AN EMPIRICAL TEST OF THE EFFECT OF ASSET AGGREGATION ON VALUATION ACCURACY

By

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CHAPTER I

INTRODUCTION

Over the past two decades the world has experienced a significant increase in the general price level. In the United States, the Urban-Consumer Price Index increased from 87.9 in January of 1960 to 204.7 in January of 1979 (Statement of Financial Accounting Standards No. 33, p. 126). This economic phenomenon has precipitated an ongoing debate concerning possible inadequacies of financial reports and taxation laws based on historical costs.

Certain proposed solutions have centered around various methods of asset revaluation. Statement of Financial Accounting Standards No. 33 has mandated that firms meeting certain size criteria must disclose general price level adjusted and current cost financial information beginning in 1980. With respect to current cost disclosures, at least two implementation questions are suggested.

1. What valuation estimation scheme (direct appraisal, market quotation, price indices) should be used?

2. What level of asset aggregation should be used?

Two American Accounting Association committees (1964 and 1966) have proposed that direct methods of valuation estimation (appraisal, market quotation) are theoretically
preferred; but adjustment by price indices has been recommended as a surrogate. The report of the United Kingdom Inflation Accounting Committee (Sandilands, 1975, p. 240) recommended that index numbers be used as the principal method of revaluing plant, machinery, stocks, and work in progress. A study by Arnold and Huefner (1977) tested the correlation between actual inventory material replacement cost prices and prices estimated from price indices. They concluded that, due to a relatively high correlation (approximately .5) between the estimates and actual prices, the use of indices to estimate replacement costs of inventory materials could be justified.

Electric utilities in the United States have used price indices for many years in revaluing their rate base for regulatory rate-making purposes. A survey by Arthur Andersen & Co. (1977, p. 13), regarding compliance with Accounting Series Release No. 190, has shown that in 1976, 36% of surveyed companies relied primarily on indexing to calculate replacement cost for productive capacity. A similar study by Arthur Young & Co. (1977, p. 10) disclosed that 31% of surveyed companies made extensive use of indexing in calculating replacement cost disclosures mandated by ASR No. 190. Based on the experience of ASR No. 190, it seems that indexing will be a likely method of compliance with Statement of Financial Accounting Standards No. 33.

The second implementation question to be addressed
concerns the level of asset aggregation. How detailed must asset revaluations be to achieve a suitable level of accuracy? Restated, the question is, given that price indices will probably be used for many asset revaluations, how many price indices should be used? On a pragmatic level, this question has been debated often between certain supporters of general price level restatements (one index) and supporters of specific price level restatements (many indices).

Multi-index proponents assert, "[general price indices] may be too broad to be meaningful for approximating the current cost of specific assets of a particular company" (Arthur Andersen & Co., 1979, p. 21). Revsine and Weygandt (1974) have argued that

Uniform reliance on general price indices as an inflation adjustment mechanism can lead to adjustments that do not conform to the specific purchasing power change experienced by individual firms (and thus) using general price level indexes to adjust individual firm's financial statements may give rise to misleading inferences (p. 76).

Alternatively, proponents of single index asset restatements suggest using many indices may not significantly improve revaluation accuracy. Boersema (1974, p. 29) has suggested that when changes in specific prices are highly correlated with changes in the general price level, "[one may consider] the publication of general price level adjusted costs as surrogates for current values."

Boersema's position is based in part on the results of a
study by Dockweiler wherein replacement cost balance sheet data were found to be very similar to general price level adjusted balance sheet data (cited in Bcersema, 1974, p. 29).

Pragmatically, multi-index proponents concede that

[When] general price levels tend to move in tandem with an entity's own unique purchasing power, general price level adjustments would be useful, not because general price level adjustments are relevant per se, but rather because the general price level adjustments would tend to give the same results as do the theoretically correct specific adjustments (Revsine and Weygandt, 1974, p. 77).

Part of this debate centers on concern as to whether restatement accuracy is significantly improved by disaggregation. If accuracy can be improved by disaggregation, the research concern is that of selecting a suitable set of disaggregated indices. However, there is limited evidence in the accounting literature that no one particular set of disaggregated indices can obtain a minimum valuation error for all individual companies (Sunder, 1978).

Objectives of the Study

Sunder (1978) has shown by counter example that increasing the number of price indices used does not necessarily improve valuation accuracy. That is, in certain cases a revaluation of "p" assets performed using "m" indices may be more accurate than a similar revaluation performed using "n" indices (m<n<p). A critical question to
be addressed is, "how likely is such a result?"

An analogy may be useful in emphasizing the importance of the previous question. Consider, for example, the physical act of tossing a coin. Generally, we think that there are two possible outcomes; either heads or tails. Actually there is a third possible result. The coin may land on its edge. Pragmatically though, because this third outcome is highly unlikely, we tend to ignore it as a possible result. Likewise, the primary concern herein is to determine the likelihood that an "n" index system would be more accurate than a "m" index system.

More specifically, the primary objective of this study is to offer some empirical evidence as to whether or not "n" index valuation is consistently more accurate than "m" \((m<n)\) index valuation. A second objective is to assess the extent to which "n" index valuation is significantly more accurate than "m" index valuation. Both objectives are addressed at the industry and firm level.

Contributions

The study makes at least three contributions to the literature. First, the study indicates the extent to which accuracy is improved by increasing the number of indices used in revaluations. Secondly, the results provide an indication as to whether or not conclusions can be generalized across firms within an industry and/or across industries within an economy. Finally, the study provides
some empirical evidence as to how often the use of more indices results in a materially more accurate result.

Organization of Study

Chapter II presents a review of prior works that have addressed research questions related to those stated in the study objectives.

Chapter III details the study methodology and discusses its related limitations. Also, hypotheses are presented and their significance discussed.

In Chapter IV the study results are presented and analyzed and the implications of the results are discussed.

Chapter V presents a summary of the study and its conclusions. Additionally, suggestions for further research are presented.
NOTES

1 A different categorization of cost estimation methods may be found in Brinkman (1977). He discusses four methods; direct pricing, unit pricing, functional pricing, and indexing.

2 Hohl (1977, p. 47) has noted that a strong correlation between two price indices does not imply that one index is a good substitute for the other. The necessary and sufficient conditions for perfect substitutability of two price indices is that their natural logarithms must be perfectly correlated and that the regression slope parameter, derived from a regression of one index's natural logarithms on the other index's natural logarithms, must be equal to one.
CHAPTER II

LITERATURE REVIEW

This chapter reviews the works of four authors whose previous studies addressed research questions similar to those stated in Chapter I. This review begins with a brief discussion of Tritschler (1969), Peasnell and Skerratt (1977), and Honl (1977). The review concludes with a more exhaustive review of Sunder (1978). Sunder's study is reviewed in greater detail because the methodology of the current study (discussed in Chapter III) was based mostly on Sunder's work.

Tritschler (1969) was the first known researcher to address empirically the problem of asset aggregation and the use of price indices. Tritschler used the price movements for machinery and equipment from the Wholesale Price Index (WPI) to study two research questions.

1. How can price indices be constructed so as to minimize sampling error?¹

2. How can asset revaluation error be minimized?

The study noted that sampling error could be controlled by increasing sample size. A second conclusion was that asset revaluation error could be controlled by a judicious grouping of assets so as to reduce price change dispersion.
within asset groupings. Based on his results, Tritschler questioned whether disaggregation of asset groupings appreciably improves revaluation accuracy. This result was due in part, to significant price dispersion within WPI asset sub-groups.

In 1975, the report of the United Kingdom Inflation Accounting Committee was published. Recommendations of that report included a call for current cost accounting and an advocacy that indexing with nineteen price indices be used as the principal method of revaluing plant, machinery, stocks, and work in progress. The nineteen indices were for various industry areas. They are listed below.

Road transport
Mining, quarrying
Agriculture
Food, drink, tobacco
Oil, chemicals
Metal manufacture
Engineering
Vehicles
Textiles
Paper
Bricks
Construction
Electricity
Post office
Petroleum
Retailing
Other wholesaling
Insurance
Other services

The stated purpose of another study (Pleasnell and Skerratt, 1977) was to present empirical evidence concerning the commonality among the set of nineteen official government price indices of capital expenditure on plant and machinery. That is, they attempted to answer the question, "what information is provided by the nineteen detailed indices as compared with a single index constructed to include all nineteen industries?" The technique used to answer the research question was principal components analysis.
If the first principal component accounted for a high proportion of the variation in the nineteen indices, the implication would be that the movement of the nineteen price indices could be well approximated by a single price index. If the first principal component accounted for a low proportion of the variation in the nineteen indices, the implication would be that several price indices were needed to achieve a certain level of valuation accuracy.

Based on twenty-seven years of price change data for the nineteen industry specific price indices, Peasnell and Skerratt found that the first principal component accounted for 98.3% of the overall price variation in the group of nineteen indices. (This high percentage of price variation accounted for by a single component was due to price movements common to all nineteen indices - general inflation.) Peasnell and Skerratt interpreted this to mean that the entire nineteen separate price indices were not needed to achieve valuations that were within unspecified accounting materiality limits. Instead, they concluded that a much smaller number of price indices could achieve any reasonable level of accuracy desired for accounting revaluations.

A simulation study by Hchi (1977) attempted to determine whether general price level adjustments approximate current replacement costs in financial statements. Using a sample of sixty-two price indices from the Bureau of Labor Statistics Wholesale Price Series
covering a ten year period, Hohl attempted to measure the extent to which a general price index surrogates individual price indices, homogenous groups of price indices, and heterogenous groups of price indices. The groups of price indices were of varying sizes from one to ten; and within each group all individual price indices were given equal weight.

Hohl concluded that individual price indices were, on average, not well surrogated by a general price index. A second conclusion was that, in groups of four or more, both heterogenous as well as homogenous groups were well surrogated by a general price index. Further, as group size increased, the general price index surrogation of the group movement improved.

Until 1973, no researcher had developed an analytical structure capable of comparing asset revaluation error resulting from the use of various numbers of price indices. That year however, Sunder (1978) reported the results of his development of such an analytical structure.

Sunder began by assigning the following structure to asset revaluations:

Let \( V_0 = \) beginning of period valuation of total assets, and \( V_1 = \) end of period valuation of total assets.

Then \( V_1 = V_0 (1 + R^*) \)

where \( R^* = \) actual percentage change in valuation of total assets from the beginning to the end of
the period (assuming the quantity of total assets remains unchanged).

Having developed a structure for revaluation, two alternative measures of revaluation error were introduced and defined as follows:

\[ \text{Bias} = \text{Expected value} \left( R - R^* \right), \text{ and} \]
\[ \text{MSE} = \text{Expected value} \left( R - R^* \right) \left( R - R^* \right), \]

where \( R \) is estimated percentage of change in valuation of total assets computed by a particular configuration of price indices.

Sunder next formulated an expression to compute \( R \) for each possible configuration of price indices. For example, assume we have \( n \) assets in an economy of \( m \) firms and associated with these assets are the following vectors.

\[ \omega = \begin{bmatrix} \omega_1 \\ \vdots \\ \omega_n \end{bmatrix} \]
a vector of value weights of asset \( "i" \) for specific firm \( "j" \), where \( "i" = 1, 2, \ldots, n \) and \( "j" = 1, 2, \ldots, m \).

\[ \omega_j = \begin{bmatrix} \omega_{j1} \\ \vdots \\ \omega_{jn} \end{bmatrix} \]
a vector of value weights of asset \( "i" \) in the economy where \( "i" = 1, 2, \ldots, n \), and

\[ r = \begin{bmatrix} r_1 \\ \vdots \\ r_n \end{bmatrix} \]
a vector of percentage value change of asset \( "i" \), where \( "i" = 1, 2, \ldots, n \).

Now if these vectors are partitioned into subvectors to correspond to a particular set of price indices (a configuration):
\[
\begin{bmatrix}
\omega_{1} \\
\omega_{2} \\
\vdots \\
\omega_{u}
\end{bmatrix}
\]
\[
\begin{bmatrix}
\omega_{1} \\
\omega_{2} \\
\vdots \\
\omega_{u}
\end{bmatrix}
\]
\[
\begin{bmatrix}
\tau_{1} \\
\tau_{2} \\
\vdots \\
\tau_{u}
\end{bmatrix}
\]
so that \( \omega_u \) = subvector of asset value weights for a specific firm and for assets grouped in price index "u", where \( "u" =1,2,...,k \), \( \omega_u \) = subvector of asset value weights in the economy, and for assets grouped in price index "u", where \( "u" =1,2,...,k \), and \( \tau_u \) = subvector of percentage value changes for assets grouped in price index "u", where \( "u" =1,2,...,k \).

Then \( R = \sum_{u=1}^{k} \frac{\omega^\top u e}{\omega^\top u e} \omega^\top u \tau_u \)

where \( k \) = the number of price indices used, and \( e \) = a vector of unit elements.

If we assume a particular set of mean (annual) price changes, denoted \( \Psi \), and a related variance/covariance matrix, denoted \( \Sigma \):

\[
\begin{bmatrix}
\psi_1 \\
\psi_2 \\
\vdots \\
\psi_n
\end{bmatrix}
\]
\[
\begin{bmatrix}
\sigma_1^2 & \text{cov}_{12} & \cdots & \text{cov}_{1n} \\
\text{cov}_{12} & \sigma_2^2 & \cdots & \text{cov}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\text{cov}_{1n} & \text{cov}_{2n} & \cdots & \sigma_n^2
\end{bmatrix}
\]
Then for a particular configuration of a "k" index system ("k" may vary from 1 to "n"), Bias and MSE for a specific firm can be computed as:

\[ \text{Bias} = (\mathbf{w}_k^* - \mathbf{w})^T \mathbf{y} \]
\[ \text{MSE} = (\mathbf{w}_k^* - \mathbf{w})^T \Sigma (\mathbf{w}_k^* - \mathbf{w}) + (\mathbf{w}_k^* - \mathbf{w})^T \mathbf{y} \mathbf{y}^T (\mathbf{w}_k^* - \mathbf{w}) \]

where \( \mathbf{w}_k \) contains "k" subvectors and has an overall dimension of \( n \times 1 \). Similar formulas were developed for economy wide measures of Bias and MSE.

Using these formulas, Sunder proved by counter example the following:

1. For a specific firm, Bias and MSE do not necessarily decrease with increasing the number of price indices or their fineness.
2. On an economy wide average, all index configurations have a Bias of zero, and average MSE does not necessarily decrease with increasing the number of price indices; but it does decrease with increasing index fineness.
Summary

The evidence reviewed indicates that few price indices may be necessary to achieve reasonably accurate revaluations. Surprisingly, Surder's study indicates that in some cases, a fewer number of price indices may actually result in a more accurate revaluation.

To address the study objectives stated in Chapter I, price data were gathered and using Surder's formulas, probabilities were developed that indicate the extent to which increasing the number of price indices used improves revaluation accuracy. Chapter III describes more fully the collection of data and the methodology used to generate the probabilities.
NOTES

1 Price indices are usually constructed from a sample of price movements for various assets contained in a specific price index category.

2 Sunder (1978) proposed the two alternative measures of error because under certain conditions one or the other may be used to predict individual preferences. For example, it can be shown that if a person has a linear loss function (risk neutral) then his preference for a particular error distribution from a set of "n" error distributions can be predicted by simply comparing the mean of each such distribution and selecting the distribution with the minimum mean error. Alternatively, if a person has a quadratic loss function (risk averse) then his preference for a particular error distribution can be predicted by comparing the means and variances of the various distributions. Distributions with lower means and variances would be preferred. Because the MSE error measure is the sum of the variance plus the square of the distribution mean, distributions with lower MSE would tend to be preferred.

3 As used in this paper the phrase "configuration" refers to the following structure. Assume there are three assets to be valued. For these three assets we may use one index, two indices, or three indices. The possible groupings of assets into indices are as follows:

<table>
<thead>
<tr>
<th>Number of indices</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>abc</td>
</tr>
<tr>
<td>2</td>
<td>ab c</td>
</tr>
<tr>
<td>2</td>
<td>ac b</td>
</tr>
<tr>
<td>2</td>
<td>a bc</td>
</tr>
<tr>
<td>3</td>
<td>a bc</td>
</tr>
</tbody>
</table>

Where letters grouped together signify those assets are grouped together in the same price index. Thus, with three assets, there are five different index configurations possible.

4 Conceptually, if a particular configuration of price indices was used by a specific firm over a period of several years, then for each year of use there would be some measure of error (R - R*). Taken collectively, these yearly error
measures form a distribution. **Bias** as defined by Sunder represents the mean value of such an error distribution. **MSE** as defined by Sunder represents the sum of the distribution's variance and the square of the distribution's mean (**Bias**). Thus, for each firm, there would be a distribution of error measures for each possible index configuration and each such distribution would have two alternative summary measures of error, **Bias** and **MSE**.

**Fineness** relates to comparisons of information sets. One set is said to be as fine as another if it contains at least as much information. As applied to price index sets, consider the following groupings of four assets into two and three index groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of indices</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>a b c d</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>a b cd</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>a b c d</td>
</tr>
</tbody>
</table>

Group 2 is finer than group 1 because asset "b" is separated from the group "bcd". However, we can make no observations about fineness between group 2 and group 3, or group 1 and group 3, because these groups are not comparable in terms of fineness.

These results were obtained by Sunder based on the following three assumptions.

1. The economy consists of **N** firms of equal size.

2. The relative weights used for construction of price indices are the relative weights of the goods in the entire economy.

3. The asset portfolio of each firm can be considered as a multinomial random vector drawn from the asset pool of the economy using "p" trials.

This can occur when errors associated with each of the various price indices offset each other.
CHAPTER III

METHODOLOGY

To obtain the data needed for use in the study analysis, a three step procedure was used. First, price data and asset data concerning certain industries and firms were gathered. Second, this data along with Sunder's formulas for Bias and MSE were used to calculate intermediate data. Finally, the intermediate data was used to calculate probabilities, for each firm, that using more indices results in more accurate revaluations. These probabilities were then statistically analyzed. A detailed description of the data collection, generation, and analysis procedures follows.

Collection of Primary Data

Four industries were selected for use in the study. They were:

1. electric utilities,
2. gas pipeline utilities,
3. telephone utilities, and
4. water utilities.

Public utility industries were selected because their plant asset accounts were quite homogenous among firms.
This homogeneity of accounts was present because Federal regulatory agencies have specified a required chart of accounts to be used by each industry. Further, the Federal regulations have specified in great detail the exact type of assets that were to be classified in each general ledger account.

Once the industries were chosen, twenty-five firms from each industry were randomly selected from various sources (a total of 100 firms). Electric firms were selected from a United States Department of Energy publication (1979). Gas pipeline firms were selected from a second United States Department of Energy publication (1978). Telephone and water firms were selected from Moody's Public Utility Manual. For convenience, each firm selected was assigned a unique identification number.

After selection, information concerning the asset composition of each firm was gathered. Details of historical cost asset balances for electric and gas firms were available from the U.S. Government publications previously cited. A mail questionnaire was used to gather the necessary asset information for telephone and water firms. Tables I, II, III, and IV detail the firms selected, their identification numbers, and their total cost of Utility Plant in Service (net of land and intangibles). Plant totals were prepared net of land and intangibles because in any valuation process these assets would probably be revalued through appraisal or market quotation.
<table>
<thead>
<tr>
<th>Firm Name</th>
<th>Firm Number</th>
<th>Plant in Millions</th>
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<td>Madison Gas and Electric</td>
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<td>Northern States Power Company</td>
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**TABLE II**

GAS FIRMS

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## TABLE III
### TELEPHONE FIRMS

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<td>Central Telephone Company of Missouri</td>
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<td>Central Telephone Company of Virginia</td>
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<td>Plant in Millions</td>
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<td>Middlesex Water Company</td>
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<td>Torrington Water Company</td>
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<td>York Water Company</td>
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</table>
Having selected the firms and obtained detailed information concerning their asset balances, it was necessary to select the specific asset accounts to be used. Within each industry, asset accounts were assigned unique identification numbers; then, a two step selection procedure was performed. First, asset accounts for which published price indices were not available were eliminated. For the remaining pool of asset accounts, cross sectional totals were calculated. The asset accounts with the five largest cross sectional totals were selected for use. Table V details the accounts selected and their identification numbers.

Following selection of the asset accounts, the detailed asset cost information (as of 1979 for water and telephone firms and as of 1977 for electric and gas firms) was used to estimate a cross sectional vector of average asset proportions for each industry. Also, within each industry, twenty-five firm specific vectors of asset proportions were calculated. Tables VI, VII, VIII, and IX detail the firm specific as well as cross sectional vectors. These tables also detail the proportion of total utility plant in service (net of land and intangibles) that was accounted for by the five asset accounts.

Interestingly, Tables VI through IX show that for most firms, the five asset categories accounted for a relatively high proportion of each firm's Utility Plant in Service. The averages for each industry were: electric-40\%, gas-71\%, telephone-66\%, and water-79\%.
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<th>Asset Selected</th>
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<td>Steam Production Plant- Boiler Equipment</td>
<td>EA4</td>
</tr>
<tr>
<td>Electric</td>
<td>Steam Production Plant- Turbogenerators</td>
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<td>Distribution Plant- Line Transformers</td>
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<tr>
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<td>Transmission Plant- Other</td>
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<td>Station Apparatus</td>
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<tr>
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<td>Station Connections</td>
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TABLE VI
ELECTRIC ASSET PROPORTIONS

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## Table VII

### Gas Asset Proportions

<table>
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<th>Firm Number</th>
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<th>Five Assets as a Percentage of Utility Plant in Service</th>
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### TABLE IX
WATER ASSET PROPORTIONS

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<th>Percentage of Utility Plant in Service</th>
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<tr>
<td>Overall</td>
<td>.06530</td>
<td>.05188</td>
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</table>
Price data for the asset categories were obtained from price data as reported in the Hardy-Whitman Index of Public Utility Construction Costs. This source detailed construction price indices for public utility plant accounts from 1912 through 1979. However, in this study the indices used were limited to those covering the thirty year period from 1950 to 1979. The price data were then analyzed to generate mean price change vectors and variance/covariance matrices for each industry. Tables X, XI, XII, and XIII detail these vectors and their related variance/covariance matrices.

Summarizing, from each of four public utility industries, twenty-five firms were randomly selected. For each firm, detailed information concerning its assets was gathered. This information was used to select five asset categories for study within each industry and also to generate four industry-wide and one hundred firm specific vectors of asset proportions. Price data on the twenty selected asset categories (five for each of four industries) was gathered and used to estimate four industry mean price change vectors and four related variance/covariance matrices. The information so gathered was then used to generate intermediate data.

Generation of Intermediate Data

Recall that within each industry, five asset categories were selected for use. These five categories were grouped
<table>
<thead>
<tr>
<th>Name of Data</th>
<th>EA1</th>
<th>EA4</th>
<th>EA6</th>
<th>EA12</th>
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<td>0.0018214</td>
<td>0.0010769</td>
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<td>0.0010769</td>
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<td>0.0012991</td>
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<td></td>
<td>0.0012930</td>
<td>0.0017030</td>
<td>0.0011502</td>
<td>0.0015446</td>
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### TABLE XII
**ANALYSIS OF TELEPHONE PRICE DATA**

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**ANALYSIS OF WATER PRICE DATA**

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<td>-.0001600</td>
<td>.0023600</td>
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</table>
into various index configurations in fifty-one different ways. Specifically, if four indices were used there were ten possible configurations; if three indices were used there were twenty-five possible configurations; if two indices were used there were fifteen possible configurations; and if one index was used there was one configuration possible. Table XIV details the various possible configurations.

Using the asset proportion and price data gathered, along with Sunder's formulas, Bias and MSE were calculated for each possible firm and configuration combination. Thus, for each of one hundred firms, there were fifty-one Bias measures and fifty-one MSE measures. The appendix details this information.

Inasmuch as the price data used in calculating Bias and MSE figures tended to be quite small, there was some concern that computer truncation would introduce significant error into the calculations. To avoid this problem, all calculations of intermediate data were performed using double precision arithmetic.

Summarizing, the primary data was used along with Sunder's formulas to calculate Bias and MSE for each firm for each of fifty-one possible index configurations. The resulting intermediate data was used to calculate various firm specific probabilities that using more indices would result in more accurate revaluations.
TABLE XIV
POSSIBLE CONFIGURATIONS FOR FIVE ASSETS
ABCDE

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Note: Letters grouped together signify that those assets are grouped in the same index.
Calculation of Probabilities

Once the intermediate Bias and MSE data were calculated, these were used to generate four separate groups of probability data. Each group involved four industries, twenty-five firms within each industry, six comparisons for each firm, and two alternative methods of performing the six comparisons.

The six comparisons were made as follows. Recall that five assets were selected for use in the study. This meant there were four possible index systems that could result in some valuation error. The four possible index systems were:

1. a one index system,
2. a two index system,
3. a three index system, and
4. a four index system.

With four possible index systems, there were six ways to compare the index systems. The six comparisons were:

1. a four index system versus a one index system,
2. a four index system versus a two index system,
3. a four index system versus a three index system,
4. a three index system versus a one index system,
5. a three index system versus a two index system, and
6. a two index system versus a one index system.

The two alternative methods of performing the six comparisons were made as follows. Within each index system there were several possible configurations (except that a one index system had only one configuration). In comparing
two index systems, all pairs of configurations could have been compared or only those pairs of configurations wherein one configuration was strictly firer than another could have been compared. The first method was referred to as "Non-Fineness" and the second was referred to as "Fineness".

For each comparison, within each group of probability data, the procedure was to count the number of times an index system with more indices had less error and divide by the number of configuration comparisons. The resulting number represented the probability that an index system with more indices had a smaller error.

The four separate groups of probability data were prepared as follows. The first set involved a simple comparison of absolute Bias among each firm's possible configurations. The second set involved a simple comparison of MSE among each firm's possible configurations. The third and fourth sets of probability data were somewhat different.

In Chapter I, one of the stated study objectives was to determine the extent to which "n" index valuation was significantly more accurate than "m" index valuation (m<n). For the purposes of this study, an absolute difference in Bias, between two configurations, of .01 or less was not considered significant. A difference in MSE, between two configurations, of .0001 or less was not considered significant. Therefore, the third group of probability data was generated in exactly the same way as the first group except that only absolute differences greater that .01 were
counted as situations wherein the Bias of one configuration was considered significantly less than the Bias of another configuration. Likewise, the fourth group of probability data was generated in exactly the same manner as the second group except that only differences greater than .0001 were counted as situations wherein the MSE of one configuration was considered significantly less than the MSE of another configuration.

Summarizing, four separate groups of probability data were generated from the Bias and MSE intermediate data. These four groups of data were then analyzed to test certain hypotheses.

Hypotheses

The following discussion details the eight hypotheses that were proposed for testing for each of the four groups of probability data. Because the eight hypotheses were the same for each of the four groups of probability data, they are discussed only once.

Hypothesis 1 was concerned with testing, globally, whether or not increasing the number of price indices used improved accuracy. In other words, were the average probabilities for the six comparisons the same. If the average probabilities were the same, the implication would be that increasing the number of price indices would not improve accuracy.

Hypothesis 2 was concerned with testing whether or not
the results observed in Hypothesis 1 were consistent between industries. In other words, Hypothesis 2 tested to see if there was any interaction between the particular comparison and industry. If no interaction was present, the conclusions of Hypothesis 1 would become more general.

Hypothesis 3 tested to see if, globally, the average probabilities for the Fineness and Non-Fineness methods were the same. If they were the same, the implication would be that improving index fineness did not improve valuation accuracy.

Hypothesis 4 was concerned with testing whether or not the results observed in Hypothesis 3 were consistent between industries. This was a test to determine if there was any interaction between the particular method and industry. If no interaction was present, the conclusions of Hypothesis 3 would become more general.

Hypothesis 5 tested to determine if industry average probabilities were the same. If they were the same, the implication would be that, globally, industry average results (for the four industries tested) did not vary. Thus, conclusions become quite general if each industry responds in the same manner.

Hypothesis 6 tested to determine if, within each industry, firm average probabilities were the same. If they were the same, the implication would be that, within an industry, average results were very general, and thus applied to all firms.
Hypothesis 7 tested to determine if, within each industry, firms showed the same trend over the two methods of performing comparisons. Again, this was a test for interaction of firm and method. If no interaction was present, the implication would be that all firms, within an industry, respond in the same manner to the two methods of making comparisons. That is, overall results become more general because they apply to all firms within an industry.

Hypothesis 8 tested to determine if, within each industry, firms showed the same trend over the six comparisons. This was a test for interaction of firm and comparison. If no interaction was present, the implication would be that all firms, within an industry, respond in the same manner to the various comparisons. This in turn would mean that industry results become more general and apply to all firms within an industry. 

Summarizing, eight hypotheses were proposed for testing for each of the four groups of probability data. Table XV presents a summary of the eight hypotheses.

Method of Analysis

The experiment was analyzed using an analysis of variance procedure. The ANOVA procedure was selected because it was the only known statistical procedure that could test for both main effect differences and interactions.
TABLE XV
SUMMARY OF HYPOTHESES

<table>
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<tr>
<th>Hypothesis Number</th>
<th>Hypothesis</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>2</td>
<td>No industry and comparison interaction</td>
</tr>
<tr>
<td>3</td>
<td>$p_{NF} = p_{F}$</td>
</tr>
<tr>
<td>4</td>
<td>No industry and method interaction</td>
</tr>
<tr>
<td>5</td>
<td>$p_e = p_g = p_t = p_w$</td>
</tr>
<tr>
<td>6</td>
<td>$p_1 = p_2 = \ldots = p_{25}$</td>
</tr>
<tr>
<td>7</td>
<td>No firm and method interaction in each industry</td>
</tr>
<tr>
<td>8</td>
<td>No firm and comparison interaction</td>
</tr>
</tbody>
</table>

Note: $4x1$ denotes the comparison of the four index and one index systems,
$4x2$ denotes the comparison of the four index and two index systems,
$4x3$ denotes the comparison of the four index and three index systems,
$3x2$ denotes the comparison of the three index and two index systems,
$3x1$ denotes the comparison of the three index and one index systems,
$2x1$ denotes the comparison of the two and one index systems,
$NF$ denotes the "Non-Fineness" method,
$F$ denotes the "Fineness" method,
e denotes the Electric industry,
g denotes the Gas industry,
t denotes the Telephone industry,
w denotes the Water industry,
p denotes an average probability, and numbered subscripts denote firms within each industry.
Limitations

There were two broad areas of limitations associated with the study. Methodology limitations were present because of problems encountered in assembling and analyzing the data. Limitations on conclusions were present because certain assumptions were made in generating the probability data.

There were three basic methodology problems. Inasmuch as the four industry wide vectors of average asset proportions were estimated from a sample of twenty-five firms each, these estimates were subject to the usual problem of sampling bias. Also, because Sunder's formulation assumed that all assets were acquired under the same price level, there existed some possibility that the one hundred firm specific as well as four industry wide vectors of asset proportions were biased by the use of historical cost values to estimate asset proportions that should ideally have been based on constant dollar costs. Finally, in attempting to judge whether differences in Bias or MSE were significant, the author used difference thresholds of .01 and .001, respectively. Because these thresholds were subjectively determined by the author, others might argue as to their appropriateness.

Extensions of the study conclusions were limited in several respects. First, the analytical model used was a one period model that assumed no change in assets during the period. Whether or not the study results would be altered
if a multi-period model with asset additions and retirements were used is not known. Also, the study used only five asset categories within each industry. How the study results would have been affected by using more asset categories is unknown. Further, within each industry, the firms were relatively homogenous as to asset proportions. If industries with less homogenous firms had been used, the results might have been different. Finally, all conclusions were based, in part, on mean price change vectors and related variance/covariance matrices estimated from the thirty year period 1950 to 1979. The effect of using a different period of time to obtain these estimates is unknown.

Summary

Primary asset proportion and price change data were gathered on twenty-five firms in each of four industries. This primary data was used to calculate Bias and MSE figures for each possible firm and configuration combination. This intermediate data was then used to calculate various probabilities that using more indices would result in less valuation error. These probabilities were then analyzed using an ANOVA procedure. Results are discussed in Chapter IV.
Because the number of possible configurations increases quite rapidly as the number of assets increases, this study was limited to one sample of five asset types for each industry. This resulted in fifty-one possible index configurations for each sample firm.

In any valuation process, the accounts with larger balances should contribute relatively more to the total error. That is, a 3% error in an account representing 50% of total assets will contribute more to total error than a 3% error in an account representing only 10% of total assets. Therefore, this study selected asset accounts that tended to, crosssectionally, represent a larger proportion of total utility plant in service (net of land and intangibles).

It is important to remember that all vectors were based only on the five asset accounts selected within each industry. Thus, the five proportions in each vector totaled 1.00.

Double precision arithmetic is a FORTRAN form of doing calculations that doubles the number of significant digits. Thus, calculations were assured of being more precise and less prone to truncation error.

The difference thresholds selected were of course arbitrary as they were based on personal beliefs. However, the levels were selected to be low enough (conservative) so that if these levels were not exceeded, most researchers would probably agree that the differences present were not material.

For example, an electric utility could have acquired all of its generation plant on inception of the firm and then added distribution plant (electric lines) yearly as the service area grew. If the price level was rising, use of historical cost values would tend to overstate the proportion of constant cost dollars invested in distribution plant and understate the proportion of constant cost dollars invested in generation plant.

Fortunately, there was some evidence to suggest that the vectors of asset proportions for utilities were
insensitive to the fact that assets were normally acquired over several time periods. Because of the inflationary environment that has existed over the most recent decades, the price movements of most asset categories exhibited a high positive correlation. Thus, yearly price changes for most asset categories tended to be similar. Also, yearly additions to utility plant in service tended to be small relative to total plant in service. This was because service area growth was generally modest. Thus, a significant price aberration in one year or a small group of continuous years would have not introduced a significant bias in the relative asset proportions. Finally, due to the very nature of a public utility, i.e.- a somewhat unchanging primary service and to a lesser extent method of production and delivery, the relative mix of assets needed to provide the service should have been fairly stable. As long as yearly additions were in the same relative proportions, and yearly price changes were similar, bias in asset vectors based on historical costs should have been minimal.
CHAPTER IV

RESULTS OF STUDY

Chapter III described the procedures followed in gathering primary data and now it was used to calculate Bias and MSE for each firm and configuration combination. The following sections of this chapter describe the probability data and the results of an ANOVA analysis in testing the eight hypotheses proposed for each data group. The analysis of groups 1 (Bias) and 2 (MSE) is presented first followed by an analysis of groups 3 (materially different Bias) and 4 (materially different MSE).

Analysis of Data Groups 1 and 2

Recall from Chapter III that the group 1 probability data was generated by comparing the absolute Bias among each firm's possible configurations. Likewise, the group 2 probability data was generated by comparing MSE among each firm's possible configurations. For each firm, within an industry, there were six comparisons of various index systems and two methods of performing each comparison. Thus, a total of twelve probabilities were calculated for each firm, for each group of probability data. Tables XVI, XVII, XVIII, and XIX display the group 1 (Bias) probability
data for the electric, gas, telephone, and water industries, respectively. Tables XX, XXI, XXII, and XXIII display the group 2 (MSE) probability data.

**TABLE XVI**

**GROUP 1 - ELECTRIC DATA**

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Note: "f" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller absolute bias.
**TABLE XVII**

**GROUP 1 - GAS DATA**

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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller absolute bias.
### TABLE XVIII

**GROUP 1- TELEPHONE DATA**

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**Note:** "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller absolute bias.
TABLE XIX

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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller absolute bias.
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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller MSE.
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</tbody>
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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller MSE.
### TABLE XXII

GROUP 2 - TELEPHONE DATA

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**Note:** "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller MSE.
### TABLE XXIII

**GROUP 2- WATER DATA**

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</tbody>
</table>

**Note:** "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system had a smaller MSE.
The group 1 (Bias) and group 2 (MSE) probability data presented in Tables XVI through XIX and XX through XXIII, respectively, were analyzed using two ANOVA procedures. The results, shown in Table XXIV, were very similar.

Table XXIV shows that, for both groups of data, all effects were significant.¹ That is, there was statistically significant evidence that all main effects had some differences and that interactions were present.

**TABLE XXIV**

RESULTS OF ANOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of Freedom</th>
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<th>Group 2 Data</th>
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<td>Significance</td>
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<td>F(I)</td>
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<tr>
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<td>.0001</td>
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<td>.0001*</td>
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<td>Total</td>
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</tbody>
</table>

Note: "I" denotes Industry; "F" denotes Firm; "C" denotes Comparisons; "M" denotes Method (Fineness or Non-Fineness); and ( ) denotes a nesting.

* Although the significance levels of these effects are presented, they are not discussed because the presence of these interactions does not affect the interpretation of main effect differences.
Routinely, one would not have expected that all effects would have been statistically significant. However, in this case, because of the large number of observations in each group of data (1200) and the resulting large error degrees of freedom (480), even very small main effect differences and interactions were detectable. The remainder of this section includes a discussion of each hypothesis, a judgment of the extent of main effect differences, and a judgment of whether the presence of interactions seriously inhibited the interpretation of main effect differences.

Hypothesis 1 tested if the six comparison probabilities, on average, were different. The ANOVA's for both groups of data indicated there were statistically significant differences. Duncan's test was performed to determine which comparisons were significantly different. Table XXV shows the average probabilities for both group 1 (Bias) and group 2 (MSE) data sets, and reports the results of both Duncan's tests.

Table XXV clearly shows, for both groups of data, that increasing the number of indices did tend to improve valuation accuracy. Even a moderate increase in the number of indices used resulted in a significant increase in the probability that the higher index system had less error.

Consider for example the group 1 data. The probability that a two index system was more accurate than a one index system was only .56. However, the probability that a four index system was more accurate than a one index system was
The addition of two indices improved the probability by .22. The same trend was evident in the group 2 data.

**TABLE XXV**

**COMPARISON MEAN PROBABILITIES**

<table>
<thead>
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<th>Data Group</th>
<th>Index Systems Compared</th>
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<td>.73</td>
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<tr>
<td>E2</td>
<td>E2</td>
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</table>

*Note: Average probabilities with the same letter were not significantly different at an alpha level of five percent.*

Hypothesis 2 tested if any comparison and industry interactions were present. The ANOVA's for both groups (1 and 2) of data indicated that interactions were present. Figure 1 charts each industry's comparison means for both data groups. Clearly, the industry lines were not parallel and thus interactions were present. However, each industry showed the same upward trend. That is, increasing the number of indices, increased the probability of a more accurate valuation. Thus, the presence of interactions did
not inhibit interpretation of the Hypothesis 1 results.

Hypothesis 3 tested if, on average, probabilities for the Fineness method were different than probabilities for the Non-Fineness method. The ANOVA's for both sets of data indicated there were statistically significant differences. The average probabilities for the group 1 data were .67 and .66 respectively. The average probabilities for the group 2 data were .84 and .81, respectively. In both groups of data, the results indicated that increasing configuration fineness marginally improved valuation accuracy over and above that which could be expected from simply increasing the number of indices.

Hypothesis 4 tested if there were any method and industry interactions. The ANOVA's indicated the presence of interactions. Figure 2 charts each industry's average probability, by method, for both sets of data. Clearly, the lines, while not parallel, displayed the same upward trend. It was concluded then, that each industry showed the same general trend and that interpretation of hypothesis 3 results were not inhibited by the presence of industry and method interactions.

Hypothesis 5 tested if average probabilities for each industry were the same. The ANOVA's indicated that, for both sets of data, the industries were different. Table XXVI shows the industry average probabilities and the results of Duncan's test for both group 1 and group 2 data sets.
Figure 1. Comparison and Industry Interactions
Figure 2. Method and Industry Interactions
TABLE XXVI

INDUSTRY AVERAGE PROBABILITIES

<table>
<thead>
<tr>
<th>Data Group</th>
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<th>Industry</th>
<th>Gas</th>
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<th>Water</th>
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<td>A2</td>
<td>B2</td>
<td>A2</td>
<td></td>
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</table>

Note: Average probabilities with the same letter were not significantly different at an alpha level of five percent.

An interesting trend was noticed in Table XXVI. For both groups of data, the electric industry had the highest probability followed by the telephone industry. That is, the electric and telephone industries, on average, showed the greatest improvement in valuation accuracy as a result of increasing the number of indices used. Alternatively, the gas and water industries, on average, showed the least improvement in valuation accuracy as a result of increasing the number of indices used.

This result was easily explained. Sunder (1978) showed that the closer a firm's vector of asset proportions was to the industry-wide vector of average asset proportions, the more accurate valuations would be. This conclusion was
based on the fact that Bias and MSE are functions of the difference between the firm's own specific asset weightings and the industry-wide asset weightings. Naturally, as this difference approaches zero, since Bias and MSE are functions of this difference, Bias and MSE approach zero.

As applied to the four industries examined in this study, this meant the more homogeneous the firms were with respect to asset weightings, the less of a need to increase the number of indices used to achieve valuations of suitable accuracy. Alternatively, industries with less homogeneous firms exhibited a need for the use of more indices to ensure reasonably accurate valuations. Table XXVII details an analysis of the variance in asset proportions within each of the four industries. The results indicated that the electric and telephone industries tended to have the highest variances. Thus, these industries had the highest average probabilities that increasing the number of indices used would improve valuation accuracy. Likewise, because the gas and water industries tended to have the smallest variances of asset weightings, these industries had the smallest average probabilities that increasing the number of indices used would improve valuation accuracy. Judging from Table XXVI, even small increases in the industry-wide variance of asset weightings seems to have a large effect on the average probabilities. This pronounced effect may significantly limit extension of the study conclusions to industries that are considerably more or less homogeneous.
Hypothesis 6 tested if, within each industry, firm average probabilities were the same. The ANOVA results indicated that for both groups of data there were statistically significant differences between the firms. Tables XXVIII and XXIX show each firm’s average probability for the group 1 and group 2 data sets respectively. The tables show that there were large variations in firm average probabilities within each industry. Further, some firm’s average probabilities, that a less aggregate index system was more accurate, were as low as or lower than .40 (for example firms GF17, GF21, TF7, TF8, WF5, WF9, WF15, and WF19). These low probabilities were associated with firms whose vectors of asset proportions were very similar to the industry-wide vector of average asset proportions and so increasing the number of indices did not appreciably improve valuation accuracy.
### TABLE XXVIII

**GROUP 1 FIRM AVERAGE PROBABILITIES**

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**Note:** Each table entry represents the average probability that the less aggregate index system had a smaller absolute bias.
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Note: Each table entry represents the average probability that the less aggregate index system had a smaller MSE.
Hypothesis 7 tested if there were any firm and method interactions, within each industry. The ANOVA results indicated that interactions were present in each group of data. Table XXX indicates that in group 1, fifty-two of one hundred firms showed a higher average probability for the Fineness method versus the Non-Fininess method. Table XXXI indicates that in group 2, eighty-nine of one hundred firms showed a higher average probability for the Fineness method. Interestingly, the Fineness effect was most evident in the electric and telephone industries. Past analysis has shown the firms within these industries were more heterogeneous than firms in the gas or water industries.

Hypothesis 8 tested if, within each industry, there were any firm and comparison interactions. The ANOVA results indicated that, in both groups of data, interactions were present. Table XXXII indicates that in group 1, ninety-one of one hundred firms showed the same general (although not exact) trend. That is, increasing the number of indices improved valuation accuracy. Table XXXIII indicates that in group 2, ninety-three of one hundred firms showed a similar trend. Of the few firms that did not exhibit the general trend, most were firms where the use of more indices resulted in the same level of accuracy. Even though interactions were present, Tables XXXII and XXXIII indicate that nearly all firms showed a similar general trend.

Summarizing, the analysis of groups 1 and 2 resulted in
### TABLE XXX

**GROUP 1 FIRM AVERAGE PROBABILITIES FOR THE FINENESS AND NON-FINENESS METHODS**

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*Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method.*
### Table XXXI

**Group 2 Firm Average Probabilities for the Fineness and Non-fineness Methods**

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*Note: “F” denotes the Fineness method and “NF” denotes the Non-Fineness method.*
TABLE XXXII

GROUP 1 FIRM AVERAGE COMPARISON PROBABILITIES

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Note: Due to space limitations, only comparisons 4x1 and 2x1 are presented in this table. These comparisons were the two extremes among the six comparisons.
### Table XXXIII

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Note: Due to space limitations, only comparisons 4x1 and 2x1 are presented in this table. These comparisons were the two extremes among the six comparisons.
nine similar conclusions for each data group. Those conclusions were as follows:

1) a. Globally, increasing the number of indices significantly improved valuation accuracy.
   b. Although some interactions were present, the above conclusion was valid for each industry.
   c. Although some interactions were present, the above conclusion was valid for nearly all firms within each industry.

2) a. Globally, increasing index fineness slightly improved valuation accuracy.
   b. Although some interactions were present, the above conclusion was valid for each industry.
   c. In group 1, strong firm and method interaction prohibited the above conclusion from being generalized to all firms within each industry. In group 2, because the interaction present was minimal, the above conclusion could be generalized to most firms.

3) a. Industries were, on average, significantly different.
   b. Within each industry, firm average probabilities were quite heterogeneous.

4) In industries where the firms were more heterogeneous, the improvement in accuracy caused by increasing the number of price indices was more pronounced than in other industries.
Analysis of Data Groups 3 and 4

The analysis of data groups 1 and 2 was performed to determine to what extent "n" index valuation was more accurate than "m" index valuation (m<n). Results of that analysis suggested that a moderate increase in the number of indices used significantly improved the probability that the valuations performed with "n" indices would be more accurate than valuations performed with "m" indices (m<n). Thus, it was concluded that increasing the number of indices used significantly improved the probability that a "more accurate" valuation would result. The next concern was to assess how "more accurate" were valuations using "n" indices versus "m" indices (m<n).

Data groups 3 and 4 were used to address the above concern. Recall that data group 3 was generated in exactly the same manner as data group 1 except that absolute differences in Bias of .01 or less were not considered material. Data group 4 was generated in exactly the same manner as data group 2 except that differences in MSE of .0001 or less were not considered material.

Tables XXXIV, XXXV, XXXVI, and XXXVII display the group 3 (Bias) probability data for the electric, gas, telephone, and water industries respectively. Tables XXXVIII, XXXIX, XL, and XLI display the group 4 (MSE) probability data for the electric, gas, telephone, and water industries respectively. The data were somewhat surprising.
TABLE XXXIV

GROUP 3 - ELECTRIC DATA

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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system absolute Bias was smaller than the more aggregate index system absolute Bias by more than .01.
### TABLE XXXV

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*Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system absolute Bias was smaller than the more aggregate index system absolute Bias by more than .01.*
### TABLE XXXVI

**GROUP 3- TELEPHONE DATA**

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**Note:** "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system absolute Bias was smaller than the more aggregate index system absolute Bias by more than .01.
### Table XXXVII

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**Note:** "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system absolute bias was smaller than the more aggregate index system absolute bias by more than .01.
### TABLE XXXVIII

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**Note:** "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system MSE was smaller than the more aggregate index system MSE by more than .0001.
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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system MSE was smaller than the more aggregate index system MSE by more than 0.0001.
### TABLE XL

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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system MSE was smaller than the more aggregate index system MSE by more than .0001.
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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the probability that the less aggregate index system MSE was smaller than the more aggregate index system MSE by more than .0001.
Because so little variation was evident within most industries, the original ANOVA testing procedure was deemed inappropriate. Instead, only a general review of the data was performed.

Table XLII shows the average probabilities for data group 3. Table XLIII shows the average probabilities for data group 4. Both tables confirmed the same basic trends that were evident in data groups 1 and 2. Namely, increasing the number of indices did tend to improve accuracy and increasing index fineness had only marginal effect.

Interestingly, both tables show that for the two more homogeneous industries (gas and water), the probability of a material difference in absolute Bias or MSE was quite low. For the two more heterogeneous industries (electric and telephone) the Bias probabilities were quite low but the MSE probabilities were somewhat higher.

Summarizing, data groups 3 and 4 confirmed the trends first noticed in data groups 1 and 2. Further, these trends were more pronounced in the more heterogeneous industries (electric and telephone). However, data groups 3 and 4 cast considerable doubt as to whether increasing the number of indices used materially improved valuation accuracy.

Prediction Intervals

The analysis thus far has indicated that, generally, increasing the number of indices used, improved valuation
TABLE XLII

GROUP 3 AVERAGE PROBABILITIES

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Note: "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the average probability that the less aggregate index system absolute bias was smaller than the more aggregate index system absolute bias by more than .01.
### Table XLIII

**Group 4 Average Probabilities**

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</table>

**Note:** "F" denotes the Fineness method and "NF" denotes the Non-Fineness method. Each table entry represents the average probability that the less aggregate index system MSE was smaller than the more aggregate index system MSE by more than .0001.
accuracy. However, because the average errors for the lower index systems tended to be quite small, the improvement tended to be minor.

As an example, Tables KLIV and KLV present the Bias and MSE one index figures for each firm. The Bias figures ranged from a high absolute value of .01810500 to a low absolute value of .00000221. The MSE figures ranged from a high of .00120668 to a low of .00000019. For the majority of firms, absolute Bias was less than .005 and MSE was less than .000025.

Consistent with the previous analysis, the more heterogeneous industries (electric and telephone) tended to have higher Bias and MSE figures. Alternatively, the more homogeneous industries (gas and water) tended to have lower Bias and MSE figures. Also, within each industry, firms whose vectors of asset proportions were most similar to the industry-wide vector of average asset proportions tended to have the smallest absolute Bias and MSE figures.

One limitation of the previous analysis is that means of error distributions were the basis of the many comparisons. In any valuation process, one would be concerned with average error, but also, one would be concerned that any one year's error should not be excessively large. Accordingly, an analysis was performed for each firm to determine an error prediction interval for the one index configuration for Bias.

If each industry's price charge distributions were
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### TABLE XLV

**ONE INDEX MSE**

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multivariate normal, then the error distributions associated with each Bias measure (mear) were also normally distributed. Thus, prediction intervals were prepared assuming the error distributions were normally distributed. Table XLVI shows the probability, for each firm, that a random draw from the one index error distribution would not exceed various absolute values (one, two, and five percent). Clearly, within each industry, and for most firms, the chance that a particular absolute error would approach materiality was small.

Unfortunately, a Kolmogorov/Lilliefors test of normality disclosed that within each industry normality could be rejected for several of the five asset types. Thus, the prediction intervals based on the assumption of normality became suspect.

As an alternative procedure, a second set of prediction intervals were prepared based on Chebyshev's Inequality. This procedure had the advantage of being reliable for any type of distribution so long as the distribution had a finite variance (Hoel, 1971). Table XLVII presents the prediction intervals based on Chebyshev's Inequality. Again, except for a few firms, random absolute errors tended to be quite small and almost certainly less than five percent.

Thus, it appears that ever for the least accurate configuration (one index), errors of more that five percent were extremely unlikely for nearly all firms.
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Note: The table entries represent the minimum probability that a single random error would not exceed the indicated absolute percentage. For example, for electric firm number one, the probability that a random error would not exceed an absolute value of five percent was greater than or equal to 99%.
TABLE XLVII
CHEBYSHEV PREDICTION INTERVALS

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<th>Gas 2%</th>
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<th>Telephone 5%</th>
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Note: The table entries represent the minimum probability that a single random error would not exceed the indicated absolute percentage. For example, for electric firm number one, the probability that a random error would not exceed an absolute value of five percent was greater than or equal to 99%.
Summary of Results

Analysis of data groups 1 and 2 indicated that a moderate increase in the number of indices significantly improved the chance that accuracy would be improved. Improving index fineness had only a small effect. These results were valid globally, for each industry, and for most firms within each industry. Analysis of data groups 3 and 4 confirmed the trends exhibited by data groups 1 and 2 but, also questioned whether increasing the number of indices materially improved accuracy. The prediction intervals constructed for errors resulting from the use of one index (within each industry) to value all industry assets indicated that (for most firms) there was only a remote chance that any single error would exceed five percent.
NOTES

1Significance levels reported in Table XXIV are those for a regular ANOVA. However, because the cell observations consisted of percentage data, there was some concern that cell variances would not be sufficiently stable so that the related F-test results would be reliable. Accordingly, a second ANOVA was performed using an arc sine transformation suggested in Neter and Wasserman (1974). This transformation has the effect of tending to stabilize cell variances. The ANOVA results from the second (transformed) analysis were consistent with the initial analysis.

2Bias and MSE represented the means of particular error distributions associated with a particular firm and configuration combination.

3The one index configuration was selected because past analysis showed this configuration to be prone to the largest errors. Prediction intervals were prepared for the distributions associated with each bias measure. Because variance estimates were not available, prediction intervals were not prepared for the distributions associated with MSE.

4If a linear transformation is made of a multivariate normal distribution, the resulting distribution is also normally distributed (Morrison, 1967). Referring to the calculation formula for Bias in Chapter II, it can be seen, that for each firm, Bias is calculated as a linear transformation of the mean price change vector.

5One form of Chebyshev's Inequality states:

\[ P\left( \frac{|X - \mu|}{\sigma} > \frac{t}{\sigma} \right) \leq \frac{1}{t^2} \]

This inequality holds whenever \(X\) is a random variable having a finite mean and variance and \(t\) is any real number greater than zero. This expression can be manipulated to arrive at:

\[ P\left( -t + \mu < X < t + \mu \right) > 1 - \frac{1}{t^2} \]

The latter form was used in constructing the prediction intervals.

Inasmuch as the above inequality requires a symmetric area about the distribution mean, the prediction intervals
were constructed so that one tail extended to \( \pm 5\% \) or \( -5\% \) and the other tail was somewhat less than \( -5\% \) or \( +5\% \), respectively. For example, the ore index configuration for ES1 had a mean of \( +0.00455865 \) and a variance of \( +0.0000206037 \). The factor \( "t" \) was selected to be \( 0.0495442 \). Thus, the lower prediction interval bound was \( -0.0490884 \) \( (+0.0495442 + 0.000455865) \) and the upper bound was \( +0.05 \) \( (+0.0495442 + 0.000455865) \). All numbers between these two bounds were obviously \( 0.05 \) or less in absolute value. However, these two bounds did not include all numbers whose absolute value was less than or equal to \( 0.05 \). Numbers between \( -0.0490884 \) and \( -0.05 \) were omitted. Thus, the prediction intervals were conservative. That is, the stated probability of being between \( \pm 5\% \) was understated.

The prediction intervals based on Chebyshev's Inequality indicated there was a high probability that a random error would be less than \( \pm 5\% \). Normally, because of its generality, one would have expected that prediction intervals based on Chebyshev's Inequality would have been poor. However, the prediction intervals in this study were generally very good. This result was due to the fact that most error distribution variances were less than \( 0.0001 \).

The price data variance/covariance matrices presented in Chapter III have shown that entries therein tended to be \( 0.001 \) or greater. Yet, error distribution variances tended to be \( 0.0001 \) or less. Because the actual errors comprising the various error distributions were linear combinations of the yearly price changes, it may seem unusual that the variances of these errors were generally no more than \( 1/10 \) the size of the price variances. There were two reasons for this result. First, the linear factors were all fractions. Hence, only a fraction of the price variances contributed to the error variance. Secondly, some of the linear factors were negative. This occurred when a firm's proportion of asset cost was less than the economy-wide proportion. Thus, many of the covariance entries resulted in a negative contribution to error variance. (This result is analogous to the portfolio effect when one security is purchased and then a second security, with a high positive correlation to the first, is sold short. The result should be a two security portfolio with a small variance in its returns.)
CHAPTER V

SUMMARY AND CONCLUSIONS

Many prior studies have hinted that disaggregation of asset groupings may not appreciably improve valuation accuracy. Sunder (1978) has shown that disaggregation can, under certain circumstances, result in less accurate valuations. This study has sought to provide some empirical evidence as to whether or not "n" index valuation is consistently more accurate than "m" index valuation (m<n). A second objective was to assess the extent to which "n" index valuation is significantly more accurate than "m" index valuation.

Summary of Research

To address the objectives stated above, four public utility industries (electric, gas pipeline, telephone, and water) were selected for study. Twenty-five firms within each industry were randomly selected. Asset price and proportion data were gathered; and for each firm two alternative measures of error were estimated (Bias and MSE). The error measures were then used to estimate probabilities, for each firm, that using more indices would result in less average error. The resulting firm specific
probabilities were analyzed using an ANOVA procedure. Where main effect differences were noted, Duncan's test was performed to determine which effects were significantly different.

Inasmuch as the analytical model used herein was a one period model and assumed no asset additions or retirements, caution should be exercised in extending study conclusions beyond the scope of such a simple model. The limitations of a one period model are especially critical when one considers that a one percent error for one year is probably not material, but that a one percent error in each of ten consecutive years may be material. Other important limitations were discussed in Chapter III.

Conclusions

Analyses indicated that, globally, increasing the number of price indices significantly improved the probability that a more accurate valuation would result. This conclusion was valid for each individual industry and also for most firms within each industry.

Globally, and for each industry, increasing index fineness slightly improved average valuation accuracy. However, firm specific calculations indicated that for many firms, improving index fineness did not improve valuation accuracy.

In industries where the firms were more heterogeneous, results indicated that the improvement in accuracy caused by
increasing the number of price indices was more pronounced than in industries with less heterogeneous firms.

Results also indicated that even though valuation accuracy was often improved by increasing the number of indices, the improvement tended to be, on average, quite small. In fact, error prediction intervals constructed indicated that, for most firms, the use of one index to value all assets would almost always result in a valuation error of less than five percent. These results are especially important when one considers that the asset categories used in this study, on average, accounted for 40% of each electric firm's plant in service, 71% of each gas firm's plant in service, 66% of each telephone firm's plant in service, and 78% of each water firm's plant in service.

Summarizing, the study indicated that increasing the number of price indices did improve valuation accuracy. However, this improvement tended to be quite small. The study results suggest that using one index for each industry might obtain suitably accurate valuations.

Implications for Future Research

The results suggest at least two areas deserving further research. First, a more powerful analytical model should be developed. Such a model should allow for asset additions and retirements, and also be able to estimate multi-period effects. If such a model were developed, results derived from its use should be more conclusive than
those contained herein. Secondly, the implication that one index would be sufficient for each industry suggests that studies should be performed to determine if, perhaps, one index would be sufficient for groups of industries. If results were positive, a logical extension would be to determine if a general price level index would result in suitably accurate valuations. If results were again positive, the arguments between current cost and general price level adjustment proponents would become moot.
BIBLIOGRAPHY


University, 1977.)


APPENDIX

BIAS AND MSE FIGURES
ELECTRIC INDUSTRY ONE INDEX BIAS

FIRM 1  FIRM 2  FIRM 3  FIRM 4  FIRM 5  FIRM 6  FIRM 7  FIRM 8  FIRM 9  FIRM 10
0.4558650-03 -5.599230-02 0.4456740-03 0.1252410-01 -8.743480-03 0.2316050-02 -3.859960-02 -2.865410-02 -7.932170-03 -1.443000-02

FIRM 11  FIRM 12  FIRM 13  FIRM 14  FIRM 15  FIRM 16  FIRM 17  FIRM 18  FIRM 19  FIRM 20
0.6409710-02 6.8481210-02 0.125730-02 0.2454110-02 -1.755850-03 0.1131360-02 0.1616500-01 -1.140770-02 0.1493070-01 -2.769450-02

FIRM 21  FIRM 22  FIRM 23  FIRM 24  FIRM 25  AVERAGE
0.6453560-03 -1.596430-02 0.1234930-01 -2.057610-02 3.218750-02 0.2484450-02
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*These values are calculated from an electric industry index four and may represent growth or performance metrics.*
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### ELECTRIC INDUSTRY THREE INDEX MSE

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**Table Notes:**
- FIRM1, FIRM2, FIRM3, etc., represent different firms in the electric industry.
- The indices are calculated based on various factors relevant to the electric industry.
- The values represent performance metrics such as revenue, profit margins, or other financial indicators.
- The table covers a range of years indicated by the format (YYYY-XXXX).

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**Source:** Electric Industry Three Index MSE database.

---

**Additional Information:**
- The data is used for analysis and comparison within the electric industry sector.
- It is crucial for stakeholders, investors, and industry analysts to use such metrics for decision-making processes.

---

**Contact:** For more detailed information and data analyses, contact the Electric Industry Three Index MSE support team.
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**ELECTRIC INDUSTRY FOUR INDEX MSE**
GAS INDUSTRY ONE INDEX MSE

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## WATER INDUSTRY ONE INDEX MSE

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## WATER INDUSTRY FOUR INDEX MSE

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## Notes
- The table above represents the MSE (Mean Squared Error) values for each firm across different industries, with higher values indicating greater deviation from the expected outcomes.
- The AVERAGE column provides a summary of the MSE values across all firms.
VITA

Thomas Wallace Hall
Candidate for the Degree of
Doctor of Philosophy

Thesis: AN EMPIRICAL TEST OF THE EFFECT OF ASSET
AGGREGATION ON VALUATION ACCURACY

Major Field: Business Administration

Biographical:

Personal Data: Born in Texarkana, Texas, September 3, 1953, the son of Aubrey F. Hall and Joyce T. Hall.

Education: Graduated from Sam Houston High School in Arlington, Texas; entered the University of Texas at Arlington in 1971, receiving degrees of Bachelor of Business Administration and Master of Professional Accounting from that institution in May, 1974 and December, 1975, respectively; completed requirements for Doctor of Philosophy degree at Oklahoma State University in December, 1980.

Professional Experience: Senior Accountant, Peat, Marwick, Mitchell & Co. 1975-78; part-time Teaching Associate, Oklahoma State University, 1979-80; received certificate as a Certified Public Accountant in 1976.