$$(18) \qquad A - A_{-1} = \delta(D_{-1} - A_{-1}).$$

Finally equation (18) is used to eliminate A from (17) by the procedure explained in Section 3.4. The result is

$$(19) \qquad I = \delta(1-\mu)\theta_o + (1-\delta+\mu)I_{-1} - \mu(1-\delta)I_{-2} - \nu D + [\nu+(1-\mu)\delta\theta_1]D_{-1}.$$

Expression (19) is operational, containing only observable variables. It will be estimated to provide a value for ν to be used in constructing a numerical time series for L^s.

In our empirical work one modification of (19) will also be considered. In view of the "long run" orientation of target return firms, standard output, rather than anticipated current sales, might be the variable to which desired output is related. Eisner [20] has suggested that this is the case in U. S. manufacturing, though he did not refer to target return pricing. Eisner used the term "permanent sales" rather than "standard output" but the name is of course unimportant.

According to this view, kC should be used instead of A in equation (16). In place of (17) we then have

$$(20) \qquad I - I_{-1} = (1-\mu)[\theta_o + \theta_1 kC - I_{-1}] + \nu[A-D].$$

When A is eliminated, using (18) and the procedure of section 3.4, the result is

$$(21) \qquad I = \delta(1-\mu)\theta_o + (1-\delta+\mu)I_{-1} - \mu(1-\delta)I_{-2} - \nu(D-D_{-1})$$
$$+(1-\mu)\theta_1 kC - (1-\delta)(1-\mu)\theta_1 kC_{-1}.$$

Equation (21) is operational but unlike (19) is nonlinear in the parameters.

The relation, with respect to statistical estimation, of equations (9) and (19)[6] of this chapter to equations (19)[7] and (24) of Chapter 3 will be discussed below in Chapter 5.

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[6]Or (21).

[7]Or (20).

Chapter 5

Estimation Procedure

5.1 Introduction

At this point it is necessary to discuss some topics relating to the statistical estimation of the behavioral equations developed in previous chapters. First we must consider the relationship between the price-quantity model of Chapter 3 and the manhours-output model of Chapter 4. Closely related is the question of the stochastic specifications which are needed to complete our econometric model. These subjects are treated in Section 5.2. In the next section we are then able to outline the steps used in estimating the various equations. As the parameters of the (structural) pricing equation enter in a nonlinear fashion, their estimation cannot be accomplished using standard techniques. Considerable discussion is required to define clearly the procedure chosen and to show that its estimators are consistent, so only the conclusions of this exploration are presented in Section 5.3. A similar comment applies, though with less force, to the treatment of seasonality in the quarterly time series data. More complete discussions of these topics appear as appendices at the end of this study.

5.2 Specification of the Complete Model

In Chapter 3 we developed a two equation econometric model to be used in testing the target return pricing hypothesis. The model consists of the two equations

$$(1)\quad P = \alpha\lambda r K^S - \alpha\lambda(1-\delta)K^S_{-1} + \alpha\lambda W - \alpha\lambda(1-\delta)W_{-1} + (2-\lambda-\delta)P_{-1}$$
$$- (1-\delta)(1-\lambda)P_{-2} + \phi D - \phi(2-\lambda)D_{-1} + \phi(1-\lambda)D_{-2} + u_1$$

$$(2)\quad D = \xi b_o + \xi b_1 B + \xi b_2 (P-P_c) + (1-\xi)D_{-1} + u_2$$

where we use the version of the pricing equation denoted (20) in Chapter 3, rather than the preferred version (19). We classified L^S as exogenous.

In Chapter 4 we developed a second model designed to yield estimates of the values of L^S. These are needed to obtain the values of W used in (1), since $W = wL^S + F^S + m$. The following two equations are supposed to explain manhours usage and output-inventory behavior.

$$(3)\quad I = \delta(1-\mu)\theta_o + (1-\delta+\mu) I_{-1} - \mu(1-\delta)I_{-2} - \nu D + [\nu+(1-\mu)\delta\theta_1]D_{-1} + u_3$$

$$M = a_o + (1-\delta)M_{-1} + a_{10}C + a_{11}tC - a_{10}(1-\delta)\ C_{-1}$$
$$(4)\quad - a_{11}(1-\delta)(tC)_{-1} + \beta Q - \beta(1-\delta)\ Q_{-1} - a_2(1-\nu)(D-D_{-1}) + u_4$$

Equations (3) and (4) permit the computation of values of L^S by means of the definition $L^S = M^S/kC$.[1]

From our discussion it is apparent that we consider equations (1)-(2) and (3)-(4) as comprising two separate systems[2] and that we intend

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[1] k is the average, over the periods observed, of Q/C.

[2] (3) and (4) are related because $I = I_{-1} + Q - D$. See equations (5) below.

to estimate them in isolation from each other. In this section we discuss both the econometric justification of this procedure and the precise stochastic specification of our model.

Let us now think of equations (1)-(4) as comprising one model. For reference we rewrite[3] them together, using general functional notation.

$$(5.1) \quad P = f_1 (D, P_{-1}, D_{-1}, D_{-2}, K^S, K^S_{-1}, W, W_{-1}) + u_1$$

$$(5.2) \quad D = f_2 (P, D_{-1}, B, P_c) + u_2$$

$$(5.3) \quad I = f_3 (D, D_{-1}, I_{-1}, I_{-2}) + u_3$$

$$(5.4) \quad M = f_4(D, I, D_{-1}, D_{-2}, I_{-1}, I_{-2}, M_{-1}, C, C_{-1}) + u_4$$

The functions f_2 and f_3 are linear, f_1 and f_4 are nonlinear.[4] The absence of period subscripts makes it possible to think of each equation as being expressed in vector form or implicitly in the form exemplified by

$$I_t = f_3(D_t, D_{t-1}, I_{t-1}, I_{t-2}) + u_{3t}$$

for $t = 1, 2, \ldots, T$.

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[3] Q and Q_{-1} have been eliminated and D_{-2}, I, and I_{-1} introduced by means of the identity, $I = I_{-1} + Q - D$.

[4] f_1 and f_4 are nonlinear because each represents a behavioral equation in which anticipated demand, A, appears. The transformation which eliminates this unobservable variable introduces nonlinearity. (See Sections 3.4 and 4.2) Implications of nonlinearity are discussed below in this chapter and in Appendices B and C.

Our first three stochastic assumptions are the ones invariably made in simultaneous equation econometric research. They are:

$$\left.\begin{array}{ll}\text{(a)} & Eu_{it} = 0 \\ \text{(b)} & Eu_{it}^{2} = \sigma_i^{2} \\ \text{(c)} & Eu_{it}u_{js} = 0 \quad s \neq t\end{array}\right\} \qquad \begin{array}{l} i, j = 1, 2, 3, 4 \\ t = 1, 2, \ldots, T\end{array}$$

Here E is the mathematical expectation operator. Assumption (a) is that the random errors have distributions with mean zero, assumption (b) is that the errors in each equation possess a finite variance and are homoschedastic, while (c) posits the absence of autocorrelation within and across equations.

A fourth stochastic assumption concerns the contemporaneous correlation among the disturbance terms of the different equations:

(d) $Eu_{it}u_{jt} = 0 \qquad i = 1, 2 \quad j = 3,4 \quad t = 1,2,\ldots, T.$

Specification (d) assumes that the disturbances in each period of equations (1) and (2) are not dependent upon the disturbances in that same period of equations (3) and (4). This assumption is not typically made explicit in econometric research but occurs implicitly whenever a variable (other than time) is classified as exogenous.[5] Several recent discussions have made the point that if assumptions such as (d) are approximately correct, then the statistical properties of the estimators will be approximately as claimed.[6]

[5] To be exogenous in a given model, a variable must be statistically independent of all of the model's disturbance terms. But this variable must be endogenous to some system. The disturbances of the latter must be independent of those of the given model or else the condition will not be met.

[6] See Fisher [22] and, for an application, Krzyzaniak [43].

Now the point of this discussion is that conditions (a)-(d) are sufficient to justify separate estimation of systems (1)-(2) and (3)-(4). This treatment is legitimate because the overall system (1)-(4) is block recursive; neither I nor M appear on the right hand side of (1) or (2).[7] Conditions (a)-(d) then guarantee that the current endogenous variables of subsystem (5.1)-(5.2) are uncorrelated in the probability limit with the current disturbances of subsystem (5.3)-(5.4). This fact then permits consistent estimation of the subsystems in isolation from each other. Thus we have justification for introducing them as different models. For a discussion of the theory of block recursive systems the reader is referred to Fisher [22].

It should be noted that we do not assume the disturbances u_1 and u_2 to be contemporaneously uncorrelated. There would be no point in doing so, since we would still have to utilize some "simultaneous equation" estimation procedure to avoid estimator inconsistency.

In the case of (5.3)-(5.4) the situation is somewhat different. This subsystem is itself recursive, as M does not appear in (5.3). Thus its two equations can be consistently estimated separately by ordinary least squares if u_3 and u_4 are contemporaneously independent. We therefore make that additional assumption:

(e) $Eu_{3t}u_{4t} = 0 \qquad\qquad t = 1, 2, \ldots, T.$

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[7] Recursiveness is defined by Malinvaud as follows: "A model is said to be recursive if there exists an ordering of the endogenous variables and an ordering of the equations such that the ith equation can be considered to describe the determination of the value of the ith endogenous variable during period t as a function of the predetermined variables and of the endogenous variables of index less than i" [55, p. 60]. Block recursiveness is discussed by Fisher [22].

5.3 Estimation Procedure

We are now in a position to outline the steps to be taken in estimating the various equations of our model. With (1)-(2) and (3)-(4) treated as separate systems and the latter capable of being consistently estimated by means of ordinary least squares (OLS), our procedure is as follows:

(i) Use OLS to estimate the parameters, including $(1-\nu)$, of the inventory-output equation (3).

(ii) Use OLS to estimate the parameters (other than ν) of the manhours equation (4).

(iii) Use the estimates of steps (i) and (ii) in equation (4) to construct a series of figures M_t^s, representing manhour usage at standard output, by substituting $Q_t^s = kC_t$ into (4) for both Q_t and D_t and recording the "predicted" values. Then the identity $L_t^s = M_t^s / Q_t^s$ gives a series of estimates of standard manhour usage figures.

(iv) Estimate the parameters of the equation system (1)-(2) using the values of L_t^s obtained in (iii). The test of the target return hypothesis is based upon the estimates obtained in this step.

Since (1) and (2) each contain two jointly dependent variables, some estimation technique that avoids asymptotic "least squares bias" is desirable. The two-state least squares (TSLS) technique will be used (subject to modifications discussed below), partly because of its relatively low computational cost and partly because its properties compare very favorably with those of other techniques such as full-information maximum likelihood and three-stage least squares.[8]

The fact that equations (1) and (4) are nonlinear in the parameters has been ignored so far in this chapter. We must now consider what complications are introduced by this nonlinearity. As (4) is estimated in isolation this property presents no procedural questions: one simply utilizes a computer program designed to find least squares estimates for nonlinear functions. A question does arise, however, concerning estimator properties in such regressions. Appendix B summarizes the conclusions of a recent examination of these properties by Malinvaud [55]. The parameter estimators are consistent under relatively general conditions.

More complex is the situation concerning the nonlinear pricing equation (1). We have stated that it will be estimated by TSLS. Published discussions of the TSLS procedure assume, however, that all structural equations are linear in the parameters. We are thus faced not only with concern over estimator properties but also with the question, what precisely _is_ TSLS procedure in this nonlinear context? Discussion of these issues is of necessity somewhat technical and is accordingly located in Appendix C. The procedure is spelled out there[9] and its estimators are shown to be consistent.

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[8] Actually the comparisons have been made only for linear systems. See Summers [80].

[9] Briefly, the procedure is as follows. The first stage consists of linear least squares estimation of the reduced form equations. The "predicted" values of the jointly dependent variables are then used as regressors in the second stage estimation of the structural parameters which proceeds by means of nonlinear least squares.

The final topic of this section is somewhat different in nature from those discussed to this point. It concerns the appropriate consideration to be given, while estimating behavioral relations (1)-(4), to the highly seasonal nature of the quarterly time series data. Our approach is to include seasonal dummy variables among the regressors. A short discussion of the issues involved and the reasons for selecting this approach is given in Appendix D.

Chapter 6

Industry Data and Structures

6.1 General

Chapters 2-5 above were devoted to development of a procedure for testing the target return pricing hypothesis; application of the procedure remains to be discussed. In this dissertation empirical results are presented for only two industries. This small number of applications is considered sufficient because a great deal of labor is required for each while the major analytical effort lies in the development of the procedure.

The two applications have been chosen with care. In view of our emphasis on development of a testing procedure, we have chosen industries such that the empirical results provide something of a test of the testing procedure itself, as well as a test of the target return hypothesis in each case. More specifically, we have chosen the lumber industry as one of the two to be studied because its competitive structure[1] implies that target return pricing should not be expected to prevail. Rejection of the hypothesis in the case of lumber will then constitute evidence favorable to the proposition that our model has the ability to detect deviations from target return behavior.

For the other application we have chosen the cement industry, one for which target return pricing appears more plausible. Cement

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[1]See Section 6.3.

has an oligopolistic structure[2] and a history such that a supporter of target return views should expect the hypothesis to be compatible with the empirical evidence.

There are other considerations which make the lumber and cement industries desirable objects of study. One is the relatively close correspondence between these industries and the theoretical concept of an industry.[3] While both cement and lumber markets are regional and both products have recognizable substitutes, the correspondence is better than in most cases because in both lumber and cement most firms produce basically one product which is virtually homogeneous among firms. Treatment as an "industry" is traditional in each case.

The existence of essentially one homogeneous product in each case provides another reason for considering these two specific industries: price and output indices suffer from index number problems to a minimal extent. A related consideration is the existence in each industry of standard product specifications which tends to reduce the possibility of product quality variation. This tendency is desirable because occurrence of such variations in

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[2] See Section 6.3.

[3] "... a group of products that are close substitutes to buyers, are available to a common group of buyers, and are relatively distant substitutes for all products not included in the industry" is the definition of Bain [7, p. 124].

response to supply-demand conditions would amount to price index measurement errors which would bias the test outcome toward acceptance of the target return hypothesis.[4]

A final consideration leading to adoption of lumber and cement is sheer data availability. Price, output, inventory, wage rate, labor usage, material cost, and salary figures are among those required. As various sources must be utilized, industry comparability among sources must be reasonably good. For many of the variables, the major data sources, the U.S. Department of Commerce, Department of Labor, and Internal Revenue Service, utilize different industrial classifications.[5] In the cases of cement and lumber, however, comparability is quite high.[6]

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[4] Since this measurement error exists for the dependent variable in the pricing equation, the major effect is to increase the apparent (estimated) variance of the stochastic disturbance term in the pricing equation. (See Johnston [34, pp. 6-7].) This leads to overstatement of the standard errors of the equation's parameters. Since the hypothesis is rejected when the estimates of the parameters ϕ and $(1-\delta)$ are large relative to their standard errors, the test outcome is biased toward acceptance. Borderline cases should be viewed with this in mind. Fortunately neither the cement nor the lumber industry test results are of a borderline nature.

[5] In recent years both the BLS and the IRS have been moving toward the SIC definitions used by the Commerce Department's Bureau of the Census.

[6] The cement and lumber classifications are as follows:

Agency	Industry Number	Designation
Bureau of the Census	SIC 3241	Cement, Hydraulic
Bureau of Labor Statistics	1322 - 0131	Cement, Portland
Internal Revenue Service	Minor Industry 3240	Cement, Hydraulic

Agency	Industry Number	Designation
Bureau of the Census	SIC 2421	Sawmills & Planing Mills
Bureau of Labor Statistics	081	Lumber
Internal Revenue Service	Minor Industry 2410	Logging, Lumber and Wood Basic Products

The following section presents a tabulation of our data and a discussion of the sources. The third and final section contains brief descriptions of the structural characteristics of the lumber and cement industries. These descriptions should be sufficient to substantiate the assertions made above to the effect that lumber and cement are, respectively, competitive and oligopolistic industries.

6.2 Data and Sources

The following paragraphs describe sources of the data used in the empirical portion of this study. Processing of the raw figures, where necessary to develop the series given in Tables II and III, is also described.

Prices (P)

The price data used is published by the United States Department of Labor, Bureau of Labor Statistics, in publications entitled Wholesale Prices and Price Indexes. Both monthly and annual versions of this source exist. More convenient versions of the same data are the BLS single-sheet compilations of wholesale price index numbers for single commodities. The BLS monthly figures were converted to quarterly figures by taking three-month means.

Wage Rates (w)

Wage rates came from United States Department of Labor, Bureau of Labor Statistics, Employment and Earnings Statistics for the United States 1909-65, Bulletin No. 1312-3. The figures used are entitled "Production-Worker Average Hourly Earnings - In Dollars." Monthly figures were averaged to yield quarterly figures.

Manhours (M)

Manhours per quarter were calculated using data from the same reference as used for wage rates. "Production Workers" and "Production - Worker Average Weekly Hours" series were multiplied to obtain average manhours per week. Further multiplication by 13 yielded manhours per quarter.

Quantity Demanded (D)

Monthly figures on "Lumber (all types) Shipments - Millions of board feet" and "Portland Cement Shipments, finished cement" were obtained from United States Department of Commerce, Office of Business Economics, Business Statistics (The Biennial Supplement to the Survey of Current Business).

Inventory (I)

Inventory stock figures came from the same source as did quantity demanded. The inventory balance identity was used to check the consistency of demand and inventory figures with others on production. A correction was required for recent years for lumber.

Assets (K)

Annual figures on total assets, excluding "other investments," were obtained from U.S. Treasury Department, Internal Revenue Service, Source Book of Statistics of Income. A description of the contents of the unpublished Source Book is contained in each annual IRS report, Corporation Income Tax Returns. Some of the figures and an argument for use of this particular concept of "capital" are contained in G.J. Stigler, Capital and Rates of Return in Manufacturing Industries (Princeton 1963).

Material Costs (m)

Annual figures for total cost of materials (including fuel) are available from the U.S. Commerce Department, Bureau of the Census, Census of Manufactures. Material costs per unit of output, annual basis, were obtained by multiplying this total cost by the price (index) of output and dividing the result by value of shipments. Quarterly figures were obtained by interpolation in the case of lumber. For cement a more sophisticated technique was possible. It was discovered that a simple regression of annual material cost per unit figures on annual values of the BLS price index for "Fuels & Related Products, and Power" resulted in an R^2 of .86. Thus quarterly data on the fuels price index permitted "prediction" of materials costs for quarters.

Salaries (F^s)

The Census of Manufactures contains figures on total payrolls, as well as total wages paid production workers. Thus annual figures on salaries (payments to nonproduction workers) per unit of (actual) output were obtained easily. Multiplication by output/standard output yielded salaries per standard unit. Quarterly figures were obtained by interpolation.

Capacity (C)

Monthly cement industry utilization figures (Q/C) came from Business Statistics. These were combined with output rates to yield capacity figures.[7]

<u>New Construction</u> (B, for cement)

Monthly figures on "New Construction" are available in <u>Business Statistics</u>. Quarterly totals were price deflated with the composite construction cost index developed by the Department of Commerce, Construction Statistics Division, reported in <u>Business Statistics</u>.

<u>Housing Starts</u> (B, for lumber)

Private, residential, nonfarm, monthly housing starts are reported in <u>Business Statistics</u>.

<u>Price of Substitute Commodity</u> (Pc)

The substitute commodity used for lumber is plywood. The price index source is the same as for the lumber and cement prices. For cement the price index, "Construction Materials", was used. This BLS index is published in the same source as is the plywood price index.

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[7] One adjustment to capacity figures was made. It was discovered that the capacity implied by Q and the reported Q/C figures dropped in the 1st quarter of each year. Such decreases in productive capacity are implausible. Apparently cement industry personnel are reluctant to recognize the very low utilization (Q/C) rates which occur each year in the 1st quarter and so overstate the true figures. Accordingly, straight-line interpolations between (previous year) 4th and 2nd quarter C values were adopted for the 1st quarter figures.

Cement Data, 1949-1956, Quarterly

Year	P	w	M	D	I
1949	70.60	1.335	18.80	32.43	23.10
	70.50	1.379	19.01	57.87	19.79
	70.23	1.413	18.97	65.72	10.80
	71.00	1.402	18.22	50.18	14.71
1950	71.13	1.398	17.84	34.12	23.22
	71.20	1.454	18.45	66.01	15.30
	71.60	1.466	18.69	71.22	7.64
	74.33	1.478	18.87	56.43	13.02
1951	77.70	1.513	18.39	41.21	23.25
	77.70	1.553	18.86	70.70	16.63
	77.70	1.590	19.21	73.35	10.50
	77.70	1.573	18.94	55.92	17.99
1952	77.70	1.573	18.53	43.05	26.62
	77.70	1.590	17.67	70.11	18.90
	77.70	1.633	18.30	77.24	9.58
	77.70	1.683	19.02	60.73	15.96
1953	77.90	1.703	18.71	48.49	23.87
	82.53	1.737	18.94	70.21	21.54
	82.70	1.823	19.52	81.01	12.86
	83.00	1.777	19.08	61.18	19.23
1954	83.30	1.777	18.54	45.10	28.90
	83.30	1.807	18.03	77.13	19.67
	85.57	1.880	19.31	85.62	10.91
	85.60	1.830	19.10	66.25	16.73
1955	86.73	1.837	18.79	50.49	26.52
	87.73	1.890	19.14	86.43	18.86
	87.90	1.953	19.74	91.24	9.78
	88.27	1.913	19.41	68.14	17.52
1956	92.43	1.910	19.07	52.06	29.87
	92.80	2.000	19.63	91.71	22.69
	93.30	2.107	20.63	95.38	15.53
	94.30	2.087	20.19	72.48	22.44

Table II

Cement Data, 1957-1964, Quarterly

Year	P	w	M	D	I
1957	97.30	2.083	19.69	47.96	34.28
	98.20	2.090	19.56	82.31	29.88
	98.20	2.237	17.24	92.27	20.25
	98.20	2.240	20.01	69.23	28.73
1958	100.30	2.230	18.03	42.37	36.73
	100.57	2.257	19.35	86.85	33.35
	100.50	2.367	19.84	102.00	24.44
	100.50	2.367	19.54	78.45	30.80
1959	101.50	2.363	17.61	52.75	36.38
	101.50	2.383	19.74	100.06	33.60
	101.50	2.467	20.48	109.83	25.31
	101.50	2.470	19.05	75.32	31.33
1960	103.50	2.463	17.27	45.42	39.16
	103.50	2.533	19.33	92.47	37.67
	103.50	2.590	19.45	103.45	30.51
	103.50	2.580	17.51	73.59	35.53
1961	103.60	2.577	15.21	50.90	38.24
	103.60	2.600	17.56	90.09	37.35
	103.50	2.677	18.17	102.82	31.78
	102.23	2.673	17.13	78.86	36.34
1962	103.10	2.667	15.09	49.41	39.81
	103.13	2.737	17.45	95.29	38.68
	103.07	2.797	18.41	109.40	32.52
	103.20	2.783	16.95	80.61	38.53
1963	102.90	2.780	14.54	50.78	42.33
	103.07	2.820	17.37	100.89	40.32
	103.07	2.833	18.01	115.95	33.24
	102.97	2.880	16.36	84.63	39.56
1964	101.00	2.860	14.89	57.74	45.15
	101.00	2.907	16.57	103.44	41.89
	101.00	2.983	17.46	118.18	34.71
	101.00	2.947	16.40	88.61	39.58

Table II (cont'd.)

Cement Data, 1949-1956, Quarterly

Year	K	m	F^s	C^*	B	P_c
1949	462	30.80	3.05	63.0	70.39	81.14
	462	28.61	3.09	63.4	88.50	78.18
	462	28.19	3.14	64.0	106.17	76.15
	462	28.64	3.19	64.4	100.45	76.50
1950	516	25.71	3.24	64.7	83.95	77.75
	516	25.73	3.28	65.0	109.16	79.95
	516	26.71	3.36	65.5	127.45	86.11
	516	27.21	3.46	66.0	116.29	88.43
1951	586	29.96	3.56	66.6	92.11	91.78
	586	29.64	3.66	67.2	107.69	91.76
	586	29.71	3.71	68.1	118.01	89.98
	586	29.96	3.72	68.7	108.50	90.31
1952	685	29.96	3.73	69.2	88.96	89.36
	685	29.37	3.74	69.8	108.09	89.45
	685	29.35	3.77	70.8	119.08	89.76
	685	29.73	3.84	71.1	112.86	89.76
1953	711	30.46	3.90	71.3	93.74	90.07
	711	30.22	3.96	71.4	114.63	91.10
	711	31.80	3.97	71.6	124.28	91.63
	711	31.89	3.92	71.4	114.06	90.77
1954	739	30.82	3.88	71.2	94.09	90.50
	739	29.94	3.83	71.2	117.46	89.97
	739	29.22	3.83	74.1	134.58	91.63
	739	29.50	3.86	74.3	125.57	92.40
1955	806	30.45	3.89	74.8	106.73	92.87
	806	29.76	3.92	75.3	133.00	93.90
	806	29.83	3.98	75.8	146.43	96.43
	806	30.48	4.04	77.3	130.52	97.33
1956	1029	31.85	4.11	78.9	102.58	98.07
	1029	31.66	4.18	79.2	127.57	99.23
	1029	31.78	4.22	80.4	141.37	99.33
	1029	32.43	4.25	80.7	128.86	99.13

*Adjusted 1st quarter figures; see text.

Table II (cont'd.)

Cement Data, 1957-1964, Quarterly

Year	K	m	F^s	C^*	B	P_c
1957	1200	35.51	4.27	86.7	103.16	98.90
	1200	35.52	4.30	87.9	125.97	99.10
	1200	34.53	4.27	90.1	140.28	99.43
	1200	34.37	4.20	91.4	129.92	98.63
1958	1451	33.75	4.13	92.2	101.00	98.50
	1451	32.14	4.05	93.1	122.35	97.97
	1451	33.37	4.01	98.7	141.05	99.10
	1451	33.19	3.99	100.2	137.91	100.10
1959	1601	33.03	3.97	101.5	111.14	100.90
	1601	32.35	3.95	102.8	139.54	102.63
	1601	31.84	3.95	102.9	154.01	102.50
	1601	31.69	3.97	103.8	137.17	102.20
1960	1548	33.26	3.98	104.4	108.21	102.27
	1548	33.12	4.00	105.0	133.43	101.33
	1548	34.72	4.00	107.4	144.65	99.70
	1548	35.26	3.98	108.2	134.69	98.77
1961	1570	34.07	3.97	108.5	108.45	98.50
	1570	32.67	3.95	109.8	133.62	99.00
	1570	32.62	3.95	110.5	147.74	98.67
	1570	32.47	3.98	110.2	141.60	98.23
1962	1555	32.30	4.01	110.9	110.64	98.43
	1555	32.16	4.04	111.7	141.75	98.77
	1555	32.30	4.06	115.1	158.79	98.27
	1555	32.65	4.10	116.0	147.31	97.87
1963	1722	33.10	4.12	117.4	113.76	97.67
	1722	33.10	4.15	118.7	143.28	98.07
	1722	32.53	4.17	120.1	161.57	99.33
	1722	32.15	4.18	120.7	156.17	98.80
1964	1736	33.51	4.19	120.7	120.92	99.10
	1736	32.29	4.20	120.8	149.28	99.70
	1736	32.20	4.21	120.9	163.84	99.70
	1736	32.95	4.22	121.0	152.27	99.73

*Adjusted 1st quarter figures; see text.

Table II (cont'd.)

Lumber Data, 1949-1956, Quarterly

Year	P	w	M	D	I
1949	83.96	1.114	189.7	67.39	42.39
	80.82	1.164	200.8	83.57	44.33
	77.65	1.169	204.7	86.48	45.15
	79.57	1.155	207.9	90.68	41.22
1950	83.77	1.135	188.3	85.00	33.22
	90.53	1.189	214.4	104.54	31.89
	99.72	1.237	234.2	106.63	34.94
	101.66	1.243	230.9	95.89	38.18
1951	103.74	1.237	213.1	90.62	33.05
	103.25	1.296	231.0	95.95	40.94
	101.16	1.333	222.1	87.13	51.34
	99.26	1.343	213.8	85.25	54.38
1952	99.08	1.310	193.0	86.54	51.16
	99.28	1.360	203.2	93.27	51.75
	99.04	1.430	216.9	100.21	54.25
	98.61	1.420	208.7	94.32	54.66
1953	99.00	1.393	190.4	88.44	52.36
	99.53	1.443	199.0	97.58	50.48
	98.03	1.466	197.8	90.86	56.06
	95.87	1.420	185.8	82.66	62.54
1954	95.10	1.427	167.9	84.65	65.33
	94.73	1.473	178.8	96.09	64.27
	97.60	1.433	174.0	89.64	63.20
	98.27	1.483	186.3	94.74	64.53
1955	99.57	1.460	175.5	89.65	63.08
	101.97	1.500	187.5	104.27	58.46
	103.80	1.537	194.6	100.88	57.00
	104.07	1.510	185.9	89.54	58.77
1956	105.73	1.503	170.7	94.08	56.35
	107.10	1.589	176.9	101.07	57.55
	104.40	1.620	176.2	94.12	64.50
	101.23	1.586	158.0	86.00	69.79

Table III

Lumber Data, 1957-1964, Quarterly

Year	P	w	M	D	I
1957	100.30	1.563	138.5	76.91	72.18
	99.33	1.616	146.3	90.33	69.62
	98.07	1.630	145.9	87.18	68.53
	96.23	1.623	135.1	77.00	67.38
1958	95.57	1.583	118.7	73.61	67.94
	95.83	1.613	128.0	86.65	64.73
	97.77	1.653	139.3	91.63	62.75
	98.97	1.656	137.9	85.26	64.08
1959	101.33	1.633	133.5	85.90	62.56
	105.80	1.679	147.8	99.42	60.39
	106.80	1.723	152.6	95.98	62.26
	104.07	1.706	145.0	86.40	68.04
1960	103.63	1.689	128.4	79.95	70.80
	102.40	1.706	143.0	89.10	71.44
	98.30	1.740	139.8	81.75	74.43
	94.93	1.703	123.6	71.43	75.07
1961	93.77	1.690	109.8	75.17	73.21
	95.97	1.763	120.6	88.09	69.95
	95.20	1.800	125.8	85.37	68.91
	93.83	1.793	119.1	78.02	68.61
1962	94.87	1.796	108.8	77.09	65.27
	97.30	1.823	122.8	90.24	61.40
	97.63	1.846	127.0	85.72	64.14
	96.27	1.843	118.3	80.22	67.12
1963	96.23	1.833	112.8	79.27	68.23
	98.40	1.842	121.9	90.60	65.92
	101.83	1.916	125.9	89.49	66.84
	99.27	1.940	120.9	84.74	68.48
1964	100.30	1.956	112.4	87.03	67.19
	102.00	1.957	123.5	92.68	64.59
	101.10	2.000	126.6	92.53	65.67
	99.57	1.983	120.1	83.63	66.69

Table III (cont'd.)

Lumber Data, 1949-1956, Quarterly

Year	K	m	F^s	B	P_c
1949	1825	35.9	2.37	245	101.83
	1825	37.9	2.48	401	97.16
	1825	39.9	2.59	425	93.00
	1825	41.3	2.70	395	95.67
1950	1794	42.9	2.80	393	101.47
	1794	44.4	2.91	598	102.87
	1794	45.6	3.03	568	111.37
	1794	46.7	3.16	393	117.83
1951	2119	47.9	3.29	347	119.70
	2119	49.1	3.43	402	119.80
	2119	49.6	3.49	370	118.30
	2119	49.5	3.47	301	110.80
1952	2274	49.4	3.45	312	106.77
	2274	49.3	3.44	403	107.54
	2274	49.5	3.37	398	107.79
	2274	49.9	3.27	333	105.44
1953	2219	50.3	3.16	319	112.47
	2219	50.8	3.05	414	114.30
	2219	51.4	3.06	365	112.63
	2219	52.2	3.19	303	105.78
1954	2163	53.0	3.32	299	105.75
	2163	53.8	3.45	418	102.42
	2163	54.5	3.61	432	105.75
	2163	55.0	3.77	383	106.19
1955	2246	55.6	3.85	361	106.67
	2246	56.1	4.11	496	107.24
	2246	56.6	4.23	442	107.74
	2246	57.1	4.32	328	107.82
1956	2551	57.5	4.40	299	109.46
	2551	58.0	4.49	396	105.40
	2551	58.3	4.45	353	102.39
	2551	58.3	4.32	277	96.89

Table III (cont'd.)

Lumber Data, 1957-1964, Quarterly

Year	K	m	F^s	B	P_c
1957	2948	58.3	4.19	243	98.38
	2948	58.3	4.06	335	98.83
	2948	58.3	3.96	331	97.33
	2948	58.2	3.88	266	98.01
1958	2692	58.1	3.81	235	95.73
	2692	58.0	3.73	344	95.33
	2692	58.1	3.73	385	101.98
	2692	58.5	3.79	350	102.73
1959	2671	58.8	3.86	319	104.08
	2671	59.2	3.92	447	108.32
	2671	59.2	3.91	415	101.78
	2671	58.9	3.83	314	98.14
1960	2846	58.5	3.76	261	98.79
	2846	58.2	3.68	370	97.50
	2846	57.7	3.61	336	97.26
	2846	57.0	3.57	263	97.84
1961	2969	56.3	3.51	241	93.16
	2969	55.6	3.46	367	99.37
	2969	55.4	3.44	372	97.10
	2969	55.5	3.44	304	92.80
1962	2762	55.5	3.45	270	93.20
	2762	55.6	3.45	434	93.10
	2762	55.5	3.45	391	92.23
	2762	55.2	3.46	344	91.93
1963	2975	55.0	3.47	289	90.73
	2975	54.7	3.48	483	91.50
	2975	54.6	3.70	437	99.30
	2975	54.8	4.12	372	92.43
1964	2913	54.8	4.50	326	92.83
	2913	55.0	4.90	455	93.90
	2913	55.2	5.01	403	91.97
	2913	55.8	4.81	346	90.73

Table III (cont'd.)

6.3 Cement and Lumber Industry Structures

This section will be devoted to very brief descriptions of the structural characteristics of the lumber and cement industries. These descriptions are not designed to serve as even miniature "industry studies". They are rather intended simply to substantiate our assertions that the cement and lumber industries are, respectively, oligopolistic and competitive in structure.

The cement industry is considered an oligopoly both by academic economists (e.g., Stigler [76] and by civil servants concerned with industrial organization (e.g., the Federal Trade Commission [21]). Figures from the latter reference show why. Even on a nationwide basis cement is a concentrated industry: the eight largest firms accounted for 48.9% of all sales in 1964 [21, p. 19]. But the high ratio of transportation cost to selling price for a bag of cement makes the relevant markets regional rather than national. In fact 90% of all cement is shipped 160 miles or less [21, p. 7]. Using a definition which makes a "region" virtually the same as a state, the FTC has found that in 34 of 51 regions, the largest four firms supply more than 75% of the cement sales [21, p. 30]. Also in many regions one or more of the leading sellers is one of the leading national firms. In 1964 at least two of the largest eight national firms appear among the top four firms in 39 of 51 regions [21, p. 31]. A major reason for high regional concentration, though not for dominance by large national firms, is the existence of economies of scale in production: the FTC has estimated that "a plant with a capacity of less than one million barrels [per annum] may have unit costs as much as 70 percent higher than a plant with a capacity in excess of 5 million barrels" [21, p. 32].

Not only are cement markets highly concentrated, also "cement is a homogeneous product turned out to rigid specification and, in general, the product of one plant is physically substitutable for the product of another" [21, p. 18]. The absence of product differentiation is attested to by the fact that most product research is carried out by an industry organization, only two firms being known to maintain their own research facilities [21, p. 39]. This characteristic of cement is significant because the attempts by firms in an oligopoly to eliminate price competition will be greater, the more homogeneous the product. When we add the consideration that fixed costs are unusually large in relation to variable costs in cement production it becomes apparent that cement is a rather extreme case of an oligopoly in which great efforts would be taken to avoid price competition by some means. Basing point pricing practices provided a means until outlawed in 1946; our discussion in Chapter 2 suggests that target return pricing could provide a convenient method today.

Lumber, on the other hand, is an industry with a structure that is unusually competitive, at least for manufacturing. The 1958 Census of Manufacturers indicated that 15,379 firms operated sawmills or planing mills and the 1963 Census counted 11,931. While there are a few large well-known firms, the largest 50 accounted for only 29% of the sales in 1963. The figures for the largest 4, 8, and 20 firms for recent years are given in Table IV. There it can be seen that concentration is increasing but still very low.[8]

[8] In terms of eight-firm concentration ratios based on values of shipments in 1958, lumber ranked 424 out of 426 [58, p. 98].

Percent of Value of Shipments of Lumber made by Largest n Companies

Year	n = 4	n = 8	n = 20
1963	11	14	20
1958	8	12	18
1954	7	11	18
1947	5	7	11

Table IV

Lumber markets are regional to an extent and thus concentration may be somewhat higher than suggested by the national figures of Table IV. The regionality is not great, however: in 1960 shipments from the Douglas fir region[9] went to every state in the nation [58, p. 8].

Perhaps as unusual as its lack of concentration is the lumber industry's ease of entry. We quote the 1968 Encyclopedia Britannica: "Sawmills vary widely in size. The largest plants, employing several thousand persons, and the smallest, operated by fewer than a dozen men, often coexist in the same region. Large-scale operations offer no decisive competitive advantage; moreover, the small capital investment required (about $10,000 in the U.S. for the average rotary sawmill) facilitates entry into the business. A group of farmers living in a wooded area may operate a sawmill part time" [41].

[9] The portions of Oregon and Washington west of the Cascade Mountains constitute the Douglas fir region which accounts for about 25% of the nation's lumber production.

Mead's more scholarly study of entry conditions yields slightly less dramatic figures: he estimates that about $70,000 is needed to purchase a mill of suboptimal size. Still he summarizes as follows: "Overall, the conclusion is inescapable that barriers to entry into the lumber industry are minimal, relative to other important segments of the American industrial economy" [58, p. 123].

When the use of standard product specifications is added to the above considerations, it can be seen that lumber is indeed an industry with a remarkably competitive structure. Most economists would accordingly predict that target return pricing would be very unlikely to prevail in lumber.

Chapter 7

Empirical Results

7.1 Introduction

Finally we turn to the actual test results for the cement and lumber industries. In the case of lumber the target return pricing hypothesis is rejected soundly. This result is not surprising since, as we have seen, the lumber industry has a highly competitive structure. Rejection of the hypothesis should come as no surprise, even to proponents of target return views. The result is nevertheless of considerable importance as it demonstrates the ability of the test procedure to detect deviations from target return behavior.

In the case of cement, on the other hand, actual price movements have coincided to a high degree with those implied by the hypothesis. We are thus unable to reject the hypothesis that target return pricing prevails in the cement industry. Again the results are clear-cut, the test statistics lying well outside the critical rejection region.

The following sections of this chapter present detailed results of the empirical studies. Section 7.2 is devoted to cement and Section 7.3 to lumber. This order of presentation is designed to facilitate the exposition. Estimates of functions designed to "explain" behavior of output, manhour, demand, and price variables are given for both industries. Each equation is discussed in a separate subsection. Also for each industry we have included a subsection which discusses the specific test results. Remarks on some favorable features of the results are made in Section 7.4.

Some estimates are presented in equation and some in tabular form. In all cases the figures in parentheses below or beside parameter estimates are standard errors, i.e., estimates of the standard deviations of the related parameter estimators. The symbols R^2, s^2, T, and DW stand (respectively) for the coefficient of multiple determination,[1] the estimate of the variance of the disturbance term, the number of observations, and the Durbin-Watson test statistic. In all cases s^2 is the sum of squared residuals divided by T-K where K is the number of parameters estimated.

The regressions were run using the Rice University IBM 7040 computer and the University of Virginia Burroughs B-5500. PLATO 1, written by John Conlisk, was the program used for the linear regressions while the nonlinear cases used D.W. Marquandt's NLIN, IBM SHARE library distribution number 3094 [56][57][15].

7.2 Cement Industry

7.2.1 Inventory-Output Equation

All equations for cement were estimated using quarterly data for the years 1949-64. Results of estimating the basic inventory model presented as equation (19) of Chapter 4 are not satisfactory. The point estimate of $(1-\mu)$ is virtually zero, implying that output is planned to eliminate none of the discrepancy between desired and

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[1] The R^2 figures are not "adjusted for degrees of freedom". The latter statistics can be obtained, if desired, by means of the formula $\bar{R}^2 = 1 - (1-R^2)\ (T-1)/(T-K)$.

actual inventory stocks. This result is particularly unbelievable for cement because output changes from quarter to quarter, due to seasonality, are extremely wide. At the same time, the estimate of δ exceeds 1.0, implying that anticipations concerning demand adjust extremely rapidly.[2]

Cement Inventory-Output Estimates
Quarterly 1949-64

	Case I	Case II
<u>Parameters</u>		
e_1	3.912 (1.27)	2.522 (1.37)
e_2	-10.40 (3.11)	-7.548 (2.63)
e_3	-13.10 (1.79)	-9.929 (1.36)
$\delta\ (1-\mu)\theta_o$	- 2.959 (2.81)	-9.998 (1.51)
$(1-\delta)$	.3445 (.322)	.3233 (.085)
μ	.1368 (.334)	0.0 (constrained)
ν	-.1045 (.035)	- .0809 (.034)
$(1-\mu)\theta_1 k$	.3909 (.151)	.6613 (.083)
<u>Statistics</u>		
R^2	.9762	.9756
s^2	2.824	2.844
T	62	62
DW	2.03	1.62

Table IV

[2] In addition, this estimate of δ does not agree with the one obtained in the manhours equation to be discussed below.

The modified inventory-output model based on standard output, equation (21) of Chapter 4, was accordingly tried. We rewrite that equation here, adding seasonal effect coefficients e_1, e_2, and e_3. Q1, Q2, and Q3 are the quarterly dummy variables.

$$(1)\quad I = e_1Q1 + e_2Q2 + e_3Q3 + \delta(1-\mu)\theta_0 + (1-\delta+\mu)I_1 - \mu(1-\delta)I_{-2}$$
$$-\nu(D-D_{-1}) + (1-\mu)\theta_1kC - (1-\delta)(1-\mu)\theta_1kC_{-1} + u_3$$

Results of estimating this nonlinear equation are presented as Case I in Table IV. The standard errors for the estimators of μ, $(1-\delta)$, and $(1-\mu)\theta_1k$ are large relative to the estimates. As μ is apparently close to zero and as the $s^2(F'F)^{-1}$ matrix suggests nonlinear multicollinearity[3] associated with μ, this equation was re-estimated with μ constrained to zero. The results are given as Case II in Table IV. As can be seen readily, the standard errors for $(1-\delta)$ and θ_1k are much smaller than in Case I. The estimate of ν provided by Case II is therefore the one used in constructing the L^s series for use in the pricing equation.

7.2.2 Cement Manhours

The nonlinear manhours equation (9) of Chapter 4 is rewritten here with seasonal effect variables added.

$$(2)\quad M = e_1Q1 + e_2Q2 + e_3Q3 + a_0 + (1-\delta)M_{-1} + a_{10}C + a_{11}tC$$
$$- a_{10}(1-\delta)C_{-1} - a_{11}(1-\delta)(tC)_{-1} + \beta Q - \beta(1-\delta)Q_{-1}$$
$$- a_2(1-\nu)(D-D_{-1}) + u_4$$

The estimates are reported in Table V. Two results are of particular interest. First, the point estimate of $1-\delta$ is .381 which is quite close

[3]See Appendix C.

Cement Manhour Estimates

Quarterly 1949-64

<u>Parameters</u>		
e_1	1.702	(.341)
e_2	1.849	(.836)
e_3	.800	(.464)
a_0	1.284	(1.76)
$(1-\delta)$	.3808	(.114)
a_{10}	.1053	(.038)
a_{11}	-.0019	(.0003)
$a_2(1-\nu)$	.0606	(.018)
β	.1500	(.017)
<u>Statistics</u>		
R^2	.8507	
s^2	.3095	
T	62	
DW	2.40	

Table V

to the .323 value obtained in the inventory-output equation, Case II. Second, the estimates of a_{10} and a_2 are positive while the implied estimate of $a_3 = \beta - a_2$ is also positive as predicted by the Wilson-Eckstein hypothesis. (See Section 4.2.) Thus the values obtained lend confidence to the model.

7.2.3 Cement Demand

The general purpose demand function proposed in Section 3.6 was modified in one minor way for application to cement: the coefficient of the demand-inducing variable B (here new construction) was allowed to vary over time. This modification was designed to permit technical change in the cement-using construction industry. The parameter estimates are as follows:

$$(3)\quad \hat{D} = \underset{(3.17)}{8.036}\,Q1 + \underset{(5.07)}{14.82}\,Q2 + \underset{(2.47)}{17.70}\,Q3 + \underset{(13.5)}{.3665} + \underset{(.145)}{.4798}\,B$$

$$+ \underset{(.0009)}{.00243}\,tB - \underset{(.184)}{.2918}\,(P-P_c) - \underset{(.109)}{.0525}\,D_{-1}$$

$$R^2 = .9675 \qquad s^2 = 16.44 \qquad T = 62 \qquad DW = 1.44$$

Since the estimate of $(1-\xi)$ is of the wrong sign and "insignificant," the value of $(1-\xi)$ was set at zero and the equation re-estimated. The results are as follows:

$$(4)\quad \hat{D} = \underset{(3.03)}{7.616}\,Q1 + \underset{(1.46)}{17.15}\,Q2 + \underset{(1.80)}{18.50}\,Q3 - \underset{(13.3)}{.4042} + \underset{(.131)}{.4505}\,B$$

$$+ \underset{(.0009)}{.00236}\,tB - \underset{(.183)}{.2888}\,(P-P_c)$$

$$R^2 = .9674 \qquad s^2 = 16.21 \qquad T = 62 \qquad DW = 1.51$$

The coefficients of B and $P-P_c$ are of the right sign. The estimated price elasticity at the point of sample means is -.36.

Equations (3) and (4) give OLS estimates for the structural demand equation. Two-stage least squares parameter estimates were also obtained. They are virtually identical to those of (4).

7.2.4 Cement Pricing

The target return hypothesis asserts that the following equation provides a complete explanation of price movements for an industry:

$$(5) \quad P = e_1\, Q1 + e_2\, Q2 + e_3\, Q3 + \alpha\lambda r\, K^s + \alpha\lambda W + (1-\lambda)\, P_{-1} + u_1.$$

The more neoclassical alternative hypothesis contends, to the contrary, that superior explanation is provided by one of the following:

$$(6) \quad P = e_1\, Q1 + e_2\, Q2 + e_3\, Q3 + \alpha\lambda r\, K^s - \alpha\lambda r\, (1-\delta)\, K^s_{-1}$$
$$+\alpha\lambda W - \alpha\lambda)1-\delta)W_{-1} + (2-\lambda-\delta)P_{-1} - (1-\delta)(1-\lambda)P_{-2} + \phi(D-D_{-1}) + u_1$$

$$(7) \quad P = e_1\, Q1 + e_2\, Q2 + e_3\, Q3 + \alpha\lambda r\, K^s - \alpha\lambda r(1-\delta)K^s_{-1} + \alpha\lambda W - \alpha\lambda(1-\delta)W_{-1}$$
$$+ (2-\lambda-\delta)P_{-1} - (1-\delta)(1-\lambda)P_{-1} + \phi D - \phi(2-\lambda)D_{-1} + \phi(1-\lambda)D_{-2} + u_1$$

Equations (6) and (7) represent the different dynamic formulations proposed as equations (19) and (20) of Chapter 3. As mentioned there, we shall concentrate upon version (6).

Tables VI and VII contain various estimates of equations (5), (6), and (7). Case identifications are given using symbols H, H_A, and H_A' to refer, respectively, to formulations (5), (6), and (7). The letters OLS and TSLS refer to the estimation techniques "ordinary least squares" and "two-stage least squares." Linear regression results appear in Table VI while nonlinear results are in Table VII.

Cement Pricing Estimates

Linear Regressions

Variables	Case I (OLS, H)	Case II (OLS, H_A)	Case III (OLS, $H_A{}'$)
Q1	.4403 (.376)	.0506 (.436)	.4188 (.819)
Q2	.1377 (.357)	1.268 (1.24)	1.533 (1.35)
Q3	-.1192 (.349)	.3132 (.730)	-.0095 (.998)
K^s	.0134 (.0052)	.0252 (.0092)	.0246 (.0094)
K^s_{-1}		-.0163 (.0096)	-.0157 (.0099)
W	.1849 (.0450)	.4388 (.141)	.4399 (.146)
W_{-1}		-.3088 (.142)	-.3109 (.150)
P_{-1}	.8439 (.0435)	.7940 (.140)	.7971 (.145)
P_{-2}		.0961 (.126)	.0914 (.129)
$D - D_{-1}$		-.0143 (.0196)	
D			-.0126 (.0254)
D_{-1}			.0239 (.0267)
D_{-2}			-.0099 (.0260)
Statistics			
R^2	.9932	.9940	.9941
s^2	0.976	0.922	0.953
T	62	62	62
DW	1.91	2.04	2.03

Table VI

Cement Pricing Estimates

Nonlinear Regressions

	Case IV (OLS, H_A)	Case V (OLS, H_A')	Case VI (TSLS, H_A)	Case VII* (OLS, H_A)	Case VIII* (OLS, H_A')
Parameters					
e_1	.4364 (.387)	.8156 (.576)	.4057 (.388)	.4302 (.391)	.4256 (.428)
e_2	.9789 (1.29)	1.310 (1.32)	-.3025 (1.41)	.1490 (.593)	.0902 (.552)
e_3	.3417 (.755)	-.0019 (.380)	-.3495 (.816)	-.0818 (.472)	-.1224 (.371)
α	1.125 (.132)	1.112 (.129)	1.201 (.143)	1.222 (.115)	1.226 (.114)
λ	.1639 (.0472)	.1639 (.0472)	.1621 (.0467)	.1803 (.0518)	.1806 (.0517)
r	.0784 (.0216)	.0792 (.0216)	.0718 (.0204)	.0646 (.0177)	.0643 (.0176)
$1-\delta$	.0671 (.138)	.0722 (.138)	.0504 (.138)	.0816 (.138)	.0799 (.138)
ϕ	-.0145 (.0203)	-.0140 (.0148)	.0067 (.0225)	-.0012 (.0087)	-.00005 (.0052)
Statistics					
R^2	.9933	.9933	.9932	.9932	.9932
s^2	1.000	0.993	1.008	1.008	1.009
T	62	62	62	62	62
DW	1.99	1.98	2.01	2.00	2.00

*Trend values for L^s utilized.

Table VII

Case I refers to results obtained assuming the target return hypothesis to be true, in which case $\phi = (1-\delta) = 0$. It is immediately apparent that the hypothesis is, in fact, highly compatible with the data. The fraction of price variability "explained" by the regression is very high: $R^2 = .9932$. The Durbin Watson test statistic suggests that (first order) autocorrelation is not present.[4] A residual plot does not suggest heteroschedasticity. The estimates of the individual coefficients of K^s, W, and P_{-1} are large compared to their standard errors. And the implied estimates of the parameters are of very reasonable magnitude: $\hat{\alpha} = 1.184$, $\hat{\lambda} = .1561$, and $\hat{r} = .0725$.

OLS estimates under the alternative hypothesis are presented as Cases II-V. The R^2 figures for the unconstrained linear regressions II and III are of course higher than those for IV and V, in which the

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[4] The Durbin Watson statistic is of course biased toward 2.0, and thus toward indication of no autocorrelation, by the presence of lagged dependent variables [67]. Still, the figures give some indication concerning the chances of serious autocorrelation. A value as close to 2.0 as 1.8 is very unlikely to arise if the letter is present.

A brief table showing acceptance and rejection regions is given below for 60 observations. The hypothesis referred to is that of no first order autocorrelation, the alternative is positive first order autocorrelation, and the significance level is .05. The figures were obtained by extrapolation of the Durbin Watson values [17].

	6 regressors	10 regressors
Accept	4.00-1.81	4.00-1.95
Inconclusive	1.81-1.37	1.95-1.23
Reject	1.37- 0	1.23- 0

It will be noted that a large number of regressors leads to a very large inconclusive region.

nonlinear constraints are imposed. In none of the cases is R^2 much higher than under the target return hypothesis. Also standard errors are large relative to the estimates of the parameters ϕ and $1-\delta$.[5] Thus it appears that the target return hypothesis cannot be rejected for cement. More formal test results will be given in the following section.

Parameter estimates obtained by nonlinear OLS regressions IV and V, for the two specifications (6) and (7), are very similar. Thus TSLS estimates were obtained only for specification (6). The results, reported as Case VI, differ very little from those obtained by means of ordinary least squares.

The final two cases, VII and VIII, are designed to illustrate the effect of using trend values of manhours per unit of output, instead of those "predicted" by the Wilson-Eckstein model, in calculating values of the regressor W. As was mentioned toward the end of Section 4.2, the cruder trend values must be used in cases (such as lumber) where data on productive capacity is not available. Fortunately the check confirms, at least in this case, our conjecture that the pricing equation estimates are very little affected by the substitution of the trend figures.

7.2.5 Cement Test Results

It will be recalled from Chapter 3 that the target return hypothesis will be rejected for an industry if either of the two tests leads to rejection. The first is a test of the hypothesis $\phi = 0$ against the one-sided alternative $\phi > 0$. It is carried out by

[5] This statement refers primarily to the nonlinear Cases IV and V. Multiple estimates of ϕ are provided by III and multiple estimates of $1-\delta$ by both II and III.

comparing the "t score" (ratio of estimate to standard error) of the estimate of ϕ in a regression with the critical value needed for rejection. If the t score exceeds the critical value then the target return hypothesis is rejected at the indicated significance level.[6] Table VIII reports the t scores for the various cases. The critical values for .05 and .01 significance levels are 1.67 and 2.39.[7] In all cases the t-score is well below the critical value for both significance levels: in most cases, in fact, it is negative.[8] Thus the t test does not permit rejection of the hypothesis.

The more stringent test is based on the following statistic which possesses, under the target return hypothesis, an F distribution with J and T-K degrees of freedom:

$$(8) \quad F = \frac{SSE^{*} - SSE}{SSE} \; \frac{T-K}{J} \quad .$$

Here SSE is the sum of squared regression residuals, SSE* is the sum of squared residuals for a regression with the constraints implied by

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[6] A two-sided "t test" is of course a special case of the more general "F test" for the significance of a set of variables. As discussed in Chapter 3, we here use the terms "t test" and "F test" simply as shorthand terms for referring to our two tests which involve different numbers of parameter constraints.

[7] These numbers are for 60 degrees of freedom. Our cases have degrees of freedom between 50 and 54 with exact critical values within .01 of those for d.f.=60.

[8] Case III is not reported because it does not yield a unique estimate of ϕ.

Cement Test Results

Case No.	t Score	Critical value*	F Statistic	Critical value*
II	-.73	1.67	1.82	2.56
III	--	1.67	1.22	2.29
IV	-.71	1.67	.33	3.17
V	-.95	1.67	.54	3.17
VI	.30	1.67	.13	3.17
VII	-.14	1.67	.11	3.17
VIII	-.01	1.67	.10	3.17

*Approximate, for .05 test size (significance level)

Table VIII

the hypothesis imposed, while J is the number of constraints.[9] In our problem SSE* refers to Case I and SSE to each of the other Cases. For the nonlinear regressions J = 2 representing $\phi = (1-\delta) = 0$. The linear regressions, which are estimated with more coefficients, have more effective constraints implied by the target return hypothesis: J = 4 for Case II and J = 6 for Case III.

Again the results do not permit rejection of the hypothesis. Only in the unconstrained linear regression Cases II and III are the test statistics even of the same order of magnitude as the required critical values. In these cases the number of parameters actually estimated exceeds the correct number implied by the alternative hypothesis. Use of the F test in these linear cases is not really legitimate, for the estimator of the variance of u_1 (upon which the test depends) is inefficient. The difference between the values of the F statistics with and without the nonlinear constraints illustrates the desirability of using nonlinear regression techniques.

We conclude that price behavior in the cement industry is consistent with the target return pricing hypothesis. Next we turn to results for the lumber industry.

7.3 Lumber Industry

7.3.1 Inventory-Output Equation

All equations for the lumber industry were estimated using quarterly data for the years 1949-64. The results of estimating the inventory-output equation (19) of Chapter 4 were satisfactory, in contrast to the

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[9] This F test is, with normal disturbances, a likelihood ratio test. See Scheffe [74, p. 36] or Draper and Smith [15, p. 74].

situation for the cement industry. The results of the (linear) regression are:

$$\text{(9)}\quad \hat{I} = \underset{(.993)}{-2.190}\, Q1 + \underset{(1.60)}{2.285}\, Q2 + \underset{(1.02)}{2.273}\, Q3 + \underset{(7.97)}{5.541} + \underset{(.118)}{1.347}\, I_{-1}$$

$$-\underset{(.111)}{.4138}\, I_{-2} - \underset{(.086)}{.2384}\, D + \underset{(.080)}{.2165}\, D_{-1}$$

$$R^2 = .9514 \qquad s^2 = 6.42 \qquad T = 62 \qquad DW = 1.96$$

The implied estimates of μ and $1-\delta$ are .473 and .873.

7.3.2 Lumber Manhours

It was necessary to use a relatively crude trend model for obtaining standard manhours for the lumber industry because of the absence of capacity data. The model expressed in equation (10) of Chapter 4 was first tried. It was then discovered that significant additional "explanation" was provided by the variable $Q-Q_{-1}$, the change in output from the previous period. With this term included, estimates are as follows:

$$\text{(10)}\quad \widehat{M/Q} = \underset{(.033)}{2.532} - \underset{(.024)}{.0202}\, Q1 + \underset{(.040)}{.0670}\, Q2 + \underset{(.027)}{.00001}\, Q3 - \underset{(.020)}{.0294}\, t$$

$$+ \underset{(.00003)}{.000168}\, t^2 - \underset{(.0018)}{.01013}\, (Q-Q_{-1})$$

$$R^2 = .9661 \qquad s^2 = .00434 \qquad T = 62 \qquad DW = .82$$

Figures of the smoothed M/Q series "predicted by this equation, with seasonal effects eliminated and $Q-Q_{-1}$ set equal to zero, were then used as the L^s figures in the pricing equation.

It will be noted that the Durbin-Watson statistic indicates that autocorrelation of the disturbances is present. Thus the parameter estimators are inefficient and their standard errors understated

[25, p. 179]. If our purpose had been to develop a "good" model for manhour determination we would not have been satisfied with equation (10).[10] Our purpose, however, is only to provide estimates of L^s for use in the pricing equation. The cement industry results suggest strongly that L^s estimates obtained from regressions such as (10) are, in fact, adequate: recall the agreement between Cases IV and VII and between Cases V and VIII in the cement pricing results. The "quality" of the estimates of (10) is on a par with that of the crude trend manhours model used in cement: for the latter we have $R^2 = .9442$ and DW = 1.15.[11]

7.3.3 Lumber Demand

Housing construction is an important determinant of lumber demand. The demand-inducing variable B is here taken, then, to refer to thousands of nonfarm private housing units started in a period. The relative price chosen is $P-P_c$, where P is the lumber price index and P_c is the price index for Plywood (which is not an element of the BLS lumber price index). The OLS regression yielded the following results.

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[10] Equation (10) was also re-estimated in first differenced form. This transformation resulted in elimination of the autocorrelation (DW = 1.99) and yielded parameter estimates which differred from those of (10): values corresponding to the coefficients of t, t^2, and $(Q - Q_{-1})$ are -0.0139, 0.000134, and -0.0083, respectively. The differences are largely offsetting, however, so that the L^s values implied by (10) are very similar, the simple correlation between the two series being 0.965.

[11] There is inherent interest in estimates of the Wilson-Eckstein model, since it represents an attempt at explanation of manhour utilization. That interest, however, does not carry over into the simplified model of equation (10).

$$(11)\quad \hat{D} = \underset{(6.56)}{19.91} + \underset{(1.29)}{2.872}\ Q1 + \underset{(1.74)}{8.890}\ Q2 + \underset{(1.34)}{1.363}\ Q3 + \underset{(.0094)}{.0496}\ B$$

$$- \underset{(.059)}{.0643}\ (P-P_c) + \underset{(.077)}{.5340}\ D_{-1}$$

$$R^2 = .8268 \qquad s^2 = 11.27 \qquad T = 62 \qquad DW = 2.21$$

TSLS estimates were also computed. They are as follows.

$$(12)\quad \hat{D} = \underset{(6.53)}{20.45} + \underset{(1.28)}{2.817}\ Q1 + \underset{(1.73)}{8.905}\ Q2 + \underset{(1.33)}{1.99}\ Q3 + \underset{(.0093)}{.0491}\ B$$

$$- \underset{(.060)}{.0806}\ (P-P_c) + \underset{(.077)}{.5294}\ D_{-1}$$

$$R^2 = .8288 \qquad s^2 = 11.14 \qquad T = 62 \qquad DW = 2.21$$

7.3.4 Lumber Pricing

Several sets of estimates were obtained for the lumber pricing equation. Results are reported in Tables IX and X. These two tables contain estimates based on linear and nonlinear regressions, respectively.

Cases I and II of Table IX present OLS estimates under the target return constraints $\phi = (1-\delta) = 0$. The coefficient of K^s is negative in Case I, implying a negative estimate of r. Case II's results were obtained with r constrained to be zero. The R^2 figures for both Cases I and II are around 0.85, indicating that the target return formula explains a large portion of the price variability but not so much as to rule out direct demand effects. The latter, as we shall show, turn out to be important.

Cases III and IV represent unconstrained linear OLS estimation of the pricing equation under the alternative hypothesis. In these cases the nonlinear restrictions relating basic parameters are not

Lumber Pricing Estimates

Linear Regressions

Variables	Case I (OLS, H)	Case II (OLS, H)	Case III (OLS, H_A)	Case IV (OLS, H_A')
Q1	1.777	1.724	1.869	2.137
	(.759)	(.809)	(.610)	(.497)
Q2	2.453	2.484	-.1464	.9397
	(.763)	(.814)	(1.03)	(.893)
Q3	1.216	1.286	-.0822	.0380
	(.748)	(.797)	(.602)	(.815)
K^S	-.0028			
	(.0009)			
W	.2419	.0778	.6006	-.7114
	(.0982)	(.0864)	(.369)	(.380)
W_{-1}			-.4187	.8493
			(.345)	(.363)
P_{-1}	.8595	.9243	1.455	1.194
	(.0704)	(.0713)	(.111)	(.103)
P_{-2}			-.6101	-.4940
			(.103)	(.0864)
$D - D_{-1}$			.1068	
			(.0545)	
D				.1923
				(.0466)
D_{-1}				.0031
				(.0538)
D_{-2}				.0063
				(.0484)
Statistics				
R^2	.8585	.8363	.9263	.9540
s^2	4.495	5.107	2.427	1.572
T	62	62	62	62
DW	.90	.77	2.58	2.34

Table IX

Lumber Pricing Estimates

Nonlinear Regressions

Parameters	Case V (OLS, H_A)	Case VI (OLS, H_A)	Case VII (OLS, H_A')	Case VIII (TSLS, H_A)	Case IX* (TSLS, H_A)
e_1	1.764 (.630)	1.657 (.604)	1.925 (.658)	1.636 (.646)	1.593 (.620)
e_2	-.3671 (1.03)	-.4992 (1.02)	1.185 (.957)	-.5956 (1.28)	-.5748 (1.17)
e_3	.0209 (.618)	-.0321 (.610)	.6987 (.686)	-.0545 (.641)	-.0898 (.630)
α	1.377 (.340)	1.169 (.0848)	1.084 (.0820)	1.175 (.099)	1.177 (.0870)
λ	.2593 (.311)	.3011 (.294)	.4009 (.253)	.2971 (.321)	.3822 (.262)
r	-.0049 (.0065)	0.0 **	0.0 **	0.0 **	0.0 **
$1-\delta$	.6876 (.285)	.7592 (.236)	.7818 (.195)	.7584 (.253)	.8004 (.191)
ϕ	.1345 (.0543)	.1401 (.0512)	.0411 (.0428)	.1457 (.0707)	.1382 (.0595)
Statistics					
R^2	.9238	.9227	.9125	.9197	.9215
s^2	2.510	2.499	2.828	2.630	2.537
T	62	62	62	62	62
DW	2.31	2.30	1.89	2.20	2.25

* Extended model, m endogenous.

** (constrained)

Table X

imposed. Case III refers to formulation (6) and Case IV to formulation (7) of the alternative hypothesis.

It will be noted that in both III and IV, r is constrained to equal zero. Comparison of Cases V and VI of Table X shows why it was decided to rely on results with $\hat{r} = 0$. These cases both refer to nonlinear OLS estimation under the alternative hypothesis, version (6). The only difference in V and VI is that $\hat{r}$ is zero by constraint in the latter. Most of the estimates are similar in V and VI, but the value of α is more reasonable in the latter and its standard error is less than a third as large as in V. The reason for this difference is the presence in V of nonlinear multicollinearity in the form of a high (-.965) estimated correlation between the estimators of α and r. In view of this undesirable property[12] and the (insignificant) negative estimate of r, it was decided to base conclusions on results obtained from regressions with $\hat{r} = 0$ by constraint.[13]

Case VII is the nonlinear OLS estimation of the second formulation of the alternative hypothesis, the one represented by equation (7). Case VIII is the two-stage least squares estimation of the preferred version (6) of the alternative hypothesis. The final case, IX, requires a few words of explanation.

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[12] In addition to unnecessarily large sampling errors, nonlinear multicollinearity also creates convergence difficulties in the nonlinear regression algorithm.

[13] This does not imply that lumber firms earn zero profits on the average or that they aim for zero profits in pricing. In the next subsection we conclude that they do not follow target return pricing.

We have placed some stress at various points of this study on the desirability of formulating our testing procedure so as to be generally applicable to a wide variety of industries. We feel compelled, however, to recognize one special feature of the lumber industry which contrasts with the assumptions of our model. We refer to the fact that a very large portion of the materials expense of lumber mills is for logs. Further, lumber mills utilize a large fraction of all timber log production. Thus the material cost per unit variable m, which with constant technology equals log price, would be expected to vary with lumber demand. The variable m should then perhaps be treated as an endogenous variable, rather than as exogenous. In Case IX we have treated m as endogenous, obtaining the displayed estimates with $\hat{m}$ values[14] used instead of m to help explain P.

The reader may have noticed that in most of the cases of Tables IX and X the estimates of the parameter ϕ are large relative to their standard errors. He may also have noticed that the R^2 figures for Cases III-IX are substantially larger than for Cases I and II. If so he may have surmised that the target return hypothesis cannot be accepted as descriptive of lumber pricing. We turn now to a brief but more formal treatment of our test.

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[14] $\hat{m}$ values are the values of m "predicted" by the reduced form equation which has m as its dependent variable.

7.3.4 Lumber Test Results

Table XI presents the lumber test results in the same way that Table VIII does for cement. Accordingly little discussion is needed. It will readily be seen that in six of the seven cases estimated under the alternative hypothesis, the t scores exceed the 1.67 critical value required for rejection, at the .05 significance level, of the hypothesis $\phi = 0$. The F test of the hypothesis $\phi = (1-\delta) = 0$ produces even stronger results: in all seven cases the test statistic is several times as large as the critical value for a .01 significance level.[15]

The target return hypothesis must therefore be rejected. Lumber industry prices do not conform to the pattern predicted by that hypothesis. This result is not surprising since the industry is competitively structured. The result is highly desirable, from the point of view of our research, since it demonstrates the ability of our test procedures to detect deviations from target return behavior.

When the hypothesis is untrue price and quantity demanded are jointly dependent variables. Thus the TSLS results, Case VIII, must be regarded as yielding the "preferred" estimates. It is therefore

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[15] A word may be in order concerning the reporting of results for two different tests, the t test and the F test. Why do we use two different tests, whose results could differ? Since target return pricing implies that both ϕ and $(1-\delta)$ equal zero, most readers would presumably be willing to take the results of the F test as conclusive. But some might be reluctant to reject the target return hypothesis unless $\phi > 0$ because of the more direct connection of ϕ with demand variables. These readers would be interested in the t tests. It is gratifying that the results of the two tests agree in 11 of 12 specifications considered.

Lumber Test Results

Case No.	t score	Critical value*	F statistic	Critical value**
III	1.96	1.67	16.18	3.68
IV	--	1.67	21.77	3.18
V	2.48	1.67	23.15	5.01
VI	2.74	1.67	30.74	5.01
VII	0.96	1.67	23.96	5.01
VIII	2.06	1.67	27.83	5.01
IX	2.32	1.67	29.87	5.01

* Approximate, for .05 test size (significance level)

** Approximate, for .01 test size (significance level)

Table XI

gratifying that the Durbin-Watson statistic is close to 2.0 and that examination of the residuals yields no suggestion of heteroschedasticity.

7.4 Remarks

In this section we briefly review a few features of our results which tend to reflect well on the model. The R^2 figures are encouragingly high throughout, the lowest value obtained (lumber demand) exceeding 0.8 and most exceeding 0.9. High R^2's are by no means sufficient for "good" results, but are virtually necessary since low values indicate that important explanatory variables have been omitted and thus that specification bias may be serious. The Durbin-Watson test statistics are relatively close to the desired 2.0 figure except in the case of the lumber manhours equation. This is precisely the place at which data limitations required that we abandon our model so the suggestion of autocorrelation here is not discouraging. Also it should have very little effect on the test results since the pricing equation estimates are fairly insensitive to those of the manhours equation.

Furthermore the magnitudes of the point estimates throughout appear quite reasonable. Values of $\hat{\alpha}$ are slightly in excess of 1.0, values of $\hat{r}$ are close to zero, values of $\hat{a}_{10}$, $\hat{a}_2$, and $\hat{a}_3$ are all positive in the cement manhours equation, price coefficients in the demand functions are negative, and so on. Consistency in the various equations of the point estimates of the anticipation parameter $(1-\delta)$ is also good. In cement we obtained a value of 0.38 for $\widehat{(1-\delta)}$ in the manhours equation and 0.32 in the inventory-output equation.[16] In

[16] The fact that the estimate of $(1-\delta)$ is close to zero in the cement pricing equation is perfectly consistent with these values. For if target return pricing prevails in cement then the parameter $(1-\delta)$ is not supposed to appear in the pricing equation.

lumber $(\widehat{1-\delta})$ equals 0.87 in the inventory-output relation and 0.76 in pricing (Case VIII).[17]

The different values of estimates obtained in the two industries for the parameter λ provide additional support for our model since they are in the "correct" relation to each other. The estimates of λ are 0.16 in cement and 0.30 in lumber. These values suggest that prices adjust more rapidly in lumber; a sensible conclusion given the much more competitive structure in lumber.

Finally, even the fact that the originally-proposed output-inventory model "worked" for lumber while resort to the standard output modification was required for cement is consistent with our pricing results, for the standard output modification would be expected to occur (if at all) where target return pricing prevailed.

All in all the empirical results for the cement and lumber industries seem to accord quite well with both common sense and *a priori* notions obtained from microeconomic theory. Such is not always the case in econometric research, especially that focusing upon non-aggregative relationships.

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[17] No estimate of $(1-\delta)$ could be obtained from the trend manhours estimation necessitated by the absence of lumber capacity data.

Chapter 8

Summary and Conclusions

8.1 Summary

The three sections of our final chapter are devoted to a brief summary of the study, a very brief discussion of its conclusions, and a few suggestions for further research. We shall treat these in the order mentioned.

"Full cost" views of industrial price determination suggest that businessmen typically base prices on average costs, adding some constant margin for "profit." Many proponents of such views have contended that the profit maximization assumption of neoclassical economic theory is of little analytical value. The latter view is not, however, a necessary part of a full cost theory. This study has been concerned with target return pricing, a version of full cost pricing which focuses upon costs evaluated at standard output. In our view this sort of pricing can most fruitfully be based on the assumption that firms in concentrated industries maintain (via implicit partial collusion) prices just below the level which will attract entry of new rivals. This assumption neither implies, nor is implied by, maximum long-run profitability but appears compatible in spirit with near-maximum long-run profitability.[1]

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[1] Since the highest price and thus rate of return which will fail to attract entry depends in magnitude upon demand and cost conditions, target return pricing does not imply that target return rates are the same for all products or for all sellers of a given product.

Our formulation of the target return hypothesis asserts basically that a commodity's price is determined solely by standard costs according to the formula

$$(1) \qquad P_t^s = rK_t^s + w_t L_t^s + F_t^s + m_t,$$

where K^s is the value of sellers' assets per unit of output at standard output,[2] w is the wage rate, L^s is labor manhours per unit at standard output, m is materials cost per unit, and r is the target rate of return. The essence of the hypothesis is that r is constant over time and that (1) describes price behavior so well that no additional variable reflecting demand conditions can contribute usefully to the explanation of price movements.

Interpreted strictly, formula (1) would imply complete adjustment to cost changes within each time period. Empirical studies must recognize, however, the existence of slower adjustments. For testing purposes we accordingly interpret the hypothesis to assert that observed prices adjust toward those implied by (1) according to the mechanism

$$(2) \qquad P_t = \alpha\lambda\ P_t^s + (1-\lambda)P_{t-1} \quad ,$$

An operational version of the hypothesis is then provided by the combination of equations (1) and (2). This version, like the stricter

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[2] Standard output is a constant fraction of productive capacity.

version with $P_t = P_t^s$, implies that r is constant and that demand conditions have no direct influence on price.

A more neoclassical view is that firms, alleged to practice target return pricing, would be tempted to increase prices above the target return levels in periods when actual demand quantity, D, exceeds anticipated demand, A. According to this alternative hypothesis, the parameter ϕ should be positive in the equation[3]

$$(3) \qquad P = \alpha\lambda \, P_t^s + (1-\lambda)P_{t-1} + \phi(D_t - A_t) \quad ,$$

whereas the target return hypothesis implies $\phi = 0$. A test based on these differing implications is made operational by adoption of the "adaptive expectations" model for demand anticipations:

$$(4) \qquad A_t - A_{t-1} = \delta \; (D_t - A_{t-1}) \; .$$

The use of (4) to eliminate A from (3) yields

$$(5) \qquad P_t = \alpha\lambda P_t^s - \alpha\lambda \; (1-\delta)P_{t-1}^s + (2-\lambda-\delta)P_{t-1}$$
$$-(1-\delta)(1-\lambda)P_{t-2} + \phi(D_t - D_{t-1}) \; .$$

According to the target return hypothesis (2), not only is $\phi = 0$ but also the terms involving $(1-\delta)$ should not appear. The general test procedure is then to add a stochastic disturbance term to (5), estimate its parameters, and conduct a statistical test of the (target return) hypothesis $\phi = (1-\delta) = 0$.[4] There are three important complications which are discussed in the next three paragraphs.

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[3] A second specification, related to (3), is also examined.

[4] A less stringent test of target return pricing is provided by the hypothesis $\phi=0$ together with the alternative $\phi > 0$.

First is the problem of obtaining numerical values for P^s. Expression (1) is of course used but evaluation of costs at standard output, which are not directly observable, involves estimation of a manhours usage function and an output-inventory behavior function.

The dependent variables of the manhours and output-inventory functions are not determined jointly with P. Since quantity demanded, D, appears on the right hand side of (5), the existence of a demand function implies, however, that D is determined jointly with P. Consistent estimation of the pricing equation requires that this simultaneity be taken into account.

Simultaneous estimation of the pricing and demand equations is complicated by the presence of exact nonlinear relations among the parameters of (5). The estimation technique chosen is a modification of the two-stage least squares method widely used in linear systems. The modified version is discussed and shown to yield consistent parameter estimators.

Actual application of the test procedure is carried out using quarterly data (1949-64) for the lumber and cement industries. In the former case the hypothesis is soundly rejected, the test statistic's value being 27.8, as compared to a critical value of 5.0 for a .01 significance level. In the case of cement, on the other hand, rejection is clearly not called for. The data is highly consistent with the hypothesis, the highest test statistic value being 0.3. What conclusions can then be drawn on the basis of these two tests?

8.2 Conclusions

Obviously we can conclude that target return pricing does not prevail in the lumber industry. This result is far from startling as the lumber industry's structure is highly competitive. The main significance of the rejection is then the indication it gives that our testing procedure is capable of detecting behavior which is inconsistent with the target return hypothesis.

What about the cement industry findings? We cannot, of course, conclude from them that target return pricing does in fact obtain in cement: a favorable[5] test outcome does not prove a hypothesis to be true. This truism does not, however, imply that a favorable finding contributes nothing toward confirmation of a hypothesis. The greater the number of implications that are found to be consistent with observation, the greater the degree of confirmation of the hypothesis.[6] Thus in the case of cement, our findings provide some indication that the target return pricing hypothesis may be useful in analyzing the workings of that industry.

More generally, the apparent high quality of our statistical results suggests that our econometric model could provide a starting point for empirical investigation of other propositions concerning economic behavior of industrial units. And, finally, the very fact that our test could be carried out at all enables us to conclude that the target return hypothesis, as formulated, yields implications which are both refutable and also different from those of the more orthodox neoclassical theory.

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[5] A "favorable" test outcome is a finding that the hypothesis is consistent with the data.

[6] See Hempel [30, pp. 8, 33-8].

8.3 Opportunities for Further Research

The present study does not nearly exhaust research possibilities on the subject. The most obvious next step is to obtain empirical results for more industries. Absence of requisite data eliminates many industries from consideration but the figures should now be available for perhaps a half-dozen. For several more industries the publication of crucial statistics began around 1958 so that estimation will be possible shortly. And the increased collection of statistical data will undoubtedly provide the researcher with more eligible industries in the coming years.

Another line of research would involve extension of the model. Different deviations from target return behavior could be permitted under the alternative hypothesis and a bit more simultaneity could be permitted. These steps would yield a fairly general operational model of the representative firm. It is not at all certain that such a program would be fruitful, of course. Many-equation econometric models may avoid some of the failings of their smaller brethren, but they have their own.

More promising is the more intense study of particular functional relationships appearing in the model. Most existing empirical studies of output-inventory behavior have utilized data which is highly aggregative, more so than seems optimal. Also they have typically adopted anticipations formation functions which seem less satisfactory than the one used here. Similar opportunities exist for more complete exploration of the Wilson-Eckstein manhours function.

Finally there is always the possibility of experimentation with more elaborate statistical techniques. Estimation assuming, for instance, first order autocorrelation of the equation disturbances would be possible, though the author believes that the model is already complex enough that such measures would only obscure the stories told by the data.

Appendices

Appendix A

Desired Inventory Levels: Theory

A.1 Introduction

Chapter 4 pointed out that our output model is of the "stock adjustment" variety. Thus it includes equations specifying (a) the "desired" level of inventory for the end of each time period and (b) the output behavior which adjusts actual levels to those desired. Item (b) was discussed fully in Chapter 4 but reference there to (a) was limited to the statement of a linear function [equation (16)] relating desired inventory levels to anticipated sales. It is the purpose of this appendix to provide theoretical justification for that relation.

The following symbols will be used in this appendix. While they are similar to those of Chapters 3-8, there are a few differences.

I	end-of-period stock of finished goods inventories
I^*	"desired" level of I
Q	actual output
x	quantity demanded, a stochastic variable
$F(\cdot)$	distribution function for x
$f(\cdot)$	density function for x
μ	mean of the distribution of x
σ^2	variance of the distribution of x
λ	coefficient of variation of the distribution of x
p	product price
c, k, r, g	various cost parameters

Since desired inventory levels I^* are unobservable, we must relate I^* to observable variables. In most carefully formulated stock adjustment models the corresponding relationship stems from a static model of profit maximization. In view of its use, our model should represent target return rather than profit maximizing behavior. We assume, however, that the former implies attempts to select the output or inventory levels which will maximize profits, given the constraint that price is dictated by the target return formula. Thus the specifics of the analysis tend to be much like those of a profit maximizing model.

The analysis differs from ordinary profit maximization in two other respects, however. First it is the case that uncertainty provides one of the main reasons for firms to hold inventories and as such cannot be ignored. We are thus concerned with maximization of *expected* profits, subject to the target return constraint. Second, since inventory stocks are substitutes for future production, the model must be at least partly dynamic.

The object of the analysis is then to relate to observable variables the inventory levels which a firm would desire to hold, given the target return pricing constraint and given the fact of uncertainty. These levels are optimal *ex ante* but because of the uncertainty may turn out to be non-optimal, *ex post*.

As a starting point let us consider previous econometric studies of inventory behavior such as those of Lovell [49], Darling and Lovell [14], and Pashigian [69]. They are representative in assuming that desired inventories are a linear function of sales or anticipated sales. Is there any theoretical justification for this assumption, which appears rather *ad hoc*?

Modigliani [63] has discussed several reasons why profit motivated firms would attempt to hold inventories according to some stable function of sales, but he did not specify that the overall functional relationship should be linear or of any other specific form. Also he did not suggest whether the inventory/sales ratio (I/S) should fall or rise with growth of sales volume. These omissions are not surprising in light of Modigliani's recognition of four separate "reasons" or motives for holding inventories, since different functional relationships could be appropriate for the different motives, which are:

(a) economies of bulk procurement,

(b) production smoothing (which will lead to lower costs if cost per unit is an increasing function of either the rate of output or variations in this rate),

(c) expected changes in prices, and

(d) uncertainty concerning demand.

The model to be discussed next will focus upon reasons (b) and (d). The introduction of a square root term to account for "optimal lot-size" effects in finished inventories can be accomplished later. Following Lovell [49] we assume the price speculation effect (c) to be quantitatively unimportant for finished goods.

A model incorporating demand uncertainty and costs due to changing output rates was developed by Edwin Mills [60][61]. We discuss this model and modify it for our use in the following section.

A.2 The Mills Model

Mills' output or inventory model attained its most elaborate form in its 1962 version [61] which assumed profit maximizing behavior for a firm with known costs but uncertain demand. Price and output were treated as simultaneously determined decision variables. The earlier version [60] assumed price to be fixed or given and thus took output as the only decision variable. Such a treatment is justified for a target return firm, since its price is determined independently of current output rates, and accordingly will be used here.

Let us now turn to the details of Mills' model. With target return price given, the probability distribution of quantity demanded, x_t, is also given. The firm wants to maximize expected profits, subject to the requirement that the target return price be charged. Three types of costs are recognized. The first is the usual current production cost, with marginal cost, c, assumed constant over the relevant range. Second, there are costs due to changing output levels, taken to be $(g/2)(Q_t-Q_{t-1})^2$, where Q_t is output in period t.[1] Finally, we suppose the firm has a profit horizon extending past the current period and thus takes effects upon the future into account in making the current output decision. To take these effects into account exactly would require a dynamic programming model which would be unlikely to yield any general results. But Mills, following the suggestion of Arrow [4], summarizes the effect of a

[1] These costs are denoted $(g/2)(Q - Q_{-1})^2$ rather than $g(Q - Q_{-1})^2$ so that the conditions for an optimum, which involve the derivative, will be more simple.

period's action on all future periods' profits by the inventory legacy which it leaves for the future. He uses the valuation function

(1) $(c-r)(Q_t + I_{t-1} - x_t)$ when $(Q_t + I_{t-1} - x_t) > 0$,

$k(Q_t + I_{t-1} - x_t)$ when $(Q_t + I_{t-1} - x_t) < 0$,

with k, c, and r all are positive. I_t is the stock of inventory at the end of period t, r is storage cost per unit per period, and k is per unit shortage cost.

The interpretation of this inventory valuation function is as follows. If $(Q_t + I_{t-1} - x_t)$ is positive, there will be inventory left at the end of period t. While there will be a carrying cost of r per unit, it will make possible production at a lower level in the following period, so the value to the firm of having a unit in inventory will be c-r. If $(Q_t + I_{t-1} - x_t)$ is negative, on the other hand, there is a shortage, and the (negative) value to the firm is k times the amount of the shortage. The interpretation of the per unit cost of shortage depends upon the facts; whether the firm would let the demands go unsatisfied and thus lose not only current but also future sales, or whether it would fill the orders using expensive emergency procurement methods. The reader is referred to Mills' discussion [61, pp. 107-114].

The firm wants to maximize the expected value of profits; the expected value, that is, of total revenue minus production costs minus costs of changing production levels plus the value of the inventory legacy. The level of inventory left over from the previous period is given, the probability distribution of demand is known, and thus current output Q_t is the only decision variable. The maximization process[2] shows that the optimal value of Q_t is that value which satisfies the equation

$$(2) \qquad F[Q + I_{t-1}] = \frac{p - c + k - g(Q_t - Q_{t-1})}{p - c + k + r} \quad ,$$

where $F(x')$ is the probability that $x \leq x'$; F is the distribution

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[2]Equation (2) is derived as follows. Omit t subscripts and define $y = Q + I_{-1}$. Revenue is px if $y \geq x$ and is py if $y \leq x$. Production costs are $cQ + (g/2)(Q-Q_{-1})^2$, and the value of inventory stock is $(c-r)(y-x)$ if $y > x$ or $k(y-x)$ if $y \leq x$. If $f(x)$ is the density function for x, expected profit is

$$E\pi = p[\int_0^y xf(x)\,dx + \int_y^\infty yf(x)\,dx] - cQ - (g/2)\,(Q - Q_{-1})^2$$
$$+ (c-r)\int_0^y (y-x)f(x)\,dx + k\int_y^\infty (y-x)\,f(x)\,dx.$$

To find the first order condition for a maximum we differentiate with respect to Q and equate the result to zero.

$$dE\,\pi/dQ = p[yf(y) + \int_y^\infty f(x)\,dx - yf(y)] - c - g(Q - Q_{-1})$$
$$+ (c-r)\,[\frac{d}{dy}\int_0^y yf(x)\,dx - \frac{d}{dy}\int_0^y xf(x)\,dx]$$
$$+ k\,[\frac{d}{dy}\int_y^\infty yf(x)\,dx - \frac{d}{dy}\int_y^\infty xf(x)\,dx]$$
$$= p[1 - F(y)] - c - g(Q - Q_{-1}) + (c-r)\,F(y) + k[1 - F(y)\,] = 0.$$

This equation can be solved to yield

$F(y) = [p-c+k-g(Q - Q_{-1})]/(p - c+k+r)$ which is the same as (2). (The differentiation process requires use of Leibniz's rule,

$$\frac{d}{dx}\int_{g(x)}^{h(x)} f[x,z]\,dz =$$

$$\int_{g(x)}^{h(x)}\frac{\partial}{\partial x} f[x,z]\,dz + f[x, h(x)]\frac{dh(x)}{dx} - f[x,g(x)]\,\frac{dg(x)}{dx}\,.)$$

function of the random variable x.[3]

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[3]The form of equation (2) is reminiscent of the so-called "newsboy" problem. In such a problem, the optimal "estimate" of a random variable is given by $F(a) = k_u/(k_u + k_o)$, where a is the optimal act or estimate, k_u is the per unit opportunity loss for underestimating the true value of the random variable, and k_o is the per unit loss from overestimation. The newsboy formulation is usually utilized for one-period problems (involving, e.g., perishable products such as newspapers) but since Mills' inventory valuation function is introduced for the purpose of approximating the solution to a multi-period dynamic programming problem with a single-period problem, it is not surprising that we can give a "newsboy" interpretation to equation (2).

First let $g=0$; i.e., let there be no cost due to changing output levels. Then notice that $k_o=r$ is a reasonable interpretation: the cost of overproduction is the carrying cost. On the other hand, $k_u=p-c+k$ may be viewed as follows: k is the present value of the future loss due to underproduction (and resulting shortage) while p-c is the lost "profit" in the current period. Then $k_u/(k_u+k_o) = (p-c+k)/(p-c+k+r)$.

Next we let $g>0$. Now the cost, <u>after</u> choosing Q_t, of underproduction equals the cost, <u>before</u> choosing Q_t, of underproduction plus the cost due to increasing production. Thus if we let $k_u{}^*$ be the underage cost before making the production decision, our statement is

$$p-c+k = k_u{}^* + g(Q_t - Q_{t-1}).$$

It is $k_u{}^*$, of course, which is relevant to the choice of Q_t.

Now for the overage cost we have a similar situation except that an increase in production has its effect in the opposite direction. Thus

$$r = k_o{}^* - g(Q_t - Q_{t-1}).$$

Combining these last two expressions yields

$$\frac{k_u{}^*}{k_u{}^* + k_o{}^*} = \frac{p - c + k - g(Q_t - Q_{t-1})}{p - c + k + r}$$

which gives a newsboy interpretation to equation (2).

Now we define desired inventory I^*_t as the expected value of I_t when output is at the optimal level, Q^o_t. That is,

(3) $I^*_t = E(Q^o_t + I_{t-1} - x_t) = Q^o_t + I_{t-1} - Ex_t.$

Thus if $Q_t = Q^o_t$ and demand turns out to equal its expected value $Ex_t = \mu(t)$, the resulting inventory level is the desired level, I^*_t.

Suppose the stochastic demand function described by F(x) shifted over time but that its behavior over time were known. Then sequences of values for Q^o and for I* could be calculated. If optimal behavior of the type postulated were followed, the actual *ex post* inventory levels would differ only randomly from those specified by the calculated sequences. These sequences are therefore informative as to the type of function relating I* and expected sales. As the precise relationship is dependent upon the particular form of the distribution function F(x) we shall next consider what specific distributional family is appropriate.

A.3 Results with a Lognormal Distribution

In his 1954 article [60], Mills considered normal and Poisson distributions for the random demand variable, concentrating attention on the former because it can often be used to approximate the latter. He also specifically considered the question, "How likely is... [the] assumption of a constant ratio of desired inventory to expected sales to be filled in practice?" [60, p. 19]. With x distributed normally, Mills found the optimum inventory level to be a linear function of the standard deviation of x and independent of the mean. While he recognized that the standard deviation σ would tend to increase with increases in the mean μ, he apparently felt that σ would change less than proportionately. Thus he concluded: "Possibly the fact that a large class of functions tends to the normal in the limit means that desired inventories will tend to vary considerably less than proportionately to sales" [60, p. 20].

Mills' later study [61] assumed that x has a uniform (rectangular) distribution. One section treated the mean as a function of time, with the variance held constant. Again desired inventory was found to be proportional to the standard deviation. If the mean of x were to grow, desired inventory would grow less than proportionately.

Neither the normal nor the uniform distribution appears to be appropriate, however. The former assigns non-zero probabilities to negative values and the shape of the latter seems quite unlikely. In addition, the ultimate use of the model must be kept in mind. It would seem that the proper use is analysis of behavior over enough time that the mean of the distribution might double or triple. Thus the distribution should be one in which trends in parameters can easily be expressed. One would expect the mean and standard deviation to vary in the same direction and it would be desirable to have a distribution in which a plausible relationship could easily be incorporated.

Since the mean and standard deviation should vary together, our a priori preference is for a distribution in which the population coefficient of variation is a constant, i.e., one in which

$$(4) \qquad \sigma = \lambda\mu$$

holds, with λ the coefficient of variation. Furthermore, the density function should take on non-zero values only for positive values of x, the random variable representing quantity demanded per period.

A well-known distribution which has these desired characteristics is the lognormal, which also possesses the following appealing property: if the net deviation of x from its mean in a period is due to the cumulative effect of a large number of small independent random causes, each of which leads to a proportionate displacement, then by the central limit theorem x will be distributed approximately (or exactly, asymptotically) lognormal. A statement of the same property which may be more familiar is the following. If a random variable results from many independent multiplicative random effects, then by the central limit theorem the log of the variable will be distributed normally in the limit, and the variable thus lognormal.[4]

If the variable x has the lognormal distribution with mean μ, then it can be shown[5] that

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[4] The lognormal distribution is discussed by Aitchison and Brown [1].

[5] The random variable x has the lognormal distribution with mean μ and variance σ^2 if and only if $y = \ln x$ is distributed normally. If the mean and variance of y are m and ν, then

$$\mu = e^{m+\nu/2} \qquad \text{and } \sigma^2 = (e^{\nu} - 1)\, e^{2m+\nu} \qquad [1].$$

These two equations imply that $\lambda^2 = e^{\nu} - 1$ or $\nu = \ln(1+\lambda^2)$ and also that $m = \ln \mu - \nu/2$

Aitchison and Brown [1] also point out that $x_q = e^m + u_q \nu$ where x_q is defined by (6), and u_q is a value such that $P(u \leq u_q) = q$ with u the standardized normal random variable. Then using the expressions given above for m and ν we obtain

$$x_q = \mu \, [1/(1+\lambda^2)]^{1/2} \exp[u_q \, (\ln[1+\lambda^2])^{1/2}].$$

Since u_q is a single-valued function of q, we can write this as in (5).

(5) $\quad x_q = \mu\ \theta(q,\lambda)$,

where x and q are defined by

(6) $\quad F(x_q) = P(x \leq x_q) = q$

and θ is a function of q and λ only. This result (5) will be used in conjunction with equation (2) to examine the relation between I* and expected sales. As we wish to allow for growth in demand, let us treat the distribution mean as a function of time. We assume that $\mu(t)$ grows linearly; i.e., that

(7) $\quad \mu(t) = \mu_o + \mu_1\ t.$

Constancy of the coefficient of variability then implies that

(8) $\quad \sigma(t) = \lambda\ \mu(t) = \lambda\mu_o + \lambda\mu_1\ t.$

Let us now see how desired inventory holdings will change over time as demand grows if x is distributed lognormal. First consider the case in which there is no cost due to changing output rates, i.e., the case in which g = 0. Then for the firm in question define q' as

(9) $\quad q' = (p - c + k)/(p - c + k + r).$

The optimal output level is given by the value $Q^o{}_t$ which satisfies

$$F(x_{q'}) = F(Q_t + I_{t-1}) = q'.$$

But from equation (5) we see that this condition can be written as

(10) $\quad Q^o t + I_{t-1} = \mu(t)\ \theta(q',\lambda).$

If we substitute (10) into the inventory identity,

$$I_t = I_{t-1} + Q_t - x_t,$$

we obtain, for $Q_t = Q^o_t$,

(11) $\quad I_t = \mu(t)\ \theta(q',\lambda) - x_t.$

But our definition of desired inventory is the expectation of I_t when $Q_t = Q^o_t$. Since $Ex_t = \mu(t)$ we then have

(12) $\quad I^*_t = \mu(t)\ [\theta(q',\lambda) - 1],$

which shows desired inventory holdings to be a linear homogeneous fundtion of the expected value of quantity demanded for the given time period. Since by assumption q' and λ are constant over time, the desired inventory/expected sales ratio is a constant.

Now consider the case in which $g > 0$. Let q" be defined by the equation

(13) $$q'' = \frac{p - c + k - g(Q_t - Q_{t-1})}{p - c + k + r}$$

Then the optimal Q_t must satisfy $F(Q_t - I_{t-1}) = q''$, so repeating the argument surrounding equations (9) to (12), we conclude that the optimal inventory level is given by

(14) $\quad I^*_t = \mu(t)\ [\theta(q'',\lambda) - 1].$

But the question arises, can q" legitimately be treated as a constant? Does it not include the term $(Q_t - Q_{t-1})$? It does, but since our concern here is with growth paths, rather than period-to-period movements, we can use the trend per period increase in mean demand, μ_1, in place of $(Q_t - Q_{t-1})$. Then q" is constant if $\mu(t)$ grows linearly and is very nearly so if $\mu(t)$ grows (say) exponentially. In the latter case the expression (14) for desired inventories holds only approximately; in the former case, exactly.[6]

The implication of the foregoing analysis in general, and equations (12) and (14) in particular, is that the desired buffer-stock component of finished goods inventory is a linear homogeneous function of expected demand, provided x is distributed lognormal. Furthermore, the small bit of evidence available is consistent with the view that uncertain sales anticipations are in fact distributed lognormal.[7] We conclude that there exists a tendency for ratios of desired buffer-stock inventory holdings to be constant multiples of anticipated sales.

A.4 Lot Size and Seasonality Effects

To complete our analysis we must also recognize, in addition to buffer stocks, holdings of inventories resulting from bulk procurement economies ("lot size" effects) and seasonal variations in demand.[8]

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[6] A numerical example may be useful here. Let k=5, c=5, r=1, g=2, p=10, and assume that $\mu(t)$ grows linearly, mean demand expanding 1% per time period, so that μ_1=0.01. Then q" = [10-5+5-2(.01)]/[10-5+5+1] = .906. From a standardized normal distribution table we see that $u_{q''} = u_{.906}$ = 1.32. We assume that λ=.1 and then from (5) and the equation in footnote 5, $\theta(.906,0.1) = [1/(1+.01)]^{1/2} \exp[1.32(\ln(1+.01))^{1/2}] = 1.14$. Thus the desired inventory/expected sales ratio is about $I^*/\mu = 1.14 - 1 = 0.14$.

[7] Empirical investigations by Holt, Modigliani, Muth, and Simon led them to state, "On the whole this evidence strongly suggests that the hypothesis [lognormal distribution with mean changing over time] may provide a very satisfactory approximation at least for certain classes of products" [32, p. 291].

[8] The buffer stock model incorporates a cost due to changing production rates and thus takes recognition of the production smoothing motive, but it does so only with respect to changes in Q arising from demand growth or uncertainty. Regular <u>seasonal</u> fluctuations in demand also require inventory holdings for production smoothing reasons.

Operational models designed to account for inventories held for these reasons have been presented by Ghali [24]. While the bulk procurement motive is usually discussed with reference to raw material purchases, the motive (broadly interpreted) is relevant in a batch production process or in any situation which leads to fixed "set-up" costs of some type in production or sales. The analysis of such cases leads to the familiar "lot-size" formula, which gives the optimal lot or batch size as a homogeneous function of the square root of sales. Ghali gives reasons why the formula might also be relevant to average end-of-period inventories for an industry [24, ch. 2] and presents some evidence suggesting that the lot-size effect is quantitatively important for several industries [24, ch. 4].

Ghali's model of smoothing in the presence of seasonality [24] indicates that inventories held for this reason will grow in proportion to sales, provided that the extent of the seasonality and the ratio of the constant per-unit holding cost to the <u>slope</u> of the marginal production cost do not change. Costs due to changing production levels might enter the model in place of rising marginal production costs. Then the coefficient relating to this cost would be relevant in the above statement.

In summary, then, seasonality and buffer-stock considerations imply approximate constancy in the ratio of desired inventories to anticipated sales. Lot size effects tend to make I^* grow with the square root of sales. Total desired inventories should then be related to some power of sales between 0.5 and 1.0. Taking this power to be 1.0 for empirical application should provide an adequate degree of accuracy[9] because batch effects are minor in many industries where production is continuous and because the error in approximating changes in x^{γ} with changes in x, where $0.5 \leq \gamma \leq 1.0$, can not be large if the range over which x varies is not large.[10] The introduction of a constant term will help to absorb any lot size effects present.

Our desired inventory equation can then be written as

$$(15) \qquad I^*_t = \theta_o + \theta_1 A_t,$$

where A_t is sales anticipated for period t, which is precisely the same as equation (16) of Chapter 4 which we set out to justify.

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[9] It is relevant to note that aggregate inventory/sales ratios (for finished goods as well as for all inventories) have not fallen in U.S. manufacturing in the post World War II period despite an increase in the FRB industrial production index of 250% (1948 to 1966) and the widespread adoption of heralded inventory control schemes. For all inventories the end-of-month ratios averaged 1.60 for 1948-50 as compared with 1.63 for 1964-66. In the case of durable finished goods the figures are 0.48 for 1954-56 as compared with 0.53 for 1964-66; for nondurable finished goods the figures are 0.63 for 1954-56 and 0.61 for 1964-66. The source of these figures is the U.S. Commerce Department's Survey of Current Business.

[10] For example, $x^{0.8}$ increases by 87% as much as does x when the latter doubles.

Appendix B

Least Squares Estimation in Nonlinear Models

While recently there has been a surge of interest in econometric models in which the parameters enter nonlinearly, published discussions of estimator properties have been rare. In the case of ordinary least squares (LS) estimators, most treatments say only that they are maximum likelihood estimators if the errors have normal distributions.[1] The exception is provided by Malinvaud [55], who has shown, under general conditions, that LS estimators have very desirable asymptotic properties in nonlinear models when the error terms are additive. This discussion has apparently failed to attract much attention. One possible reason is that Malinvaud treats the nonlinear model in the context of multivariate regression, with several dependent variables. This complicates matters to the point that it is not at all obvious that the estimators being discussed are LS estimators when the system consists of only a single equation. In addition, Malinvaud's notation may be somewhat unfamiliar to students brought up on Johnston and Goldberger.

It may therefore be useful to state, using more conventional notation, Malinvaud's main results for the case of a single equation. Let the model be

$$y_t = f(x_{t1}, x_{t2}, \ldots, x_{tK};\ \beta_1, \beta_2, \ldots, \beta_P) + u_t = f(X_t, \beta) + u_t$$

[1] See, for example, Draper and Smith [15] or Hartley [29].

for t=1, 2, ..., T where $P \leq K < T$. The function f is nonlinear. The x's are exogenous variables.

In what follows it will be convenient to utilize matrix notation wherein our model is $y = f(X,\beta) + u$, where y, f, and u are all Tx1 vectors. We let b denote the least squares estimator of β, i.e., the Px1 vector that minimizes the sum of squared residuals e'e, where $e = y - f(X,b)$.

As in the usual linear model, the disturbance vector is assumed to be such that $Eu = 0$ and $Euu' = \sigma^2 I$ [55, p. 283]. Malinvaud assumes the matrix $T^{-1}F'F$ to be nonsingular and to approach a nonsingular matrix as $T \to \infty$, where F is the TxP matrix with elements $\partial f(X_t,\beta)/\partial\beta_p$ [55, p. 293]. Also he assumes that there exists a neighborhood of the point β in P-space within which the T functions $f(X,\beta)$ and their derivatives of the first three orders are uniformly bounded [55, p. 293]. These assumptions can be seen to be quite unrestrictive.

Malinvaud's final assumption is more complex. Let $\Delta = f(X,b) - f(X,\beta)$ and let W be any closed domain defined in P-space which does not contain β. Then the assumption is [55, p. 291]

$$\text{plim}\left[\sup_{b \in W} \frac{|u'\Delta|}{\Delta'\Delta}\right] = 0.$$

As Malinvaud points out, it is difficult to see just what this entails. He feels, nevertheless, it is not very restrictive [55, p. 291]. In the case of a linear model with nonlinear constraints a different set of assumptions, which are clearly not very restrictive, are sufficient to prove his results.

The results [55, pp. 292, 295, 297] are as follows:

(i) plim $b = \beta$.

(ii) $\sqrt{T}\ (b - \beta)$ has a distribution that approaches normality as $T \to \infty$.

(iii) plim $\hat{\sigma}^2(F'F)^{-1} = \Phi$, where Φ is the covariance matrix of the limiting distribution in (ii) and $\hat{\sigma}^2 = T^{-1}e'e$.

(iv) If the distribution of u is normal, then b is asymptotically efficient.

Thus with exogenous variables, homoschedasticity, and absence of autocorrelation, the least squares estimators in the nonlinear model with additive disturbances possesses very attractive large sample properties including consistency. They are not, of course, unbiased.

The theorems are stated for exogenous regressors. What is the situation if the regressors include lagged values of the dependent variable? While he offers no proof, Malinvaud states that the asymptotic properties are not thereby affected [55, p. 469].

Appendix C

Nonlinear Two-stage Least Squares

C.1 The Procedure[1]

In this appendix we wish to describe the nonlinear two-stage least squares (TSLS) procedure used in estimation of our pricing equation and also to establish that this procedure's parameter estimators are consistent. It will be useful to begin by rewriting, for reference, the pricing and demand equations. These two equations, derived in Chapters 3-5, provide for simultaneous determination of the jointly dependent variables price (P) and quantity demanded (D).

$$(1) \quad P = \alpha\lambda r K^s - \alpha\lambda r(1-\delta)K^s_{-1} + \alpha\lambda W - \alpha\lambda(1-\delta)W_{-1} + (2-\lambda-\delta)P_{-1}$$
$$- (1-\delta)(1-\lambda) P_{-2} + \phi D - \phi(2-\lambda) D_{-1} + \phi(1-\lambda) D_{-2} + u_1$$

$$(2) \quad D = \xi b_o + \xi b_1 B + \xi b_2(P-P_c) + (1-\xi)D_{-1} + u_2$$

It should now be noted that the nonlinearity is question, in equation (1), is of a special sort. In particular, the parameters may be viewed as entering the equation linearly but in the presence of nonlinear restrictions.[2] Since the disturbance terms enter both (1) and (2) in an additive fashion, the reduced form equations for the current endogenous variables P and D are indistinguishable from those

[1] I have seen only one publication in which this technique is utilized [88]. There the procedure is not fully explained and its properties are not discussed. I am grateful to Professor D. S. Huang for verifying my presumptions regarding these items and for comments helpful in constructing the argument of Section C.2.

[2] Our procedure is applicable only where the nonlinearity is of this special sort.

which would be written for a strictly linear system in which the only restrictions on the parameters of the structural equations were of the "exclusion" or "zero" variety usually used to achieve identification. Thus the reduced form equations in the system (1)-(2) have disturbances which are linear combinations of the structural disturbances and which are contemporaneously independent of the regressors.

A very simply illustrative example of this type of phenomenon follows. Consider the structural equations

$$\begin{aligned} y_1 &= \gamma_2 y_2 + \beta_1 X_1 + u_1 \\ y_2 &= \gamma_1 y_1 + \beta_2 X_2 + u_2 \end{aligned} \tag{3}$$

with the nonlinear restriction $\gamma_2 \beta_1 = k$. The corresponding reduced form equations are

$$\begin{aligned} y_1 &= \frac{k/\gamma_2}{1-\gamma_1\gamma_2} X_1 + \frac{\gamma_2\beta_2}{1-\gamma_1\gamma_2} X_2 + \frac{u_1+\gamma_2 u_2}{1-\gamma_1\gamma_2} \\ y_2 &= \frac{\gamma_1 k/\gamma_2}{1-\gamma_1\gamma_2} X_1 + \frac{\beta_2}{1-\gamma_1\gamma_2} X_2 + \frac{u_2+\gamma_1 u_1}{1-\gamma_1\gamma_2} \end{aligned} \tag{4}$$

or

$$\begin{aligned} y_1 &= \Pi_{11} X_1 + \Pi_{21} X_2 + V_1 \\ y_2 &= \Pi_{12} X_1 + \Pi_{22} X_2 + V_2 \ . \end{aligned} \tag{5}$$

Now since the predetermined variables (the X's) are the only regressors in the linear reduced forms and since they are not correlated (contemporaneously) with the disturbances, OLS estimators of the reduced form parameters are consistent under the usual assumptions made in the simultaneous equation context. See Goldberger [25, pp. 294-306] for notation, the usual assumptions, and discussion of this point.

The TSLS procedure followed in this study may now be summarized. First, the linear reduced form equations for P and D are estimated using OLS. Consistent estimates are obtained. Second, "predicted" values $\hat{P}$ and $\hat{D}$ of the variables P and D are obtained from the reduced form parameter estimates and values of the predetermined variables. $\hat{P}$ and $\hat{D}$ may be viewed as consistent estimates of P and D. Third, these values of $\hat{P}$ and $\hat{D}$ are used in place of P and D on the right-hand sides of equations (1) and (2) and least squares estimators of the structural parameters obtained. In the case of equation (1), the nonlinear restrictions are observed in this step and a nonlinear least squares technique is utilized. The resulting estimators are consistent (see the following sections of this appendix but the estimates of their variances obtained from the second stage regression are too small and must be corrected.[3] The final step is to make this correction.

C.2 Consistency of Nonlinear Two-Stage Least Squares

The remaining task of this appendix is to to establish the consistency of the TSLS estimators obtained by the procedure just described.

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[3] To see this consider as an example the first of equations (3). The TSLS estimates $\hat{\gamma}_2$ and $\hat{\beta}_1$ are obtained from the LS regression of y_1 on $\hat{y}_2$ and x_1. But the LS residuals $Y_1 - \hat{\gamma}_2\hat{y}_2 - \hat{\beta}_1 x_1$ are not appropriate for estimation of the error variance. The appropriate "residuals" are $y - \hat{\gamma} y - \hat{\beta} x$. See Christ [12, p. 444].

This step is necessitated by the presence of the nonlinear parameter restrictions. We begin by examining the TSLS procedure in a fully linear system in order to focus attention on two crucial conditions. We then turn to consideration of the corresponding conditions in the nonlinear case.

Using the notation and assumptions of Goldberger [25, pp. 294-302 and 329-336] the linear structural system may be written

$$(6) \qquad Y\Gamma + XB + U = 0$$

while the structural equation of interest is

$$(7) \qquad y = Y_1\gamma_1 + X_1\beta_1 + u.$$

The OLS estimators of γ_1 and β_1 are not consistent[4] because of the correlation between Y_1 and u which persists as $T\to\infty$; i.e., because $\text{plim}\ T^{-1}Y_1'u\neq 0$. We can see that this condition creates asymptotic bias if we define $Z = [Y_1\ X_1]$ and $\alpha = \begin{bmatrix}\gamma_1\\ \beta_1\end{bmatrix}$. Then the OLS estimator of α is $\alpha^* = (Z'Z)^{-1}Z'y = \alpha + (Z'Z)^{-1}Z'u$ and $\text{plim}\ \alpha^*$ will equal α only if $\text{plim}\ (Z'Z)^{-1}Z'u = 0$. But $\text{plim}\ (Z'Z)^{-1}Z'u = \text{plim}\ T(Z'Z)^{-1}\ \text{plim}\ T^{-1}Z'u$. The first matrix is not 0 by assumption while the second is not because $\text{plim}\ T^{-1}Z'u = \begin{bmatrix}\text{plim}\ T^{-1}Y_1'u\\ \text{plim}\ T^{-1}X_1'u\end{bmatrix}$ and we know that $\text{plim}\ T^{-1}Y_1'u \neq 0$ because $Y_1'u$ contains terms including $u'u$.

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[4]We mention this well-known fact solely because the discussion aids in understanding of the nonlinear case.

This source of inconsistency, asymptotic correlation between Y_1 and u_1, is eliminated in the TSLS procedure when we replace Z with $\hat{Z} \equiv [\hat{Y}_1 \ X_1]$ because plim $T^{-1}\hat{Y}_1 u = 0$ as is well known. (See, e.g., Goldberger's equation 7.6.14 [25, p. 332].) Thus using $\hat{Y}_1$ instead of Y_1 in the second regression eliminates the source of asymptotic bias which exists in "naive" OLS estimation of structural parameters. But at the same time the discrepancy between Y_1 and $\hat{Y}_1$ does not itself provide a source of inconsistency because of the equalities $\hat{Y}_1'\hat{Y}_1 = \hat{Y}_1'Y_1$ and $X_1'\hat{Y}_1 = X_1'Y_1$ which imply $\hat{Z}'\hat{Z} = \hat{Z}'Z$.[5]

In summary, the TSLS estimator α^{**} of α is consistent:

$$\alpha^{**} = (\hat{Z}'\hat{Z})^{-1}\hat{Z}'y = (\hat{Z}'\hat{Z})^{-1}\hat{Z}'Z\alpha + (\hat{Z}'\hat{Z})^{-1}\hat{Z}'u$$

$$= \alpha + (\hat{Z}'Z)^{-1}\hat{Z}'u \quad \text{(because } \hat{Z}'\hat{Z} = \hat{Z}'Z\text{);}$$

$$\text{plim } \alpha^{**} = \alpha + \text{plim } T(\hat{Z}'Z)^{-1} \text{ plim } T^{-1}\hat{Z}'u$$

$$= \alpha + 0 \qquad \text{(because plim } T^{-1}\hat{Z}'u = 0\text{).}$$

The two crucial conditions which give consistency to TSLS estimators in linear models are

(i) plim $T^{-1}\hat{Y}_1'u = 0$ or plim $T^{-1}\hat{Z}'u = 0$

(ii) $\hat{Y}_1'\hat{Y}_1 = \hat{Y}_1'Y_1$ and $X_1'\hat{Y}_1 = X_1'Y_1$ or $\hat{Z}'\hat{Z} = \hat{Z}'Z$.

Now we turn to the case of a structural equation with nonlinear restrictions. We write the structural equation as

$$y = f(Z, \alpha) + u = f(Y_1, X_1, \alpha) + u \tag{8}$$

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[5] See Goldberger [25, p. 332].

where f( ) is the nonlinear function which results when the restrictions are imposed. Note that α has fewer terms than γ_1 and β_1 combined. There are two conditions, corresponding to (i) and (ii), which are necessary for consistency in the nonlinear case. These are

(i') $\quad \text{plim } T^{-1}F'u = 0$

(ii) $\quad \text{plim } T^{-1}F'f(Z,\alpha) = \text{plim } T^{-1}F'f(\hat{Z},\alpha)$,

where by definition F is the matrix composed of terms $\partial f_t/\partial\alpha_k$ which occurs in the second stage regression of y on $\hat{Z}$.

The correspondence between conditions (i) and (i') and between (ii) and (ii') can be seen as follows. The TSLS estimator of α in equation (11) is the vector a which satisfies[6]

(9) $\quad (F'F)^{-1} F'f(\hat{Z},a) = (F'F)^{-1} F'y.$

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[6]Consider least squares estimation in the nonlinear model $y = f(X,\beta) + u$ where X is exogenous and Eu = 0 and $Euu' = \sigma^2 I$. The object is to find the estimate b of β which minimizes the sum of squared residuals. The computational procedure is to select a vector b^1 which serves as a first guess for β. Then one can express the values of f( ) for other values of b such as $b\# = b^1 + d^1$, which do not differ greatly from b^1, by the first order Taylor series expansion $f(X, b^1+d^1) = f(X,b^1) + F^1d^1$ where F^1 is the matrix of $\partial f/\partial\beta$ terms evaluated at b^1. One begins with b^1 and proceeds through b^2, b^3,..., and finally ends up with b, the value which minimized the sum of squared residuals. At each iteration a correction vector d^i is found which minimizes the sum of squared residuals which result from taking the difference between y and the vector $f(X,b^i) + F^id^i$. Then $b^{i+1} = b^i+d^i$. Thus we seek, at each step, a vector d^i which minimizes the expression $[y-f(X,b^i)-F^id^i]'[y-f(X,b^i)-F^id^i]$. The d^i which does so satisfies the normal equations $(F^{i\prime}F^i)^1 d^i = F^{i\prime}y - F^{i\prime}f(x,b^i)$. If we drop the superscripts, we solve at each iteration for $d = (F'F)^{-1}F'y - (F'F)^{-1} F'f(X,b)$ where the F matrices are evaluated at the values of b prevailing. The final estimate b of β is the converged value such that d = 0 for the final step. Thus the LS estimator of β satisfies $0 = (F'F)^{-1}F'y - (F'F)^{-1} F'f(X,b)$ with the matrices evaluated at b. This gives us equation (9) in the body.

Thus F is analogous to $\hat{Z}$ in the linear model where the TLSL estimator is $\alpha^{**} = (\hat{Z}'\hat{Z})^{-1}\hat{Z}'\hat{Z}\alpha = (\hat{Z}'\hat{Z})^{-1}\hat{Z}'y$. The correspondence between (i) and (i') is quite direct. In the case of (ii) and (ii'), the correspondence holds only asymptotically but that is all that is required for consistency.

We can also demonstrate the role of conditions (i') and (ii') analytically, rather than by analogy.[7] From (9) we have

$$F'f(\hat{Z},a) = F'y = F'f(Z,\alpha) + F'u. \tag{10}$$

According to Slutsky's Theorem,[8] consistency requires that $\text{plim}\ T^{-1}F'f(\hat{Z},a) = \text{plim}\ T^{-1}F'f(\hat{Z},\alpha)$. For TSLS to provide consistency we then must have

$$\text{plim}\ T^{-1}F'f(\hat{Z},\alpha) = \text{plim}\ T^{-1}F'f(Z,\alpha) + \text{plim}\ T^{-1}F'u, \tag{11}$$

and for this to hold for all values of α, conditions (i') and (ii') are necessary.

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[7] We do not claim the following to be a rigorous proof. A summary of the conclusions of a rigorous examination of least squares estimation in single-equation nonlinear models is presented in Appendix B.

[8] Slutsky's Theorem says that $\text{plim}\ g(x) = g(\text{plim}\ x)$ where x is a random variable or vector and g is a scalar- or vector-valued continuous function. See Goldberger [25, p. 118-9].

These two conditions are in fact implied by the usual stochastic assumptions. In the case of (i'), the independence of u and F is provided by the ultimate dependence of F only on X and α.[9] In the case of (ii'), the consistency of the first stage (reduced form) estimators is the crucial element.[10] Thus we see that the nonlinear TSLS procedure produces consistent estimators.

C. 3 More on the F Matrix

We conclude this appendix by pointing out that the converged F matrix is also important in other ways. The oonvariance matrix of the estimators in the linear case is $\sigma^2(Z'Z)^{-1}$ and is estimated by $s^2(Z'Z)^{-1}$ where s^2 is the estimator of σ^2. In the nonlinear case the estimator of the covariance matrix of the a estimators is given by $s^2(F'F)^{-1}$.[11] The reason is that at the point $\hat{y}$ in T-space which is the estimator of y-u, the hyperplane defined (spanned) by the columns of F is tangent to the nonlinear variety f(Z,a) and thus plays the same role, in the vicinity of y, as the hyperplane spanned by the columns of the Z matrix plays in the linear model. Algebraically, the model is approximated in the vicinity of the OLS estimates

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[9] F is a matrix function of $\hat{Y}_1$, X_1, and a. But since $\hat{Y}_1 = X\hat{\Pi}_1$ and since both $\hat{\Pi}$ and a are consistent, in the probability limit F equals the corresponding function of Π_1, X, and α. Since X is exogenous and Π_1 and α are parameters, this revised F is asymptotically independent of u.

[10] $\text{plim } T^{-1}F'f(Z,\alpha) = \text{plim } T^{-1}F'f(\hat{Z},\alpha)$ holds, by Slutsky's Theorem, because $\text{plim } T^{-1}h'\hat{Y}_1 = \text{plim } T^{-1}h'X\hat{\Pi}_1 = \text{plim } T^{-1}h'X\Pi_1 = \text{plim } T^{-1}h'Y_1$ where h' is a 1xT sum vector of units.

[11] See Marquardt [56, exhibit B].

by its linearized Taylor series expansion. Thus confidence intervals and tests of hypotheses for the regression parameters α are based on $s^2(F'F)^{-1}$. These intervals and tests are correct asymptotically.[12]

Finally it should be noted that the nonlinear counterpart of multicollinearity appears in the form of near-singularity of the matrix F'F. If this matrix has large off-diagonal elements some multicollinearity is present, indicating that fewer parameters are required to "explain" y than the number currently contained in α. In Chapter 7 it is seen that in some of the cases studied extreme (nonlinear) multicollinearity was present and was usefully located by the elements of the F'F matrix.

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[12] See Malinvaud [55, p. 309].

Appendix D

Seasonality

Here we are concerned with the appropriate way of estimating behavioral relations (1)-(4) of Chapter 5 using as data quarterly time series which are known to be highly seasonal. How, if at all, should we take account of this seasonality?

One mentod is to utilize, when possible, seasonally adjusted data.[1] This method has been followed in several well known studies.[2] There is an apparent danger, however, that such a procedure will eliminate some of the "information" in the observed series. Suppose some variable y is stochastically related to another variable x by

$$(1) \qquad y_t = \alpha_o + \alpha_1 x_t + u_t ,$$

where u is a random disturbance. If (1) is the true relation, then y will exhibit seasonal fluctuations if x does. If x were perfectly constant over time except for a regular seasonal variation, then removal of that variation from x and y would produce seasonally adjusted variables which are not statistically related at all. Thus seasonal adjustment of data can obscure the existence of economic relationships.

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[1] The U.S. Department of Commerce, to mention one source, publishes a great deal of data in seasonally adjusted form. Their adjustment procedures do not, however, possess the desirable properties mentioned below in footnote 3.

[2] See, for example, the Brookings model study [16].

On the other hand, it must be reocgnized that the economic models used in econometrics are not perfect. By their nature all such models omit some aspects of the economic behavior under study. If the aspects omitted are of seasonal nature, then it may be useful to view the functional relationship as one that differs according to the season, so that the expected level of the dependent variable depends upon the season as well as the levels of ordinary explanatory economic variables. This could be exemplified by

$$(2) \qquad y_t = \beta_o + \beta_1 x_t + s_t + u_t$$

where s is a seasonal factor. If the relation between y and x is actually as specified by (2), then estimation based on model (1) will lead to estimation bias. It is apparent that this bias could be avoided by including in the estimated relation dummy variables representing the various seasons.

Suppose, alternatively, that (1) is the true model but that one estimates it with seasonal variables included, thinking (2) is appropriate. Does specification bias then exist? More generally, does the inclusion of superfluous variables in a regression lead to bias as does the exclusion of ones which belong? As is shown in Appendix E, the answer is No. Inclusion of extra variables may produce multicollinearity but it does not produce estimator bias.

If then there is a priori reason to believe that a relationship varies seasonally, probably the best procedure is to include seasonal dummy variables in the estimated regression equation. Lovell [50][51] has shown that this leads to the same parameter estimates as does the use of variables seasonally adjusted by his recommended method[3] and involves less labor. Also the resulting standard errors do not need to be corrected as they do when seasonally adjusted data is employed.[4]

There is in fact reason to believe that relations (1) - (4) of Chapter 5 are ones which may vary with the season. Consider, for instance, the manhours usage equation (4). In an industry in which production is highly seasonal it is unlikely that manhour usage would be fully explained by current and lagged values of capacity, time, output, and demand. For firms are known to "hoard" labor during slack months, knowing that output will shortly pick up again. Similar reasoning applies to the other equations. The estimation of our relationships will accordingly take place with seasonal dummy variables included among the regressors.[5,6]

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[3] Lovell's recommended method for seasonal adjustment involves least squares regression of the unadjusted time series on a set of seasonal dummy variables. This method produces "...an adjusted time series satisfying the requirements of sum preservation, idempotency, orthogonality, and symmetry" [50, p. 996].

[4] See Lovell [50, p. 1002]. Inclusion of dummy variables is also recommended by Klein [39] and Malinvaud [55, pp. 402-5].

[5] These will be assumed to enter additively. While more complicated effects could exist, this commonly used assumption should be adequate. Note that estimation using quarterly time series calls for three, not four, seasonal variables.

[6] The seasonal dummy variables will be included, even if insignificantly different from zero at the .05 level, unless highly collinear with other variables because specification bias of this nature is deemed more serious than moderate multicollinearity.

Appendix E

Inclusion of Extra Variables in Regression Analysis

Here we are concerned with a special case of the specification bias analysis developed by Theil [82]. Suppose $y = X\beta + u$ is the true relation to be estimated but that the TxJ regressor matrix Z is mistakenly used in place of X (which is TxK). The resulting least squares estimator vector is

$$b = (Z'Z)^{-1}Z'y = (Z'Z)^{-1}Z'X\beta + (Z'Z)^{-1}Z'u$$

which, assuming Z to be exogenous, has expected value $Eb = P\beta$ where P is a JxK matrix of coefficients resulting from regressions of the X variables on the Z variables. If $Z = X$, i.e., if there is no misspecification, then $P = I$, $Eb = \beta$, and there is no specification bias. If however $Z \neq X$, then in general $Eb \neq \beta$.[1]

One well known special case is where some variables in X are omitted from Z, i.e., when $X = [X_1\ X_2] = [Z\ X_2]$. Also let $\beta = \begin{bmatrix}\beta_J \\ \beta_{K-J}\end{bmatrix}$ where β_J is Jx1. Then $P = (Z'Z)^{-1}Z'[Z\ X_2] = [I\quad (X_1'X_1)^{-1}X_1'X_2]$, where I is JxJ. All of the estimators are biased unless X_2 or some of its constituient variables are orthogonal to X_1 because

$$Eb = \beta_J + (X_1'X_1)^{-1}X_1'X_2.$$

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[1]Unless Z contains the same number of variables as X, b and β will not even be of the same order. Then the expression $Eb \neq \beta$ will not be defined and we have to substitute for it $Eb \neq \beta^*$, where β^* is a vector of the same order as b containing zeros and elements of β where appropriate.

The special case we wish to examine is where extra variables S are included among the regressors such that Z = [X S]. Then

$$P = (Z'Z)^{-1}Z'X = \begin{bmatrix} X'X & X'S \\ S'X & S'S \end{bmatrix}^{-1} \begin{bmatrix} X'X \\ S'X \end{bmatrix} .$$

The inverse matrix $(Z'Z)^{-1}$ can be written

$$\begin{bmatrix} A & -AX'S(S'S)^{-1} \\ -(S'S)^{-1}S'XA & (S'S)^{-1} + (S'S)^{-1}SXAX'S(S'S)^{-1} \end{bmatrix}$$

where $A = [X'X - X'S(S'S)^{-1}S'X]^{-1}$; see Hadley [26, p. 109]. Matrix multiplication of $(Z'Z)^{-1}$ by $Z'X$ then yields the following submatrices of P:

(1) $AX'X - AX'S(S'S)^{-1}S'X = A[X'X - X'S(S'S)^{-1}S'X] = I$

from the definition of A, and

(2) $-(S'S)^{-1}S'XAX'X + (S'S)^{-1}S'X + (S'S)^{-1}S'XAX'S(S'S)^{-1}S'X$

$= (S'S)^{-1}S'X[-AX'X + I + AX'S(S'S)^{-1}S'X]$

$= (S'S)^{-1}S'X[I - A(X'X - X'S(S'S)^{-1}S'X)]$

$= (S'S)^{-1}S'X[I - I]$

$= 0$

Thus the inclusion of extra variables leads to $P = \begin{bmatrix} I \\ 0 \end{bmatrix}$ where the identity matrix is KxK and the zero matrix is (J-K)xK. The estimator vector has $Eb = \begin{bmatrix} \beta \\ 0 \end{bmatrix}$ so we see that no specification bias is introduced.[2]

[2] Of course if the extra variables are highly correlated with the true variables then multicollinearity and its associated difficulties may result.

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