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**THE RELATIVE ACCURACY OF THE RANDOM WALK THEORY IN
LONG-TERM MARKET FORECASTING**

City University of New York

PH.D. 1982

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**THE RELATIVE ACCURACY OF THE RANDOM WALK
THEORY IN LONG-TERM MARKET FORECASTING**

by

STEVEN PHILIP SCHNAARS

**A dissertation submitted to the
Graduate Faculty in Business in
partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
The City University of New York**

1982

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1982

This manuscript has been read and accepted for the Graduate Faculty in Business in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

July 1, 1982
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Abstract

THE RELATIVE ACCURACY OF THE RANDOM WALK THEORY IN LONG-TERM MARKET FORECASTING

by

Steven P. Schnaars

Advisor: Professor Conrad Berenson

Can long-term market growth be predicted? Do annual unit sales series follow a predictable pattern, as suggested by the product life cycle, or do they wander aimlessly? Will an econometric approach to long-range forecasting yield more accurate forecasts than time-series approaches? Do complex approaches to forecasting yield more accurate forecasts than simple methods? Does combining forecasts lead to greater accuracy? This research sought to answer these questions.

The relative accuracy of ten widely used market forecasting methods was examined on a "hold-out" sample for one through five year forecasts generated from a large number of product sales series. In total, over 10,000 forecasts were generated and compared.

Not only were simple models found to provide the most accurate forecasts, a result consistent with recent research findings, but the most simple Random Walk model yielded the lowest mean absolute percentage error. This implies that popular marketing concepts such as the product life cycle should be reconsidered. A large percentage of the sales series tested in this research showed no inertia in their evolutionary process.

The predictability of various subgroups within the sample varied greatly by method. Product perishability, time horizon, data availability, judgmental assessments of stability, autocorrelation structure, and the number of runs were all found to affect the relative accuracy of the forecasting models tested. The product class/form dichotomy did not affect accuracy. These findings suggest that marketers should focus more intently on the forecasting situation.

Econometric models (single equation) were not found to yield superior forecasts even though the predictors chosen were deemed by experts to be crucial to the future of their industry.

ACKNOWLEDGMENTS

To begin, I would like to thank Professor Leon G. Schiffman who, although he was not a formal member of the dissertation committee, has provided immeasurable support and wise counsel. Professor Schiffman initially suggested that I enter the Ph.D. program, and has always believed in my potential. For his support, guidance, and encouragement I am extremely grateful.

I would also like to thank Professor Jae Won Lee for his careful reading of the dissertation, and his helpful comments. In addition, our long talks about forecasting while commuting on the Long Island Railroad were a source of enlightenment, and one of the only pleasant aspects of commuting.

Professor Sidney Lirtzman also deserves my sincere appreciation. As Executive Officer of the Doctoral Program he agreed to take time out of his busy schedule to sit on the committee. His encouragement and advice are greatly appreciated, and helped focus the research topic.

I would also like to thank Dr. Mel Tainiter for reading the dissertation, and offering his helpful comments.

I have saved the best until last. Professor Conrad Berenson has been a mentor in the truest sense of the word. He has provided guidance along every step of the Ph.D. process, yet has not restricted my research interests. I consider myself extremely fortunate to have been able to work with him all these years. What I have learned from him will surely be reflected in my future research efforts. I am deeply and very sincerely appreciative for all Professor Berenson has done for me. I am forever grateful, and hope to continue our good relationship.

Finally, I would like to thank Bob Lehrer and Phil Trejera of the Baruch College Educational Computer Center for their invaluable help in writing the computer programs required to generate the forecasts used in this dissertation.

On the home front, I would like to thank my wife Gail. In many respects, the Ph.D. process has been harder on her than me. She is so used to being married to a "perpetual" student, I do not think she realizes that it has ended. She seems to be convinced that I will shortly return for

another degree.

I would also like to formally acknowledge my ten month old son, Paul, who was born during the writing of this dissertation. I am convinced that to date he believes the world is largely madeup of sheets of paper and saturated with the continual patter of typewriter keys.

TO MY WIFE AND SON
GAIL AND PAUL

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CHAPTER 1

INTRODUCTION

Over the years forecasting has been the practice of the seer, the sage, the soothsayer, and more recently, the market researcher. The goal of forecasting has generally remained the same, to foretell some future event. In the context of long-range market forecasting this usually entails predicting the long-term growth prospects for a given market.

The ability to forecast market trends has obvious value. An accurate long-range forecast, whether implicitly or formally generated, provides invaluable information for strategic planning, and a definite competitive advantage for the firm possessing it. Resources can be allocated to growth markets and withdrawn from declining ones with a leadtime that is sufficient to respond to changes in future market conditions. This allows the firm to better manage its portfolio of businesses over the long run.

Likewise, an innaccurate forecast, or the failure to heed the advice of an accurate one, can have a disastrous effect on the future well-being of the firm. Even

if the firm does not subscribe to formal forecasting, if its objectives are predicated on a mistaken notion of the future it is preparing for a future that will never come. In terms of missed opportunities and wasted resources the firm will be hurt.

The past is replete with examples of how the accuracy of a long-term forecast underlying the firm's plan can dramatically affect its future well-being. Coca-Cola sensing a probable decline in the long-term growth rate for sales of its primary product due to the aging of its key customer group, the baby-boom generation, sought a new growth market in wine products. Wine products were chosen on the basis of fast growth over the past few years and the forecast that the baby-boom generation was now entering that age which traditionally made-up the heavy users' group for wine products. Coke acquired the Taylor Wine Co., and with its well known marketing skills, maintained its franchise with this largest of American consumer groups (Business Week, 1977, p. 70).

American automobile manufacturers were less insightful. Their myopic perception of long-term market changes represents a classic failure of forecasting and how the well-being of an entire industry can be affected by a lack of

foresight. The member firms of this industry patently failed to anticipate the rapid growth of the subcompact car market and as a result have steadily lost market share to foreign competitors. Had they forecast this turning point sooner their position in today's market would surely have been less precarious (Business Week, 1980, p. 78).

American television manufacturers, and the entire consumer electronics industry in general, failed to foresee the extent to which American consumers would become enamoured with miniturization. Long after the movement was under way, American manufacturers continued to concentrate on huge console televisions and steadily lost ground to foreign competitors (Tsurumi & Tsurumi, 1980).

The information processing industry is currently experiencing a profound change in the complexion of its market. The market growth rate for large mainframe computers is declining while that for mini- and micro-computers is growing rapidly. As Business Week (1982) observes "for the most part, though, the full-line computer makers, which account for the bulk of mainframe sales, have been slow to realize that they were facing

a fundamental shift in their business and that mainframes were taking a background role in information processing. Sperry Corp. even divested its only possible entry into the "office of the future" between 1976 and 1979 leaving it most heavily dependent on mainframes!

The list goes on and on. Kresge's transformation into K-mart versus their competitor's actions, ATT's videophone (Electronics, 1973), William Lear's Steam Car (Business Week, 1969, p. 40), the expected decline, but actual growth of cigarette sales (Business Week, 1980, p. 52), and the infamous Baldwin Locomotive Co. (Steiner, 1969, p. 69) all offer good examples.

The key point here is that accurate forecasts of long-term market growth are extremely important if the firm seeks to proactively pursue a long-term growth strategy.

The emergence of strategic planning as a focal point of academic research and business practice only heightens the importance of this point. Strategic plans inevitably stand atop a long-range market forecast, be it implicitly or formally derived, whose realization greatly affects the viability of that plan. A well-drawn plan predicated on an inaccurate forecast is generally doomed to failure.

A current example of this point is Xerox, who is mortgaging nearly its entire future on the "office of the future" and its ability to serve this market with its "ethernet" system. Entry into this market is being financed by its photocopier business which is forecast as a declining market to be replaced by the non-paper document stored in the "office of the future" (Business Week, 1981, p. 126).

A failure of the forecast for the "office of the future" or "ethernet" might result in a Xerox that is a shadow of its former self.

1.1 - STUDY OBJECTIVES

The primary goal of this research is to provide market planners with a more accurate means of estimating long-term market growth and decline. Toward this end this research focuses on three broad objectives.

The first objective of this research is to assess the extent to which the Random Walk Theory explains changes in long-term market trends. Under what conditions can a market forecast be expected to do no better than chance? A series of tests are used to support or refute this theory in a form similar to that employed in studies of financial time-series (Fama, 1965).

The second objective is to assess the overall relative accuracy of ten widely used forecasting methods for one, two, three, four, and five year forecasts. The models tested are:

Time-series models

1. naive (Random walk)
2. double exponential smoothing
3. triple exponential smoothing
4. linear regression (sales as a function of time)
5. regression polynomial
6. exponential growth curve (constant percentage growth)

Econometric models

7. linear regression (additive)
8. non-linear regression (multiplicative)

Combinations

9. double exponential smoothing + linear econometric model
10. polynomial regression + non-linear econometric model

Each of the models is evaluated on a wide variety of product categories. In addition to the above models, a comparison is also made of various groups of forecasting methods, simple vs. complex, combined vs. single, and times series vs. econometric.

The third objective of this research is to delineate those characteristics particular to a given market forecasting situation that affect the relative accuracy

of the tested methods. To accomplish this objective, ten characteristics are identified. Each of the sales histories, which serve as the sample, is classified as follows:

Situation characteristics

1. time horizon of the forecast
2. years of data available
3. durable/nondurable product
4. product class/product form
5. number of turning points
6. stability of the data
7. autocorrelation of the original data
8. autocorrelation of first differences
9. number of "runs"
10. results of "runs" test

This second stage of the analysis results in a series of prescriptive statements indicating in what situations one approach is preferable to another.

1.2 - QUESTIONS TO BE EXAMINED

In light of the three broad objectives presented above and the deficiencies in the forecasting literature offered in the first section, a number of specific research questions are considered.

First, how does time-series analysis compare with econometric model building as the time horizon of the forecast shifts from short- to long-term?

Second, overall is the increased complexity of method apparent in the recent literature warranted? In what situations, if any, do complex models outperform simple ones?

Third, what is the status of the product life cycle? Is there any evidence that the forms of the product life cycle as suggested by Cox (1967) are superior to other types of forecasts? In what situations is the product life cycle most appropriate?

Fourth, will a strategy that combines methods from different approaches outperform forecasts generated by a single method? Since combinations of forecasts incorporate models that look at the data in different ways, will such an approach be preferred in situations where change is rapid and the situation is unstable?

The specific hypothesis is derived from these questions are presented in a later chapter.

1.3 - STUDY RATIONALE

The centrality of an accurate forecast to the achievement of the firm's objectives suggests that re-

search aimed at assessing and improving forecast accuracy would be highly desirable. Unfortunately, forecasting research has proved to be highly deficient in this respect. The following five points discuss the shortcomings of previous research and a subsequent section offers improvements on this research.

The first deficiency in the literature, especially the marketing literature, concerns the feasibility of long-range forecasting overall. Is it even possible to forecast into the relatively distant future in a turbulent environment such as exists today? By definition, long-range market forecasting seeks to predict events that have yet to occur. It might be, and in some applications has been, shown that forecasting efforts are a ruse. The evolution of a time-series appears random due to the unpredictable occurrence of exogenous factors, such as news events, oil embargoes, economic factors, brand switching and technological innovation, which have not been considered in the forecasting model. Known as the Random Walk Theory, it has repeatedly been shown to be the best explanation for the observed behavior of many financial time-series including stock prices, interest rates and corporate earnings. Due to the lack of compa-

rative studies the extent to which this model describes long-term marketing data has not been established. Further evidence on this crucial issue would surely benefit the users of market forecasts, if not the forecasters themselves.

Second, few studies have actually compared the relative accuracy of available forecasting models. This shortcoming has been noticed by some of the key authors in the forecasting literature. For instance, Granger (1980) notes, "At this time there has been no comprehensive study comparing forecasts from a variety of different methods on many economic series" (p. 162). Wheelwright and Makridakis (1980) state, "Unfortunately, comparisons among alternative decomposition methods and other techniques of forecasting have not been reported in the literature" (p. 44). Armstrong (1978) states, "I can not think of anything worthwhile to say about research based on a single model. On the other hand, most published research on forecasting is done using a single method. This just goes to show you can fool most of the people most of the time" (p. 276).

Only when more than one approach to forecasting is employed can statements about which procedure is most accurate be made. As a result, "real" progress in the ability to call long-term market changes has suffered. To date, market planners have not been provided with a clear indication as to what methods of forecasting should be used in a given situation.

A third deficiency in the existing literature arises from the fact that forecasting researchers are inexorably allied with either one of two distinct theoretical paradigms that characterize the literature, time-series analysis and econometric model building. Each of these paradigms is discussed in detail in a later section.

Briefly, a time-series analysis approaches the forecasting problem by searching for patterns in past values of that item to be forecast. Econometrics focuses on identifying the "structure" of the system in which the item to be forecast is found and by forecasting changes in some elements of the system derives a forecast for the item of interest.

Comparisons between forecasts generated by the two paradigms are rare, in particular, when compared to fore-

casts generated by a process assuming a random walk. However, a delineation of those situations where one paradigm is preferable to the other would provide market planners with valuable information concerning the evolution of their markets.

The fourth deficiency of existing research is that there is a strong trend within each of the above paradigms toward more complex forecasting methods with no empirical examination as to whether this leads to more accurate forecasts. Econometric models consisting of hundreds of regression-based equations and time-series methods such as ARIMA and state-space models offer examples of more complex models. The limited, and often indirect, evidence on the issue of whether complex models provide more accurate predictions has been negative (Armstrong, 1978). Further evidence is needed so that market planners can better decide whether to invest large sums of money and considerable effort in this direction.

The fifth, and final, deficiency in the existing literature concerns the delineation of those situations in which one approach to forecasting outperforms another;

a contingency theory of forecasting. To date, almost no work has been reported in this area based on empirical evidence.

Different forecasting models look at the available data in different ways. It is reasonable to assume that the application of different methods will result in different rankings of relative accuracy under different sets of forecasting conditions. Even if the Random Walk Theory is supported in some situations, in others it might be possible to forecast better than this chance model. A number of hypotheses regarding the relative accuracy of forecasting methods under different situations have been suggested but they 1) have not been empirically tested, and 2) do not consider the chance model (Armstrong, 1978; Chambers, Mullick and Smith, 1971).

The end result of such an empirical investigation would be to offer a set of conditional statements describing those situations in which forecasting should be avoided altogether, and those where an existing forecasting model would do better than chance. Such findings would have great value to market planners and provide a basis for further research.

1.4 - SCOPE OF STUDY

This study represents a comprehensive comparison of long-term forecasting methods. Approximately ten thousand forecasts are compared over a wide variety of product categories. To date, a study of this scope has not been reported in the marketing literature.

Of the few comparative studies that have been reported most have focused on highly aggregated economic time series such as GNP. Others, of greater interest to marketers, have been less comprehensive, relying on a single time series. Armstrong and Grohman (1972) investigated the relative accuracy of three forecasting models on one time series, revenue passenger miles in the U.S. air travel market. Geurts and Ibrahim (1975) forecast the level of Hawaiian tourism using two forecasting methods.

This study also examines a large number of forecasting methods. As stated previously, most studies examine only a single method or, at most, compare a few methods. Ten forecasting methods are examined in this study. The methods were chosen from a larger number of existing models on the basis of widespread

usage by market forecasters. This assessment was judgmental and based on the extent to which such methods are discussed in the literature.

Both time-series models and econometric models are compared. Most comparative studies, with the exception of Armstrong and Grohman (1972), compare models from within one of these two paradigms. Time-series models are, generally, easier to apply to many data bases due to their mechanical application. The same procedure is applied to each data series. Econometric models require that either a specific model be designed and applied to each data series or the results from published models be used. Comparisons of econometric forecasting have usually focused on non-marketing applications such as predictions of the general economy by the major econometric services (Nelson, 1972).

The different skills required to apply each of these approaches, the mechanical nature of time-series methods, the scarcity of published econometric models for marketing applications, and the difficulty of constructing econometric models for many data series have made generalizations regarding the relative accuracy of the two approaches difficult.

The key limitation of this study involves the generating of econometric models. First, since different researchers might be expected to derive different econometric models when forecasting in the same market, how should the optimal model be selected? If the accuracy of the model used in a comparison is poor is this because econometric models, in general, perform poorly, or because a poor model was constructed?

This problem was approached in the following way. A search of the economics literature revealed the existence of any previously constructed models. A trade association, in one case, was able to provide a model used in their industry. This model, with slight variations, was employed here. If no model was available a review of business publications was conducted to reveal those factors that were felt would determine future sales levels. A model was built from these factors. While a better model might be constructed, the one used here was one that might be expected from a reasonable effort.

A second limitation of the study concerns the fact that each time-series required a separate econometric model. Since 98 data series were employed, econometric

models were constructed for only a subset, or 15 of the data bases. All comparisons involving these methods are, therefore, made only on this subgroup.

Some of the secondary delimitations of this study are presented below:

1. Only unit sales were considered to eliminate the effect of inflation and other price-related variables.
2. Only annual sales were considered since the focus of this study is long-range forecasting.
3. Only consumer products were studied.
4. While data reflecting sales at the level of product class (i.e., automobiles, deodorants, cigarettes) and product form (i.e., sub-compact autos, roll-on deodorants, low-tar cigarettes) was employed, no brand data is considered.
5. All forecasts were constructed on the original data. First differences were not forecast.

1.5 - STUDY IMPORTANCE

The goal of this study is to offer a significant contribution to the forecasting literature. It seeks evidence on the following issues.

First, this research examines the most basic issue in long-term market forecasting, is it feasible? Testing the extent to which the Random Walk Theory is supported on annual, unit sales data, given its substantial support in financial applications, will yield new insight into the apparent behavior of long-term sales data. Strong support for the Random Walk Theory would suggest that market planners reassess their assumptions regarding growing and declining markets. If the theory is not supported long-term forecasting efforts should be encouraged and expanded.

Second, the comprehensive scope of this research, in terms of sample size and the number of methods tested, should greatly extend the level of knowledge regarding this field of study.

Third, a clear delineation of the factors that affect the relative performance of various forecasting methods would spawn further research and aid "real-world"

planners and forecasters. To date, little empirical evidence is available on this issue.

Fourth, the relative value of complex methods, combinations of forecasts, and the product life cycle when used as a forecasting tool, are examined. While these concepts "seem reasonable", and much has been written about their value, very little in the way of empirical evidence has been offered to support these claims. If such methods are shown to offer a real predictive advantage, further research, and increased usage in the business community, should be encouraged. If not, they should be replaced with other more accurate methods with possibly less intuitive appeal but more empirical support and predictive validity.

1.6 - ORGANIZATION OF THE DISSERTATION

Chapter II reviews the relevant forecasting literature that pertains to long-term market forecasting.

Chapter III presents a detailed discussion of the forecasting methods tested, the sample, and other aspects of the research design.

Chapter IV presents and discusses the results of the study.

Chapter V summarizes the findings and makes inferences concerning long-term market forecasting.

CHAPTER II

LITERATURE REVIEW

This chapter focuses on three distinct aspects of the forecasting literature. First, the literature on comparative forecast accuracy is reviewed. Second, past efforts aimed at assessing the determinants of forecast accuracy are presented. Third, the evolution of the Theory of Random Walks is traced, and the literature regarding its validity reviewed.

2.1 - DIRECT COMPARISONS OF FORECASTING METHODS

The most constructive research in forecasting surely comes from a direct comparison of two or more forecasting methods. Employing this paradigm helps answer the question, Better than what? That is, a forecasting procedure that misses its mark by plus or minus twenty percent can not be judged "accurate" or "inaccurate" without comparing it to procedures that are currently used or currently available, including a "chance model."

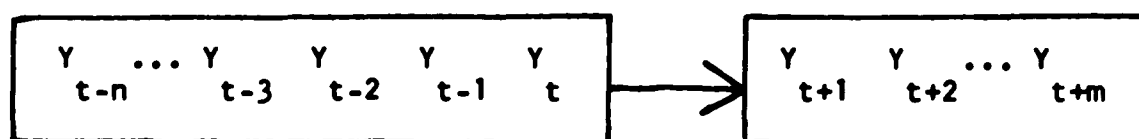
2.11 - The Relative Accuracy of Various Time-Series Forecasting Methods

Time-series methods have one element in common, they rely solely on past observations of a data series. No consideration is given to possible causal factors. Figure 2.1 illustrates this point. The basic assumption of the approach is that past values of a series contain information that is useful for predicting future values. Its goal is simply to identify the inherent "pattern" in the data. This pattern can take the form of a trend or a consistently recurring course of events. Some examples of patterns identified in business data-series include the business cycle, seasonal variation, diffusion of innovation, the product life cycle and the "head-and-shoulders" formation in stock market data. Other patterns are peculiar to a given data-series. Whether many of these patterns are real or imagined is a point of contention in forecasting.

Dozens of time-series models are available to choose from when forecasting sales. These range from simple heuristic procedures such as moving averages and exponential smoothing, and the myriad of extensions of these basic schemes, to regression-based extrapolation models that

FIGURE 2.1

THE STRATEGY OF TIME-SERIES ANALYSIS



where:

Y is the value of the time-series

t is the present time-period

n is the number of periods used to construct the forecast

m is the time horizon of the forecast

fit linear, polynomial, and S-curve patterns to a series.

Comparisons as to the relative accuracy of these standard forecasting tools have yielded some important results. Kirby (1966) compared exponential smoothing, moving averages, and linear regression, with time as the independent variable, on monthly sales data for 23 sewing machine products. One and six month forecasts were generated from a base of seven-and-one-half years of monthly sales data. For the one month forecasts, exponential smoothing showed a slight, but statistically significant, advantage. For the six month forecasts, exponential smoothing and moving averages provided similar predictions, while regression was judged to be slightly inferior. Kirby hypothesizes that time-series regression would fare better in longer term applications. However, Elton and Gruber (1972) found that the relative accuracy of regression, in comparison to exponential smoothing, decreased as the time horizon of the forecast increased from one to three years.

Levine (1967) compared the same three models as Kirby. He also found a slight advantage for exponential smoothing in short-term forecasting.

Adam (1973) compared various forms of exponential smoothing, moving averages, a random walk model, and adaptive smoothing, a complex method, on five simulated data patterns. Again, exponential smoothing was found to provide the most accurate short-term forecasts. It also provided the most accurate long-term forecasts. The random-walk model placed second in both instances suggesting that, except for exponential smoothing, the time-series models tested did no better than chance. Adaptive smoothing, the complex model, never ranked higher than sixth, out of the seven models tested, on any of the five data patterns for long- or short-term forecasts. Adam suggests that this model tended to follow "noise" induced into the data patterns, mistaking it for changes in the pattern itself.

Raine (1971) also failed to find any advantage in adaptive smoothing. He also found exponential smoothing to be more accurate.

Recently, market forecasters have focused a great deal of attention on ARIMA models (Integrated-Autoregressive Moving Average), a highly complex approach to time-series

forecasting. Initially developed in the 1930's, this method was popularized by Box and Jenkins (1970) whose names are now synonymous with the method. Briefly, ARIMA models consist of three steps. First, it "searches" the autocorrelation structure of a data-series. Second, it "fits" one of a number of possible models to that series, depending on the number and pattern of "significant" autocorrelations. In cases where simple autocorrelation structures are found, simple models such as exponential smoothing, or in more extreme cases a random walk model, is fit. In other words, these models are really a subset of the class of models fit by ARIMA. Third, the autocorrelation of the forecasting "errors" using the fitted model is calculated and examined. In the absence of any autocorrelation the proposed model is accepted. If autocorrelation is present in the errors step two is repeated and another model is fit.

The procedure is highly complex. Many books have been written to describe it (e.g. Granger and Newbold, 1977; Nelson, 1973; Makridakis and Wheelwright, 1978). Recent efforts have even proposed a multivariate version of

ARIMA (e.g. Makridakis and Wheelwright, 1978; Granger and Newbold, 1977).

The application of ARIMA models can be expected to grow rapidly in the near future. Widely used software packages such as SPSS (1981) and SAS/ETS (1980) now contain canned programs to construct ARIMA forecasts. Whether this easy access will lead to improved forecasts or merely the blind application of yet another complex method remains to be seen.

It would seem that the ultimate test of the approach is in its ability to out-predict other models. A few comparative studies have tackled this question.

Bates and Granger (1969) compared ARIMA (Box-Jenkins) and exponential smoothing over 12 one month forecasts of airline passenger miles flown. The ARIMA forecast was constructed by Box and Jenkins themselves. Exponential smoothing provided more accurate forecasts in 7 cases. Box-Jenkins was most accurate in 4. There was one tie.

Groff (1973) compared ARIMA and exponential smoothing on 63 monthly series representing shipments of drug items and automotive parts. One and six month forecasts were generated. Overall, ARIMA forecasts were either equal to

or slightly worse than forecasts generated via exponential smoothing.

Geurts and Ibrahim (1975) also compared the same two methods. Using monthly data on the number of Hawaiian tourist from 1952 to 1969, they generated 24 one month forecasts for 1970 and 1971. No difference was found between forecasts generated by ARIMA and those generated by exponential smoothing.

Newbold and Granger (1974) conducted a comprehensive comparison of the two methods on 106 economic time-series. One to eight month forecasts were generated. Box-Jenkins proved more accurate in 73% of the one month forecasts. As the time horizon increased this advantage was seriously eroded.

Moriarty and Salamon (1980) tested the relative accuracy of multivariate ARIMA and the univariate form similar to that studied in the previous studies. One and three month forecasts were constructed from unit sales data of a frequently purchased branded good. Multivariate ARIMA provided the most accurate forecasts in all of the eight situations tested.

In sum, exponential smoothing has been shown to be an extremely robust forecasting tool. It has been tested over a wide range of data-series and found to provide the most accurate means of generating forecasts.

Only one caveat must be made. This generalization applies only to short-term forecasting, since past research efforts have focused solely on applications of this type. This concurs with an existing notion in the forecasting literature that exponential smoothing is a short-term forecasting tool. The Conference Board (1978), Michael (1979), in an American Marketing Association Monograph, and Makridakis and Wheelwright's (1978) Interactive Forecasting, a computer software package, all state that this approach should be used only for short-term forecasting. Whether research efforts have been guided by this notion, or are the reason for it is unclear. Whatever the case, this caveat is not based on empirical findings. The relative accuracy of exponential smoothing in longer-term applications has not been tested. Given the success of this method in short-term forecasting suggests that this would be a fruitful avenue for future research.

The value of complexity in time-series methods has not been supported. Complex methods, such as ARIMA, have generally failed to out-predict simpler ones, namely exponential smoothing. Possibly, Kirby's (1966) notion that complex methods respond incorrectly to peculiarities in a given series applies here. These methods might be finding patterns that do not really exist. This, in conjunction with the huge data requirements of ARIMA, a minimum of 30-points (Makridakis and Wheelwright, 1978), renders the approach of little value when forecasting with yearly data. Marketers would be best advised to concentrate their efforts on other, more simple, approaches.

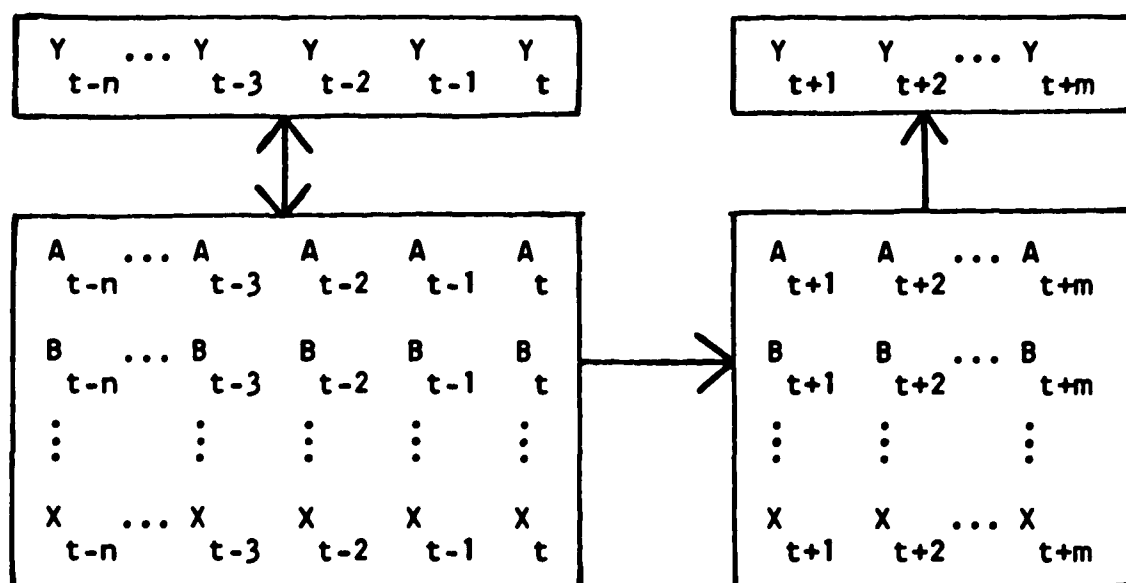
Finally, the evidence regarding the value of the currently popular multivariate version of ARIMA is too meager to draw any conclusions. Whether this new method truly captures the complexity of marketing situations or merely offers increased complexity with little payoff in accuracy is unclear. Further work is needed to assess the relative accuracy of this approach. Marketers, however, should keep in mind that increases in conceptual and methodological complexity do not necessarily lead to more accurate predictions of the "real world."

2.12 - The Relative Accuracy of Various Econometric Forecasting Methods

Econometric models attack the forecasting problem from a different perspective than time-series methods. Rather than looking for patterns in the history of a series, they attempt to discern the "structure" of the system in which the item to be forecast is found. If this structure can be specified, and changes in it are not imminent, then forecasts of the future value of some elements in the system (independent variables) can be used to predict the item of interest (dependent variable). The key assumptions of the econometric approach are that, 1) the system can be numerically specified, 2) the structure of the system will not change much over time, and 3) other elements in the system (independent variables) can be forecast with greater reliability than the item to be forecast itself (dependent variable). For example, if it is known that sales levels are systematically affected by variations in marketing expenditures, cost of the item being sold, and the state of the economy, then predicting future levels of these three implied causal factors would indirectly allow for the prediction of sales. Figure 2.2

FIGURE 2.2

THE STRATEGY OF ECONOMETRIC MODELS



where:

Y is the value of the time-series

$A, B, \dots, X$ are the independent variables

t is the present time period

n is the number of periods used to construct the forecast

m is the time horizon of the forecast

illustrates the philosophy of econometric methods.

A key criticism of this approach is that it is not really forecasting but a method that shifts the forecasting problem to other variables (Nelson, 1973, p. 3). To temper this criticism, and capitalize on the benefits of econometric models, market forecasters should choose "independent variables" that can be forecast with greater accuracy than the "dependent variable" at hand. For example, Coca-Cola might not have been able to forecast the growth in wine sales directly, but through market research discovered that one age segment of the market constituted the "heavy-user" group. Since the proportion of the population in a given age group is more readily forecast, they could use this information to predict future wine sales. (Business Week, 1977).

Another criticism of econometric models is that they rely heavily on the stability of the specified structure (Makridakis and Wheelwright, 1978, p. 582). Changes in the relationships among the variables considered greatly decreases the viability of this approach (Christ, 1951). However, time-series methods also rely heavily on the

patterns of the past. Therefore, there is no reason to believe that in turbulent times time-series forecasts should be preferred.

Econometric models generally rely on regression analysis. Levels of complexity range from a single equation with only a few independent variables to systems of hundreds of interrelated structural equations. As with time-series methods the ability of complex methods to provide more accurate forecasts has been seriously questioned (Armstrong, 1978).

Comparisons of the relative accuracy of econometric methods have generally focused on predictions made by the various econometric models of the economy, Wharton, Chase, DRI. The item forecast by these models is usually of a highly aggregative nature, such as GNP, unemployment, and inflation. Some interesting findings have emerged.

Cooper (1972) compared the predictions made by seven econometric models and found that all were about equal in accuracy. Quarterly forecasts from 1961 to 1965 were used.

Fromm and Klein (1973) compared predictions made by eleven commercial econometric models. No one model showed an overall superior record.

McLaughlin (1973) tested the relative accuracy of twelve commercial econometric services. Again, sometimes one model proved most accurate, sometimes another. In fact, he observed a negative correlation in the year-to-year accuracy rankings. That is, the order, from best to worst, in 1971 tended to be followed the next year, 1972, by a reverse ranking.

McLaughlin (1975) also reported little difference among predictions made by the various econometric services.

In sum, no one model of the United States economy has consistently provided the most accurate predictions. No comparisons between different marketing-oriented econometric models were found in the literature. However, comparisons between a marketing-oriented econometric approach and time-series methods are reviewed in the next section. This should help shed light on the value of econometric models in market forecasting.

2.13 - The Relative Accuracy of Time-Series and Econometric Models

Only a few studies have actually compared the relative accuracy of these two radically different approaches to forecasting. However, this limited evidence suggests an interesting hypothesis; that time-series methods are most accurate in short-term applications, while econometric models prove best over the long-term (Armstrong, 1978).

Armstrong and Grohman (1972) compared predictions made by a constant percentage growth rate model and a single equation econometric model. One, two, three, four, five, and six year forecasts of the U.S. air travel market were constructed with each method. The econometric model was constructed to predict air travel levels as a function of 1) the price of air travel, 2) average airborne speed, 3) GNP, 4) population, and 5) a safety factor, based on deaths per 100 million revenue passenger miles. The constant percentage growth rate model was constructed by calculating the average rate of growth over the previous ten years. The econometric model provided the most accurate forecasts, dramatically so for the longer time horizons.

Armstrong (1968), in his doctoral dissertation, compared three time-series models with an econometric model on "backcasts" of camera sales. Data from 1965 to 1960 were used to generate a six year "backcast" of 1954 camera sales. The three time-series models were: 1) a naive, or random walk model, 2) a growth curve, and 3) a linear extrapolation. The econometric model postulated that camera sales were a function of 1) size of the market, 2) real consumer expenditures per capita, and 3) cost of cameras. The econometric model provided the most accurate "backcasts," with a mean absolute percentage error (MAPE) of 30%. The worst predictor was the random walk model, with a MAPE of 67%. The other time-series models performed significantly better than the naive.

O'Herlihy (1967) tested the relative accuracy of an econometric model and a growth curve on British sales of energy, coal, automobiles, consumer durables, and consumer expenditures on automobiles. The econometric model provided much more accurate forecasts.

In comparisons involving shorter-term forecasting applications, Nelson (1972), Naylor, Seeks, and Wichern (1972), Cooper (1972), and Cooper and Nelson (1975) compared

predictions made by commercial econometric models of the economy and time-series models.

Nelson (1972) tested an ARIMA model against the FRB-MIT-PENN model of the U.S. economy. For one quarter-ahead forecasts, the ARIMA model yielded the most accurate forecasts.

Naylor, Seaks, and Wichern (1972) compared quarterly predictions made by the Wharton Econometric Model and an ARIMA model for the years 1963 to 1967. Forecasts of investment, unemployment, GNP, and GNP price deflator were compared. In all four cases, the ARIMA model provided the most accurate forecasts.

Cooper (1972) compared a straight-line extrapolation with forecasts generated by seven econometric models. In quarterly forecasts from 1961 to 1965 the extrapolation model provided more accurate forecasts in about half of the time-series tested.

Cooper and Nelson (1975) also examined the relative accuracy of an ARIMA model and the FRB-MIT-PENN model. They also found the ARIMA model most accurate in one quarter-ahead forecasts.

In sum, it appears, from the limited evidence presented above, that long-term forecasts are best constructed by econometric methods, while short-term forecasts are best handled with time-series analysis. This suggests that the time horizon of a forecast is an important moderator, or determinant, of forecast accuracy.

However, these findings might be explained in terms of a different moderator, the forecasting situation. Most of the studies that have examined long-term forecasting have focused on marketing-oriented data, while comparisons of short-term accuracy have focused on economic series. It is possible that the different findings are not due to the time horizon of the forecast but the nature of the application. That is, economic forecasts respond better to time-series analysis while longer-term marketing forecasts are more amenable to econometric modeling.

Overall, the findings presented above suggest that one approach to the forecasting problem is not most accurate all the time. The next section deals more fully with the issue of moderators of forecast accuracy.

2.2 - THE DETERMINANTS OF FORECAST ACCURACY

The accuracy of a forecast is dependent upon many factors. Of primary interest to market forecasters, would be research aimed at providing a contingency framework that would allow them to match the forecasting situation with an appropriate forecasting method. Ideally, the goals of this research would be to:

1. identify the salient attributes that affect forecasting performance.
2. rank these attributes according to the extent to which they affect forecasting performance.
3. determine how these attributes affect forecasting performance.

Research aimed at assessing the determinants of forecast accuracy has not reached that stage where a consensus exists as to what form such a contingency framework should take. In fact, virtually no empirical studies have tackled this problem directly. As a comparison, consider the case of consumer behavior research, in particular, Diffusion of Innovation research. Market researchers can call on a vast body of empirical literature that consistently points to a set of characteristics that can

be used to differentiate between innovators and non-innovators (Rogers and Shoemaker, 1971; Schiffman and Kanuk, 1978). In forecasting, little empirical evidence points to the characteristics that will differentiate between one approach to forecasting being more accurate than another.

What does exist in the forecasting literature is a number of hypotheses regarding the relationship between forecasting methods and the forecasting situation (e.g., Armstrong, 1978; Makridakis and Wheelwright, 1978; Rao and Cox, 1978; Chambers, Mullick, and Smith, 1971). However, many of the proposed relationships in these studies contradict one another. Only direct empirical investigations can help resolve this confusion.

Makridakis and Vandenburg (1974) did attempt to predict the relative accuracy of a forecasting method on the basis of characteristics of the forecasting situation. They used data on the pattern in the series (trend, cycle, seasonal, and random), the number of data points available, and the autocorrelation structure of the series to explain variations in accuracy. A low R^2 was found, under .3. The authors conclude that better

results might have been obtained had additional variables describing the forecast situation been considered.

A host of potential moderators of forecast accuracy have been proposed, and the lists that contain them overlap to a large extent. Table 2.1 summarizes these lists of potential moderators, and illustrates this overlap. What follows is a discussion of them in greater detail.

The time horizon of a forecast is a key determinant of forecast accuracy. Obviously, the longer the time horizon the less accurate the forecast can be expected to be. Virtually all discussions concerning moderators in forecasting concur on this point. Opinions diverge, however, when considering the relative accuracy of forecasting methods over varying time horizons. As stated in the previous section, Armstrong (1978) hypothesizes, on the basis of an extensive literature review, that econometric methods are most accurate for long-term forecasts. He contends that in short-term forecasts, no difference between econometric and time-series methods will be found. Armstrong defines long-term in terms of the rate of environmental change in a given forecasting situation (p. 365).

TABLE 2.1

FIVE PROPOSED DETERMINANTS OF FORECAST ACCURACY

	Time Horizon	Data Avail- ability	Level of aggre- gation	Pattern in the Data/ Complexity of Behavior	Stability of the Data (Randomness)
Adam (1973)	X			X	
Armstrong (1978)	X	X		X	X
Chambers, Mullick, and Smith (1971)	X	X	X		
Conference Board (1978)	X	X	X		X
Kirby (1966)	X			X	X
Makridakis & Wheelwright (1978)	X	X		X	X
Makridakis & Vandenburgh (1974)	X	X		X	X
Michael (1979)		X			
Rao and Cox (1978)	X	X	X		
Wheelwright & Makridakis (1980)	X		X	X	X

Generally, for business-related applications, long-term consists of forecasts greater than two-years ahead. Makridakis and Wheelwright (1978) and Wheelwright and Makridakis (1980) define long-term in a similar manner, greater than two-years ahead. However, they contend that such forecasts are best handled by technological forecasting methods, growth curves and other extrapolations. Econometric models are deemed most appropriate for medium-term forecasts, three months to two-years. For the short-term they hypothesize a clear advantage for time-series methods. Chambers, Mullick, and Smith (1971) offer a similar framework for short-term forecasting, but suggest that complex time-series methods, such as Box-Jenkins and X-11, will provide the most accurate forecasts in such applications. For long-term forecasts these authors contend that econometric methods and trend projections would be the best choice. It is hypothesized that simple econometric methods would perform poorly in such applications.

The amount of data available when forecasting is another proposed determinant of forecast accuracy. Chambers, Mullick, and Smith (1971) and Michael (1979)

suggests that the more data available for forecasting, the greater the accuracy that can be expected. Makridakis and Wheelwright (1978) contend that while this is generally true, long data-series frequently contain changes in the underlying pattern that "confuse" the forecasting model, and result in a loss of accuracy. They suggest that in many situations the use of the minimum amount of data required to apply a given method will result in more accurate forecasts (p. 611). Overall, how market forecasters should decide on the amount of data to use when constructing a market forecast is unclear, and has not been empirically tested.

The level of aggregation, or unit of analysis, of the item to be forecast is another factor that reportedly affects forecast performance. Economics generally deals with highly aggregated items such as GNP, unemployment, and investment. Sales forecasts are usually concerned with less aggregated items such as industry, company, product-class, product-form, or brand sales levels. As shown in the previous section, econometric models have proved most accurate for the less aggregated, and generally

longer-term, sales forecasts. The Conference Board (1978) seems to concur on this point. Within sales forecasting applications, they contend that econometric models yield the most accurate results when the unit of analysis is industry-wide demand for a generic product (p. 96).

In less aggregated sales forecasting applications, such as company sales of a particular product, they feel that the approach is less accurate, due to the myriad of additional factors that must be considered. Chambers, Mullick, and Smith (1971) also suggest that econometric methods are highly appropriate for forecasting the sales levels of product classes. Overall, only limited evidence exists pertaining to the level of aggregation and forecast performance. Further research is needed to better match the forecasting situation with the appropriate method.

A key determinant of forecast accuracy is the pattern present in the data, or the complexity of the behavior of the system being studied. The pattern in the data is of primary interest to time-series forecasters. The complexity of the system is a key concern of econometric forecasters. Much of the evidence on finding patterns in

past data is tied directly to the functional form of the proposed model. It is well known that where a "horizontal" pattern exists in a data series simple time-series methods, such as moving averages and exponential smoothing, that differentiate such patterns from random error, will suffice. In other situations, more complex patterns require more complex time-series methods. (Makridakis and Wheelwright, 1978). Unfortunately, this matching of past pattern and future value is not that simple. These complex time-series methods are highly capable of detecting "spurious" patterns. As shown in the previous section, ARIMA models have proven to be no more accurate than more simple methods.

In regard to econometric methods, Armstrong (1978) suggests that the complexity of the behavior of the system in which the item to be forecast exists is important in the choice of a forecasting method (p. 360). However, he also suggests that simple econometric models yield forecasts just as accurate as do complex ones (p. 204-211). How then is this complexity in behavior accounted for?

Overall, while it has been observed that varying degrees in complex patterns and behavior of a system exist, it is not clear how best to develop the most accurate

forecast. Evidence presented in the previous section suggests the simple heuristic: 1) given any pattern in the data, use exponential smoothing, and 2) given any level of complexity in the behavior of a system, use simple, single-equation econometric models. Only further empirical research will truly settle this issue.

In sum, while the goals of research aimed at assessing the determinants of forecast accuracy should be to provide market forecasters with a means of matching the forecasting situation with the appropriate forecasting method, little consensus exists on just how such a framework should be constructed. This is unfortunate since forecasting research possesses such a "solid" dependent measure, deviation of forecasted values from actual outcomes.

One attempt to provide market forecasters with a contingency framework has been proposed in Sibyl/Runner, an interactive computer software package by (Makridakis and Wheelwright, 1978). This package suggests a forecasting method on the basis of 1) the time horizon, 2) the pattern in the data, 3) the type of model desired; time-series versus causal, 4) the importance of the forecast, 5) the accuracy

required, 6) the complexity that can be tolerated, and 7) the availability of historical data (Makridakis and Wheelwright, 1978). It is limited, however, by its strong reliance on time-series methods, and does not consider the limitations of the findings presented above.

It is probably too early to offer a contingency framework to market forecasters, since what is known about the determinants of forecast accuracy has not been fully delineated. Further empirical evidence is needed before such a framework can be provided. With this in mind, the next section considers whether forecasting is even feasible.

2.3 - RANDOM WALK THEORY

The Theory of Random Walks holds that the observed changes over time in a data-series are best described as chance movements. That is, at any point in its history subsequent values of the series can not be forecast.

This theory has received the most extensive attention and empirical support from the study of short-term financial time-series. As early as 1900, Bachelier (1900) offered evidence that prices on the French government bond market followed a random walk. His research stood as an isolated event until later in the century when students of modern day stock markets again noticed this same phenomenon. Kendall (1953) studied twenty-two price-series and found little statistical dependence within each series. As a result, efforts to forecast future values of the series using an autoregressive scheme were judged a failure. He concludes that if any systematic patterns exist in the series, they are so small as to be swamped by random effects. Roberts (1959) found further support for the theory when he demonstrated that graphed, weekly values of the Dow Jones Industrial Average were indistinguishable from graphs constructed using a roulette wheel. Cootner (1962)

and Alexander (1964) tested whether filter rules, relying on the past behavior of the data, could be used to "beat-the-market." Generally, they could not. Fama (1965) found that when broker commissions on the extensive trades required by the filter rules were considered their performance was dismal. Francis (1976) contends that no filter rule has been developed that outperforms a naive buy-and-hold strategy.

In sum, Fama (1965), in a comprehensive investigation, found overwhelming support for the Random Walk Theory. He argues that the voluminous empirical evidence in favor of the theory, and the lack of evidence to the contrary, strongly suggests that "the future path of the price level of a security is no more predictable than the path of a series of cumulated random numbers" (p. 34).

Random Walk Theory has onerous implications for those who attempt to discern the future values of a series by searching for trends or patterns in past values of the data-series. As Malkiel (1973) defines it, "The history of stock price movements contains no useful information that will enable an investor consistently to outperform a buy-and-hold strategy" (p. 12).

Past information is of no real value when forecasting since successive values of the data-series are independent of one another, or uncorrelated. That is, there is no inertia in a trend or consistent reversal pattern in the data since future values of the series are determined by chance.

2.31 - Autocorrelation

Autocorrelation analysis is one of the primary tools used to test the Random Walk Theory. It checks for the presence of significant correlations between successive observations in a time-series. This is done by correlating the data-series with a lagged version of itself, hence the name auto- or serial correlation. Excellent, in-depth discussions of autocorrelation are provided by Makridakis and Wheelwright (1978), Nelson (1973), and Granger and Newbold (1977).

A strong serial correlation implies a strong association between adjacent periods in the data indicating a trend or pattern. The absence of autocorrelation implies a random walk.

Most of the research investigating financial time-series and random walks has focused on autocorrelations of

"first differences." Here, changes from one period to the next are correlated as opposed to the original observations. Since it is known that most stock price-series increase over the long-run, are correlated, autocorrelations of first differences have been used to see if any short-term patterns consistently repeat themselves (Fisher and Lorie, 1968). This notion of repeating patterns is the basis of many technical theories of the stock market.

To date, little autocorrelation has been observed in financial time-series. Kendall (1953) and Fama (1965) found such results over a wide variety of data-series.

It is interesting to note that autocorrelation is an integral part of many complex market forecasting methods. In particular, the Box-Jenkins and ARIMA methods rely heavily on this tool. Basically, these methods examine the autocorrelation structure of a data-series and fit one of a number of possible methods. In the absence of autocorrelation a random walk, or naive, model is fit to the data. However, the results are not clearly presented to forecast users as such. Rather, the forecast is presented as an ARIMA (1,0,0). While the market forecasting

literature abounds with research on technical aspects of ARIMA models, it is suprisingly silent on the extent to which a random walk model is the specific type of ARIMA model that best describes the data. Is a random walk frequently encountered in marketing time-series? If so, why has not an in-depth analysis of this phenomenon been conducted? Given the overwhelming lack of autocorrelation in financial time-series this would seem to be a worthwhile endeavor.

2.32 - Runs Tests

Counting the number of runs in a data-series and comparing it to the number that might be expected by chance alone yields further evidence on the validity of the Random Walk Theory. In particular, the primary benefit of this test is that it can detect those data-series that appear random for most of their history but exhibit strong autocorrelations for short periods (Francis, 1976).

A run is an unbroken string of same direction changes in a data-series. A twenty period data-series that shows continued growth in all periods consists of one run. One that exhibits consistent reversals, one period of growth followed by a period of decline followed by a period of growth and so on, has many runs. Fama (1965) provides

a statistical test to determine whether the number of runs observed is likely to have occurred by chance.

Berenson and Levine (1979) offer a similar test and explain that too few runs suggest a trend in the data, since like changes tend to cluster, while a greater than expected number of runs suggests a systematic pattern.

In the financial literature researchers have failed to detect either trends or patterns with the runs test. Alexander (1961), Moore(1964), and Fama (1965) all found that the number of runs observed in stock price-series did not differ from the number that might be expected by chance alone.

No studies were found that applied the runs test to long-term marketing data.

2.33 - Naive Forecasts

A key test of the validity of the Random Walk Theory is to actually construct a forecast based on the theory and compare its relative accuracy to that of forecasts constructed using other methods. The theory is captured in a naive forecast. It is constructed by simply using the current period's value as a forecast for next period, or x periods hence. For example, if this year's sales

were five million units, next year's naive forecast would also be for five million.

Nelson (1973) offers a rationale for this method. He notes that in a random walk, where successive changes are independent, a data series, Z , will change from period $t-1$ to period t as follows:

$$Z_t - Z_{t-1} = U_t$$

The magnitude of the change, U_t , is a random variable
 1) with a mean of zero 2) that is drawn independently from a probability distribution. Since the series, Z , changes by a random variable, U_t , at each step in its evolution, it also will appear random.

$$Z_t = Z_{t-1} + U_t$$

As the time horizon lengthens the series unfolds as follows:

$$Z_{t+1} = Z_t + U_t$$

$$\begin{array}{cccc} Z_{t+2} & = & Z_t & + U_t + U_{t+1} \\ \vdots & & \vdots & \vdots \end{array}$$

$$Z_{t+n} = Z_t + U_t + U_{t+1} + \dots + U_{t+n}$$

Since U_t has a mean of zero, the best, minimum mean square error, estimator for U_{t+1} , U_{t+2} , ..., U_{t+n} is

$$Z_{t+n} = Z_t$$

A naive forecast for n years into the future is simply the current value of the series. In a random walk one can hope to do no better since historical data are of no value. The relative accuracy of this model offers evidence as to the value of past information, and the validity of the Random Walk Theory.

In the financial literature, Johnson and Schmitt (1974) compared ten time-series methods, including a naive forecast, on earnings-per-share forecasts. They found that no method outperformed the naive forecast for one, two, and three year time horizons. This suggests that past data can not be used to increase forecast accuracy. Watts and Leftwich (1977) compared forecasts generated by Box-Jenkins and a random walk model for annual corporate earnings. The random walk model clearly outperforms the other method suggesting a random walk for earnings. Albrecht, Lookabill, and McKeown (1977) found that Box-Jenkins did not beat a random walk model on deflated

and non-deflated annual earnings forecasts.

In sum, the Theory of Random Walks seems to offer a reasonable description of the behavior of stock prices over time. It has also been found to apply to corporate earnings. Given these findings, does it also apply to company sales? If so, what about industry sales, or sales at the level of product-class, or product-form? Is brand forecasting possible? In other words, what are the boundaries of the Random Walk Theory? At what point, as we move from "financial" time-series to "marketing" time-series, if ever, does forecasting via traditional time-series methods become feasible?

The following section discusses the applicability of the Random Walk Theory to marketing-oriented time-series.

2.34 - Marketing and the Random Walk Theory

Little direct discussion of the Random Walk Theory has appeared in the marketing literature. However, some indirect evidence on its applicability to marketing time-series is available. Much of it centers on a key long-term pattern suspected in marketing time-series, the product life cycle.

As Day (1981) notes, "There is tremendous ambivalence toward the product life cycle concept within marketing" (p. 60). Much of this ambivalence can be traced to empirical efforts aimed at verifying the existence of this pattern in long-term marketing time-series.

Early attempts at verification identified not one, but a myriad of curves that describe the long-term pattern of marketing sales data (Buzzell, 1966; Cox, 1967). This research is deficient in at least two important respects. First, such a large number of curves have been fit to sales data that virtually any pattern could be modeled by one of them, including a random walk. Armstrong (1970) had no trouble obtaining a "good fit" to random numbers when a large number of models were available to select from. In fact, Cox (1967) found that a fourth-degree polynomial best described the cases in his sample. This complex curve permits a maximum amount of data-fitting. Second, in terms of forecasting these curves are of little value. They were fit *aposteriori*, with no indication as to what curve would best predict the future behavior of the series given some initial set of values.

Pollt and Cook (1969) argue that research of this type is a "sterile exercise in taxonomy" (p. 388).

Other researchers have argued against the notion of a discernable pattern in the sales histories of product classes, forms, and brands. Pollt and Cook (1969) found that predictions made by one popular version of the product life cycle, a bell-shaped curve, were no better than those of a "chance" model. Likewise, Dhalla and Yuspeh (1976) argue that there is no basis for assuming a consistent, and repeating pattern in long-term marketing data. They found that it is difficult to determine what stage the series is now in, when it will enter the next stage, how long it will remain at a given level, and what level sales will ultimately reach. Day (1981) asks similar questions.

In sum, no solid evidence has been provided to support the contention that long-term sales data follow a particular pattern that can be used to forecast sales. Much of the evidence that has been provided suggests the opposite; that a wide range of unforeseeable, and possibly randomly-appearing, patterns make up the evolution of a time-series.

In a consumer behavior application one study directly tested the viability of a random walk model. Lawrence (1975) fit a random walk model to consumer choice data reported by Kuehn (1962) and compared its relative accuracy to Kuehn's linear learning model. He found that consumer brand choice followed a random walk.

2.35 - Negativism and the Random Walk Theory

As Francis (1976) notes, "The so-called random-walk theory is a very negative statement" (p. 584). It means that time-series forecasting methods that search for regularities in past data are worthless and the evolution of long-term sales appear random. This carries onerous implications for those who provide investment advice on the basis of these tools.

The implications are not as onerous for marketers. Marketers can affect the future course of sales through manipulation of marketing decision variables. Their counterparts in finance have no such power. Financial series such as the stock market can only be monitored; the system which generates them is diverse and efficient (Fama, 1970). Many of those who discard the notion of the product life cycle as a predetermined pattern suggest that marketers

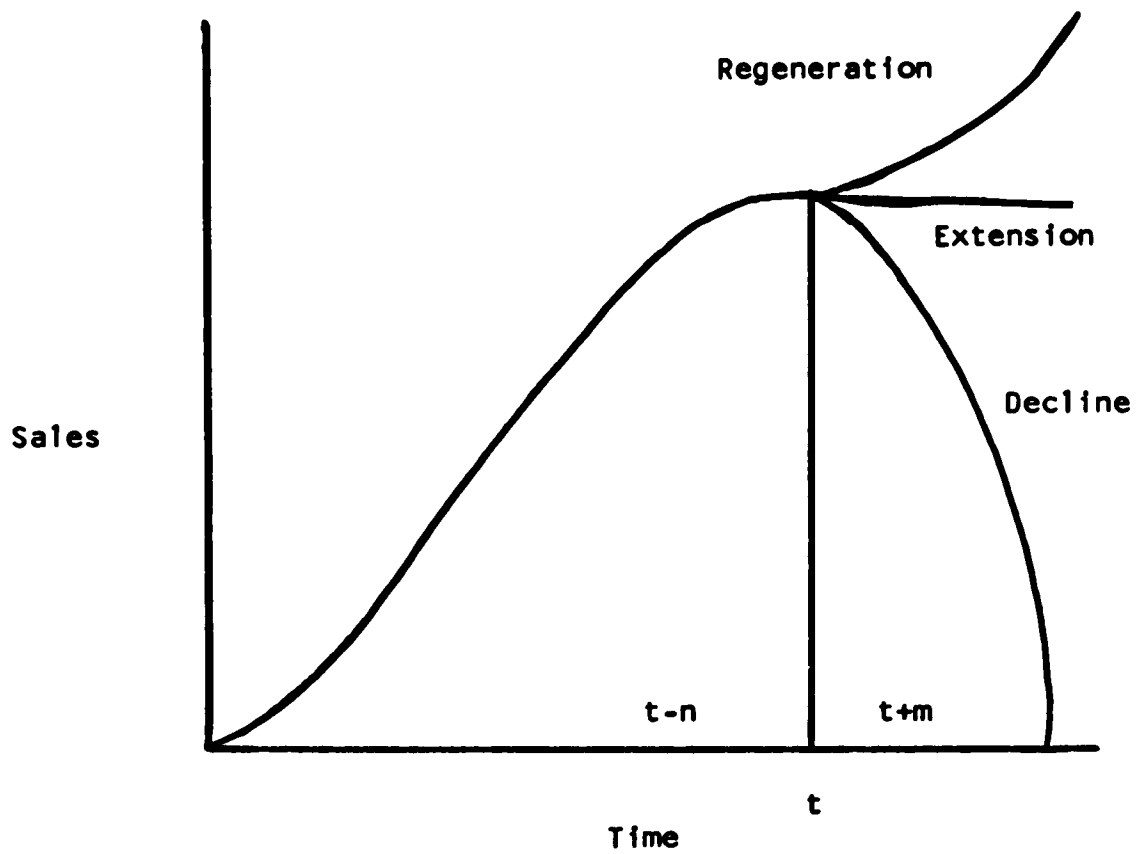
focus on controlling the long-term evolution of sales. (Dhalla and Yuspeh, 1976).

Textbook discussions of the product life cycle seem to agree. Staudt, Bowersox, and Taylor (1976) explain that following the maturity stage in the life cycle three future courses are possible. Figure 23 illustrates their point. They contend that at this stage marketing decisions can greatly affect the future course of events. Levitt (1965) also argues that marketers should affect the future level of sales. Needless to say, marketers have adopted strategies that have resulted in all three of the patterns shown in the graph.

This point is not negated by the Random Walk Theory. What is disputed is that a detached forecaster seeking to predict the future course of sales using time-series methods may view the underlying process as a random walk. If Figure 23 is viewed from this perspective it says that following maturity sales might rise, fall, or remain the same. Since what ultimately occurs depends to a large degree on marketing decisions not considered by time-series methods a naive, or random walk, model might be found to

FIGURE 2.3

THE RANDOM APPEARANCE OF THE PRODUCT LIFE CYCLE



Source: Staudt

be the minimum mean square estimator for the series.

In sum, the Random Walk Theory really tests the product life cycle as a time-series forecasting model, not a marketing decision tool.

If the shape of the product life cycle is found to be indistinguishable from a random walk marketers would have to be cautioned against making strategic decisions based on the "inevitable" future course of events. As Day (1981) notes, "The implications of the difference between a temporary or even an extended pause in sales growth versus a true topping out of growth are profound" (p. 64).

Support for the Random Walk Theory on long-run sales data would dictate that efforts spent on time-series methods be redirected to an econometric approach. Armstrong (1978) and Dhalla and Yuspeh (1976) contend that such efforts will result in more accurate forecasts in long-range applications.

Overall, an empirical test of the Random Walk Theory would shed considerable light on the validity of the product life cycle as a forecasting tool, and possibly clear up the ambivalence the theory now generates.

CHAPTER III

RESEARCH DESIGN

This chapter discusses the nature of the sample, the individual forecasting methods that were tested, the measure of accuracy that was used, and the situational determinants of forecast accuracy. Hypotheses are presented throughout the chapter.

3.1 - THE SAMPLES

Two samples were utilized in this study, a core sample of 98 marketing time-series, and an apparent sample of forecasts derived from the core sample. In total, nearly 10,000 individual forecasts were generated in this study. Each of the samples is described below.

3.11 - The Core Sample

Ninety-eight time-series were sampled from secondary data sources and made-up the core sample. Each time-series represented annual sales over time for a particular product category. Only annual data were considered since the focus of this research is on long-term forecasting. All sales data were collected as unit sales, as opposed to dollar sales, in order to eliminate the exogenous effects of inflation, and other price-related factors.

Time-series were deliberately chosen to portray sales for products at two levels of aggregation. Polli and Cook (1969) differentiated between product-class and product-form in their study of the product life cycle. This same typology is used here. As Table 3.1 illustrates, some of the time-series are distinct subsets of others. In total, 20 product-class time-series, and 78 product-form time-series were examined.

Table 3.1 also categorizes the time-series according to, 1) the number of data points available, and 2) whether the product is a durable, or non-durable good. These variables are used in a later section to assess the relative accuracy of different forecasting methods in various situations.

The time-series were sampled from trade association data, industry studies, and commercial data services, such as Predicasts. Table 3.1 lists these sources. In most cases, the sales data included in this study were provided to trade associations directly from individual manufacturers, and reported to the public only in an aggregated form.

TABLE 3.1

THE SAMPLE

Time-Series	Source	Number of Data Points	Product Class or Form?	Durable or Non- Durable?
1. Blended Whiskey	<u>Newsweek Research</u> <u>Report: The U.S.</u> <u>Market for Beverage</u> <u>Alcohol</u> (Clark Gavin Assoc.)	28	F	N
2. Bourbon	same	28	F	N
3. Brandy and Cognac	same	28	F	N
4. Canadian Whiskey	same	28	F	N
5. Cordials and Liqueurs	same	28	F	N
6. Gin	same	28	F	N
7. Prepared Cocktails	same	28	F	N
8. Rum	same	28	F	N
9. Scotch Whiskey	same	28	F	N
10. Vodka	same	28	F	N
11. Total Wine	same	15	C	N
12. Table Wine	same	15	F	N
13. Desert Wine	same	15	F	N
14. Champagne	same	15	F	N
15. Vermouth	same	15	F	N
16. Total Beer	same	15	C	N
17. Packaged Beer	same	15	F	N
18. Draught Beer	same	15	F	N
19. Total Deodorants	<u>Drug Topics</u>	14	C	N
20. Aerosol Deodorants	same	14	F	N
21. Cream Deodorants	same	14	F	N
22. Stick Deodorants	same	14	F	N
23. Roll-on Deodorants	same	14	F	N
24. Pad Deodorants	same	14	F	N
25. Powder Deodorants	same	14	F	N
26. Liquid Deodorants	same	14	F	N
27. Total Shaving Preps.	same	14	C	N
28. Aerosol Shave Lathers	same	14	F	N
29. Soaps and Sticks	same	13	F	N
30. Pressed Cake Cosmetic				
Powder, compact, blush	same	14	F	N
31. Loose Face Powder	same	14	F	N

TABLE 3.1 (CONTINUED)

32. Total Feminine Deodor.	same	13	C	N
33. Powder Douches	same	12	F	N
34. Liquid Douches	same	12	F	N
35. Total Automobiles	<u>Automotive Trade</u> <u>Statistics: 1964-79</u> U.S. Int. Trade Comm. June 1980	16	C	D
36. U.S.-made Autos	same	16	F	D
37. Imports sales	same	16	F	D
38. Sub-Compact Autos	<u>Ward's Automotive</u> <u>Yearbook</u>	14	F	D
39. Compact Autos	same	14	F	D
40. Intermediate Autos	same	14	F	D
41. Full-Size Autos	same	14	F	D
42. Luxury Autos	same	14	F	D
43. Soft Drinks	<u>Beverage Industry</u> <u>Annual Manual</u>	18	C	N
44. Total Domestic Cigarettes	<u>The Maxwell Report</u> Lehman Brothers	18	C	N
45. 100mm Cigarettes	same	18	F	N
46. 85mm Cigarettes	same	18	F	N
47. Low-Tar Cigarettes	same	18	F	N
48. High-Tar Cigarettes	same	18	F	N
49. Filter Cigarettes	same	18	F	N
50. Non-Filter Cigarettes	same	18	F	N
51. Electric Ranges	<u>Merchandising</u>	20	C	D
52. Free-Standing Elec. R.	same	13	F	D
53. Built-In Elec. Ranges	same	13	F	D
54. Microwave Ovens	same	10	F	D
55. Gas Ranges	same	20	C	D
56. Built-In Gas Ranges	same	20	F	D
57. Free-Standing Gas R.	same	13	F	D
58. Refrigerators	<u>Current Business</u>	20	C	D
59. Food Freezers	<u>Merchandising</u>	20	C	D
60. Upright Freezers	same	13	F	D
61. Chest Freezers	same	13	F	D
62. Washing Machines	<u>Current Business</u>	20	C	D
63. Automatic Washers	<u>Merchandising</u>	13	F	D
64. Ringer and Spinner W.	same	13	F	D
65. Clothes Dryers	<u>Current Business</u>	20	C	D
66. Gas Clothes Dryers	<u>Merchandising</u>	20	F	D
67. Elec. Clothes Dryers	same	13	F	D

TABLE 3.1 (CONTINUED)

68. Household Fans	same	20	C	D
69. Desk Fans	same	13	F	D
70. Floor Fans	same	13	F	D
71. Portable Fans	same	13	F	D
72. Window Fans	same	13	F	D
73. Room Air Conditioners	same	20	C	D
74. Electric Toothbrushes	same	17	F	D
75. Elec. Water Pulse	same	14	F	D
76. Dishwashers	same	20	C	D
77. Non-portable Dishwashrs.	same	11	F	D
78. Portable Dishwashers	same	13	F	D
79. Food Waste Disposal	same	20	C	D
80. Total Radios	<u>Elec. Mkt.</u>	20	C	D
81. Household Radios	same	20	F	D
82. All Table Radios	same	20	F	D
83. Table Radios FM/AM & FM	same	20	F	D
84. All Clock Radios	same	20	F	D
85. Clock Radios FM/AM & FM	same	20	F	D
86. All Portable Radios	same	20	F	D
87. Portable FM/AM & FM	same	20	F	D
88. Total TV Sets	same	20	C	D
89. B & W TV Imports	<u>CIR MA36M</u> *	12	F	D
90. B & W TV Sets	<u>Consumer Electronics</u>	20	F	D
91. Console B & W TV	same	13	F	D
92. Portable B & W TV	same	13	F	D
93. Color TV Imports	<u>CIR MA36M</u> *	12	F	D
94. Color TV Sets	<u>Consumer Electronics</u>	13	F	D
95. Combination Color TV	same	13	F	D
96. Console Color TV	same	13	F	D
97. Portable Color TV	same	13	F	D
98. Audio and Video recorders and players	<u>CIR MA36M</u> *	12	C	D

★

Government publication reported by Predicasts Inc.

3.12 - The Extended Sample

The core sample served as a basis upon which to generate forecasts. To increase the effective size of the core sample a successive updating procedure, as described by Armstrong (1978) and employed by Armstrong and Grohman (1972) and Williams and Goodman (1971), was applied. This procedure entailed "holding out" the last five years of data from each time-series. A one, two, three, four, and five year forecast were then generated. In most cases, this involved building the forecasting model on historical data up to and including 1974, and predicting yearly to 1979, the last year of data available in most time-series. All forecasts were, therefore, strictly "unconditional" in that they did not rely on data after 1974. Next, one year was added to that part of the time-series used to construct the forecasts. In effect, it was now assumed to be 1975 and again yearly predictions were made using a newly constructed forecasting model incorporating these additional data. At this stage a one, two, three, and four year forecast were made. At the next stage, another year was added to the model building stage and used to make

"unconditional" forecasts for the remaining three years. This iterative procedure was continued until the data was exhausted. In total, each time-series yielded 5 one-year, 4 two-year, 3 three-year, 2 four-year, and 1 five-year forecasts.

For each of the time-series methods of forecasting tested, including the Random Walk model, all 98 time-series were subjected to this procedure. This resulted in 490 one-year, 392 two-year, 294 three-year, 196 four-year, and 98 five-year forecasts for each method tested. Since six strictly mechanical time-series methods were applied, this yielded 2940 one-year, 2352 two-year, 1764 three-year, 1176 four-year, and 588 five-year forecasts.

The econometric models were applied only to a subset of the 98 time-series, since each model had to be specifically constructed for a given industry. Models were constructed for the 8 time-series of the automotive industry, and the 7 time-series of the cigarette industry. The successive updating procedure was employed in each of these 15 cases yielding 75 one-year, 60 two-year, 45 three-year, 30 four-year, and 15 five-year forecasts for each of the econometric models tested.

This same subset was also used for the test of the two combination forecasts since they are based, in part, upon the econometric models.

Overall, the two econometric models and the two combinations of forecasts yielded 300 one-year, 240 two-year, 180 three-year, 120 four-year, and 60 five-year forecasts.

In sum, two extended samples were used. For those forecasts constructed via time-series methods the apparent sample consisted of 1470 "sets" of forecasts; each "set" consisting of those forecasts generated by each of the 6 time-series methods. More specifically, 490 one-year, 392 two-year, 294 three-year, 196 four-year, and 98 five-year "sets" of forecasts were available for testing the relative accuracy of time-series methods.

The extended sample for the econometric models, and the combinations of forecasts that include them, was 225 "sets" of forecasts, 75 one-year, 60 two-year, 45 three-year, 30 four-year, and 15 five-year. Comparisons of forecast accuracy that involve 1) only econometric or combination forecasts, and 2) these models versus the time-series models are made only on this subset.

In total, 9720 forecasts were generated and used to test the relative accuracy of the Random Walk model and the other available long-term forecasting methods.

3.2 - THE MODELS TESTED

Ten forecasting models were tested in this study, six time-series models, including the random walk, two econometric models, and two combinations of forecasts consisting of the average of an econometric and time-series model. Each of these is discussed below and the hypotheses regarding their expected outcome are presented where appropriate.

3.21 - The Random Walk Theory

Central to this research is an assessment of the Random Walk theory. It is tested in two ways. First, the theory is tested by applying a number of statistical procedures such as autocorrelation and the runs test. Second, the relative forecasting performance of predictions generated by this theory are compared with those constructed by other competing approaches. Each of these tests is described below.

Autocorrelation analysis and the runs test are the means by which the Random Walk theory has traditionally been tested in financial applications. In this research they serve two masters. First they are employed as a direct test of the validity of the Random Walk theory. Second, they are used in subsequent analyses as moderators of the forecasting situation.

The absence of autocorrelation in a data series indicates the presence of a random walk since successive values of that series are independent of one another. The autocorrelation structure of a series is calculated by correlating that series with lagged versions of itself. On the basis of this analysis, the degree of autocorrelation in a given series is measured by counting the number of statistically significant autocorrelation coefficients over a wide range of lags. The extent to which long-term marketing time-series as a whole follow a random walk is inferred from the proportion of series that exhibit no autocorrelation structure to those that exhibit some and extensive autocorrelation structures. No autocorrelation is defined as a series exhibiting no significant autocorrelation over a wide range of lags.

"Some" autocorrelation is a series where only one significant autocorrelation coefficient was observed.

"Extensive" autocorrelation is defined as more than one significant autocorrelation. The following hypothesis can be proposed on this basis:

Hypothesis 1

H : The proportion of series exhibiting "some" or "extensive"
1 autocorrelation is equal to or less than the proportion of series exhibiting "no" autocorrelation.

H : The proportion of series exhibiting "some" or "extensive"
0 autocorrelation is greater than the proportion of series exhibiting "no" autocorrelation.

This simple test compares the relative proportions of the presense and absence of autocorrelation in long-term marketing time-series. The following hypothesis defines

the Random-Walk theory in less-strict terms:

Hypothesis 2

H : The proportion of series exhibiting "extensive"
1 autocorrelation is equal to or less than the proportion of series exhibiting "some" or "none."

H : The proportion of series exhibiting "extensive"
0 autocorrelation is greater than the proportion of series exhibiting "some" or "none."

This hypothesis represents a weaker test of the theory since limited autocorrelation structure is grouped with none at all.

The runs test adds further evidence for an assessment of the Random Walk theory. The number of runs observed in a series is compared to what might be expected by chance alone. The series are then categorized according to whether they contain a statistically significant difference in the number of runs observed or not. Again, the proportion of series with a chance number of runs are compared to those with a non-chance number. The following hypothesis is proposed:

Hypothesis 3

- H : The proportion of series exhibiting a chance number
1 of runs is greater than or equal to the proportion
of series exhibiting a non-chance number.
- H : The proportion of series exhibiting a non-chance
0 number of runs is greater than the proportion of
series exhibiting a chance number of runs.

Considered jointly, these three hypotheses should help shed light on the existence of "patterns" and "trends" in long-term marketing time-series.

Forecasts generated by the Random Walk theory take the form of a naive forecast. A naive forecasting procedure simply states that next year's sales will equal this year's. Consistent with the notion of no autocorrelation structure, this model does not rely on past values of the series since in a random walk period-to-period changes are assumed to be independent of one another. For longer-term forecasts a naive forecast relies on the same procedure; this year's sales as a forecast for two, three, four, and five years out. The relative accuracy of this forecasting method should yield evidence as to the comparative feasibility of this approach. The following hypotheses are offered:

Hypothesis 4

H : Naive forecasts are relatively more accurate than both
1 other time-series methods and econometric methods.

H : Naive forecasts are relatively inaccurate when compared
0 with both time-series and econometric methods.

This hypothesis tests a marketing analog of Malkiel's

(1973) broad form of the Random Walk theory in Finance.

This form of the theory holds that financial time-series

are random in every sense of the word and that even forecasts

generated by econometric methods, that do not search for patterns in the past history of an individual series, will not yield more accurate forecasts.

To test Malkiel's narrow form of the Random Walk theory, that no patterns exist in financial time-series, and, therefore, only time-series methods will not prevail, the following hypothesis is offered:

Hypothesis 5

H : Naive forecasts are relatively more accurate than other
1 time-series methods.

H : Naive forecasts are relatively inaccurate in comparison
0 to other time-series methods.

Overall, the Random Walk theory is tested using a number of different approaches. The accumulated evidence for or against this approach should provide marketers with valuable information regarding the future evolution of their markets.

3.22 - Exponential Smoothing

Exponential smoothing is a widely used time-series method that is similar to moving averages but with two important advantages. First, it places decreasing weight on older observations in a data series on the reasonable assumption that older observations contain less information about the future course of a series than do more recent ones, hence the name exponential smoothing. Second, it gives the forecaster a greater flexibility in allocating weight between the most recent data available and the stream of past values in the series. This has the effect of increasing or decreasing the speed with which the information contained in past data is discounted.

Many forms of exponential smoothing have been proposed (Brown, 1959; 1963; Holt, 1960; Harrison, 1965; Winters, 1960). The forms proposed by Brown (1959) are employed in this research. The basic algorithm for this form of exponential smoothing is:

$$S_{t+1} = Ax_t + (1-A)S_t$$

where:

t = the present time period

S = the forecast

x = actual sales

A = "alpha" a smoothing constant chosen by the researcher to distribute weight between the most recent and past past observations in a data series. It ranges from 0 to 1.

This algorithm holds that future sales is some combination of the most recent period's sales and the stream of past values of the series. The relative importance of these two elements is determined by selecting an appropriate value of "alpha." More weight given to the most recent period's sales value implies that past sales contain little information regarding the future. Note that when "alpha" is set at 1.0, exponential smoothing reverts to a naive forecasting procedure.

The most widely accepted method of selecting an alpha level is to fit a wide range of possible values and select the one that historically has yielded the lowest deviation from actual sales values.

Brown offers many versions of exponential smoothing, some more complex than others. The simplest form, shown above, is capable only of forecasting horizontal patterns. More complex versions based on it will track linear, or curvilinear trends. These two latter versions are the forms employed here.

Double exponential smoothing fits a straight line to past data and forecasts by extrapolating along the line. It is similar to linear regression analysis against time in its objective but estimates the parameters of the line using the exponential smoothing algorithm presented above rather than least-squares. The similarity in the two procedures would suggest that they would provide similar forecasts. However, double exponential smoothing might be hypothesized to provide more accurate forecasts because of the advantages of exponential weighting, and flexibility in weighting stated above. These advantages apply to a comparison with time-series regression as well as moving averages.

Hypothesis 6

H : Double exponential smoothing provides more accurate
1 forecasts than time-series regression.

H : Time-series regression provides forecasts of equal
0 or greater accuracy than double exponential smoothing.

Since a key objective of this research is to compare the relative accuracy of different forecasting methods, in particular the Random Walk theory, the following hypothesis is offered:

Hypothesis 7

H : Double exponential smoothing provides more accurate
1 forecasts than a naive forecast.

H : A naive forecast provides forecasts of equal or
0 greater accuracy than double exponential smoothing.

This hypothesis should help shed light on the issue of whether this highly robust linear model can outperform the Random Walk theory over a wide range of long-term marketing time-series.

Triple exponential smoothing is a more complex form of exponential smoothing. It fits curvilinear as well as linear trends. Whether this added complexity in methodology allows the model to more fully capture the complexity in real-world sales data, or merely tracks

spurious patterns, is tested here. Triple exponential smoothing is similar to polynomial regression analysis, where time and time-squared are used as the independent variables. Again, similar predictions made by the two models might be expected, but the advantages of exponential smoothing might be hypothesized to result in greater accuracy for that approach.

Hypothesis 8

H : Triple exponential smoothing provides more accurate
1 forecasts than polynomial regression analysis.

H : Polynomial regression analysis provides forecasts
0 equal to or greater in accuracy than triple exponential smoothing.

In regard to the issue of the value of increased complexity in forecasting the following hypothesis is offered:

Hypothesis 9

H : Triple exponential smoothing provides more accurate
1 forecasts than double exponential smoothing.

H : Double exponential smoothing provides forecasts
0 of equal or greater accuracy than triple exponential smoothing.

Finally, in regard to how well this method predicts in comparison with the Random Walk theory the following

hypothesis is offered:

Hypothesis 10

H : Triple exponential smoothing provides more accurate
1 forecasts than a naive forecasting method.

H : A naive forecasting method provides forecasts of
0 equal or greater accuracy than triple exponential
smoothing.

Overall, the five hypotheses regarding the relative accuracy of exponential smoothing forecasting methods should yield useful information on how this widely-used approach stacks up against the Random Walk theory.

3.23 - Time-series Regression

Three time-series models based on regression analysis were constructed, a linear, polynomial, and exponential (constant percentage growth rate) curve.

The linear regression model used time, in years, as the independent variable to predict sales. The model was of the standard form:

$$Y = A + Bt$$

where the parameters of the model were estimated by least-squares. In addition to the hypothesis comparing the accuracy of this model with double exponential smoothing presented in the previous section, the

following hypothesis compares predictions made with this model against those made by the Random Walk theory.

Hypothesis 11

H : Linear regression provides more accurate forecasts
1 than the naive method.

H : The naive model provides forecasts equal to or
0 greater in accuracy than linear regression.

The polynomial regression extrapolation adds to the above model a second independent variable, time-squared. This has the effect of allowing one "bend" in the fitted-curve. As with triple exponential smoothing the objective is to allow more complex patterns to be fitted. The form of the model was:

$$Y = A + B_1 t + B_2 t^2$$

Relative to the linear model this model was deemed to be more complex. To test whether this increased complexity offers a predictive advantage the following hypothesis is tested:

Hypothesis 12

H : Polynomial regression provides more accurate forecasts
1 than linear regression.

H : Linear regression provides forecasts equal to or of
0 greater accuracy than polynomial regression.

To test the accuracy of predictions made by this model relative to those made by the Random Walk model the following hypothesis is offered:

Hypothesis 13

H : Polynomial regression provides more accurate forecasts
1 then the naive model.

H : The naive model provides forecasts equal to or of
0 greater accuracy then the polynomial regression.

The final regression-based model fit to the data-series was an exponential growth curve. This model captures the widely used measure of market growth and decline, percentage change in the market over time. That is, that a market that exhibits a X% growth rate over some range of values will continue on that course in the future.

The form of this model was:

$$Y = Ae^{rt}$$

Since the majority of product categories studied here have existed for decades it is hypothesized that a model such as this that postulates continued percentage growth, exponential growth, will prove relatively inaccurate.

Therefore, the following hypothesis is offered:

Hypothesis 14

H : The exponential curve provides forecasts that are
 1 less accurate than those of other time-series models.

H : The exponential curve provides forecasts that are
 0 equal or more accurate than those of other time-series models.

To test the accuracy of predictions made by this model and the Random Walk theory the following hypothesis is offered:

Hypothesis 15

H : The exponential curve provides forecasts that are
 1 more accurate than those of the naive model.

H : The exponential curve provides forecasts that are
 0 equal to or less than those of the naive model.

3.24 - The Product Life Cycle

Overall, the three regression-based extrapolation models are capable of detecting and projecting a wide variety of patterns. In particular, when considered jointly these models should be able to monitor the patterns suggested by the product life cycle. If a pattern truly does exist in long-term sales data then these time-series models should be able to readily outperform the Random Walk model. However, no one of

models tested above, or a host of others not tested here, has been universally accepted as descriptive of the life cycle process in all situations. Therefore, two hypotheses are proposed here, one that tests a single, widely used surrogate of the cycle, and another that considers all three models jointly. This might be termed a strong and a weak test of the product life cycle hypothesis, respectively.

While no one time-series model has been universally accepted as describing the product life cycle, the polynomial regression model comes the closest. Both Buzzell et al (1969) and Cox (1967) offer this curve as a primary descriptor of the process. Connelly and Daignault (1974) used a similar model and found it to provide the best "fit." In addition, numerous marketing texts portray the life cycle in this manner. Even if this curve is not the optimal one it should still be able to outperform the Random Walk theory if some form of the cycle is present, and can be used to predict future values of the series.

Therefore, this strong test of the product life cycle compares the relative predictions made by the polynomial regression model and a naive forecasting procedure. Hypothesis 13, stated in the previous section, is used to assess the product life cycle as a forecasting tool.

A weaker test of the product life cycle directly acknowledges that no one model is applicable in all situations. Therefore, all three regression-based extrapolations are considered jointly and compared with the Random Walk model. To consider these models jointly an average of their respective mean absolute percentage errors was calculated. Over the large number of forecasts calculated their combined accuracy is tested against the Random Walk theory. The following hypothesis is offered:

Hypothesis 16

- H₁ : The average error of forecasts generated by three extrapolation models descriptive of the product life cycle is less than that for the naive method.
- H₀ : The average error of forecasts generated by three extrapolation models descriptive of the product life cycle is equal to or greater than that of the naive model.

This test of the life cycle is considered to be a weaker test because it provides market forecasters with no indication as to which of these three models might be selected apriori. It actually compares the random model against a combination of forecasts rather than some specific version of the product life cycle.

Overall, these two hypotheses, plus the accumulated evidence for or against the Random Walk theory should provide an indication as to the value of the product life cycle theory in long-term market forecasting.

3.25 - The Econometric Models

Two types of econometric models were constructed, a single-equation additive regression-based model, and a multiplicative one. Unlike the strictly mechanical time-series models discussed above that could easily be applied to all 98 data-series in the sample, it was necessary to build the econometric models specifically for each industry studied. This was done for both the automotive and cigarette industries. Each is described below.

The Automotive Industry

To begin, one econometric model was constructed and applied to each of the eight time-series that made-up the automotive industry. These time-series were:

- 1) Total automobile sales
- 2) Imported automobile sales
- 3) U.S. made automobile sales
- 4) Sub-compact automobile sales
- 5) Compact automobile sales
- 6) Intermediate-size automobile sales
- 7) Full-size automobile sales
- 8) Luxury automobile sales

These series represented sales of a durable product class or form and varied in length.

While ideally it might be argued that an econometric model that represented the industry "standard" should have been used, none was found that fit this criterion. A search of the Journal of Economic Literature, a source for locating existing econometric models for specific industries, yielded a number of proposed models. Dagenais (1975) studied the more micro-level issue of household

demand for automobiles. He found income, education, number of children, and anticipatory data to be the best predictors of demand based on survey data. Hess (1977) also constructed a model to predict household demand for automobiles and found interest rates to be the key variable. Johnson (1978) empirically investigated aggregate demand for automobiles using consumer income and rental price as the key predictors. More recent efforts by Duncan (1980) and Greenless (1980) found gas prices to be a key factor in predicting automobile sales. Levendahl (1980) found that income of the household affected automobile purchases.

Overall, while each of these models identified a number of key predictors of automobile sales, none was overwhelmingly superior. Furthermore, many of these studies focused on an aspect of automobile sales slightly different than that considered here. Most importantly, all of these models were offered in the literature after 1974, the date at which forecasts are made in this study. Using any one of these models would give the econometric approach an unfair advantage since the model would have been constructed with the invaluable

benefit of perfect foresight. Therefore, a model was constructed specifically for this research based on the variables that were 1) identified above, and 2) are mentioned in the business literature prior to 1975 as possible predictors of coming changes in the automotive market. However, since forecasts were also made in subsequent years, what was desired was a list of variables that consistently affected sales in this market over the entire range of the predictions.

A search of the general business literature prior to 1975, the first year for which a forecast is generated, confirmed the expected effect of many of the variables identified above, and added some additional ones. Business Week (July 6, 1974) reported that the industry felt the sales mix of various product-forms in 1975 would be affected by inflation, smaller family size, urban congestion, gas prices, and auto prices. Later that year, Business Week (Oct. 5, 1974) reported that industry hopes for a rebound in automobile sales would be dashed by higher sticker prices and lower consumer confidence in the economy. Finally, Business Week (Dec. 14, 1974) summarized the many factors that have and

will continue to affect sales of the industry's product offerings. Economic performance and consumer sentiment regarding the economy are identified as two important factors affecting automobile sales. Another is the real income consumers possess with which to purchase automobiles. Gas prices and automobile prices are also identified as causal factors. However, it is suggested that the initial resistance to higher prices will be overcome due to the inevitable rise in "scrapage" rates, the number of automobiles junked every year. It is noted that the number of cars scrapped has recently surpassed the number of new cars sold.

Considering both past econometric efforts, and the lists of possible causal factors identified in the business literature, unconditional econometric models were built using the following independent variables:

1. Consumer sentiment
2. Intention to buy an automobile
3. Real disposable income
4. GNP
5. Automobile price index
6. gas prices
7. Scrapage rate

Interest rates were not considered since they are not mentioned in the pre-1975 literature as a possible causal factor.

The data for these variables were obtained from Predicasts, with the exception of the first two variables, consumer sentiment and intention-to-buy an automobile, which were obtained from the Conference Board's Consumer Attitudes and Buying Plans survey ranging from its inception in 1967 to the present.

Only data up to and including 1974 were used to construct the initial regression model. The model was of the form:

$$Y = A + B_1 X_1 + B_2 X_2 + B_3 X_3 + B_4 X_4 + B_5 X_5 + B_6 X_6 + B_7 X_7$$

where the parameters A and B are specific to each of the eight data-series for which the model was constructed.

To forecast with these models it was necessary to obtain future values of the independent variables. The actual future values were not used because this would give the econometric approach the distinct advantage of perfect foresight. Instead, the predictions offered by Predicasts were used. A naive forecast was used for

the consumer sentiment variable. The stated intention-to-buy was used as the predictor for automobile sales.

These projections were "plugged into the regression model and a one, two, three, four, and five-year forecast were generated. The successive updating procedure described in the previous section required that the model be reconstructed using the actual sales figures for 1975. Forecasts of the independent variables were again found in Predicasts and another series of sales forecasts were then generated using this "new" model. This iterative build model - predict independent variables - forecast sales - update model procedure was repeated until each data-series was exhausted. Since five distinct regression models were built for each of the eight time-series studied, a total of 40 separate econometric models were constructed.

This same procedure was followed for the construction and use of the more complex multiplicative econometric model. This model was of the form:

$$Y = (A)(X_1)^{B_1}(X_2)^{B_2}(X_3)^{B_3}(X_4)^{B_4}(X_5)^{B_5}(X_6)^{B_6}(X_7)^{B_7}$$

where the parameter B is read as an "elasticity." This model form has been widely applied in economics.

The results of these models were discouraging. The large number of independent variables, seven, relative to the length of the automotive time-series, thirteen or fifteen data-points depending on the series, caused the t-values for the regression coefficients to be very low. Another set of models was constructed without the consumer sentiment and intention to buy variables. This left five independent variables which improved the t-values somewhat, although they were still insignificant in many cases. The elimination of other variables did not greatly improve the t-values and resulted in a dramatic decrease in R^2 of the model. It was decided that the model using the five independent variables was most acceptable when looking at the "fit" of the model in that stage of the analysis. Furthermore, a strong "apriori" case could be made on the basis of industry's belief that these variables were crucial to the future outcome of sales. Given the limitations on the length of the series, and the requirements of the econometric approach, the model selected was the best that could be expected.

The Cigarette Industry

Two separate regression models were constructed for each of the seven time-series in this industry. These time-series were:

1. Total Domestic Cigarette Sales
2. 100mm cigarette sales
3. 85mm cigarette sales
4. Low-tar cigarette sales
5. High-tar cigarette sales
6. Filter cigarette sales
7. Non-filter cigarette sales

These series represent sales of a non-durable product class or form.

A search of the Journal of Economic Literature produced no econometric models for predicting consumer sales in this product category. However, the Tobacco Merchants Association of the U.S., a trade association, provided information on a number of existing econometric models produced for the industry. Tennant (1950) used per capita income, and time as independent variable when predicting per capita consumption of cigarettes.

Sachrin (1962) constructed a single equation regression log model where real prices, per capita income, and time were used as the independent variables when predicting per capita consumption of cigarettes. Vernon, Rives, and Naylor (1969) used a log-log model to forecast the total consumption of cigarettes in the U.S. with real prices and real disposable income as the predictors. Kellner (1973) forecast total domestic cigarette sales on the basis of lagged time, deflated cigarette prices, a health scare dummy variable, advertising expenditures, and per capita disposable income. Finally, Sutton (1974) constructed a complex simulation of the industry using many of the same variables above. He surprisingly notes that the single-equation regression model he used as a comparison was most accurate.

Unlike the automotive applications the econometric models proposed in this industry overlap to a large extent. Most consider the same or highly similar variables.

The general business literature identifies other possible predictors of cigarette sales, in particular, those variables that would be more relevant to predicting the product forms studied here.

Business Week (Dec. 6, 1976) states that 18 to 24 year olds are the biggest customers for cigarette products. Changes in the percentage of the population in this age group would swell or shrink the ranks of potential smokers. Business Week (Dec. 12, 1980) suggests that females have been consuming cigarettes at a growth rate greater than that of men. Therefore, the percentage of the population that consists of women in the target population stated above should be particularly important in forecasting future cigarette sales. The article also mentions advertising expenditures as a key determinant of future cigarette sales.

From the existing econometric models and the predictors suggested above, the following independent variables were selected:

1. Real disposable income
2. Tobacco products retail price index
3. Smoking materials industry expenditures for general magazine advertising
4. U.S. population between 15 and 24 years old
5. U.S. female population between 15 and 24 years old

Values for the independent variables were obtained and projected from Predicasts in a procedure identical to that used in constructing the models in the automotive industry. The successive updating procedure yielded five distinct econometric models for each of the seven data-series studied. In total, 35 models were constructed and used to forecast.

The procedure was repeated with the multiplicative model. This model had a form identical to that described in the previous section, except a different number of independent variables was used.

Overall, the econometric models are compared with 1) each other, 2) time-series methods, and 3) the random walk model. Consistent with past research it is anticipated that the more simple additive model will yield forecasts as least as accurate as the more complex multiplicative model.

Hypothesis 17

H : An additive regression model provides forecasts equal
1 to or more accurate than a multiplicative model.

H : An additive regression model provides forecasts less
0 accurate than a multiplicative model.

As noted in the previous chapter, econometric models have proved especially accurate on marketing-oriented time-series. It might, therefore, be hypothesized that the econometric approach will also prove more accurate in this application.

Hypothesis 18

H : The most accurate of the econometric models is more
1 accurate than the most accurate of the time-series models.

H : The most accurate of the econometric models is not
0 more accurate than the best of the time-series models.

In order to compare the relative accuracy of this approach to long-term market forecasting with predictions made by the Random Walk model the following hypothesis is offered:

Hypothesis 19

H : The best of the econometric models yields more accurate
1 forecasts than the Random Walk theory.

H : The Random Walk theory yields forecasts equal to or
0 more accurate than the best of the econometric models.

In sum, these three hypotheses should provide new information on the relative accuracy of this widely used approach to long-term market forecasting.

It should be noted, however, that the econometric models constructed in this research were extremely simple, single-equation models. Inferences as to the relative accuracy of the econometric approach, in general, based on the performance of such simple models are tentative at best. In fact, the term econometric models to describe the models constructed in this research is probably a misnomer. They might more accurately be described as regression-based models that employ the strategy of econometrics.

Some other caveats are in order. First, the series upon which the models were constructed were short, consisting, in most cases, of only about 20 data-points. This may have hindered the performance of these models. Second, the short series prohibited the use of more than a few independent variables due to restrictions on the remaining degrees of freedom.

Overall, this research does not seek to evaluate the econometric approach in general, but models that employ the strategy of this approach. Given the short series encountered with annual sales data, this research attempts to evaluate the relative accuracy of this approach to long-term market forecasting when such limitations are present.

3.26 - Combinations of Forecasts

Combining forecasts generated by drastically different approaches is motivated by the notion that each approach utilizes the knowledge contained in the present situation in a different way. This greater utilization of existing knowledge has been hypothesized to lead to more accurate forecasts. The empirical evidence on this issue is mixed. Granger and Newbold (1974) found that a combination of a time-series method and an econometric model yielded a more accurate forecast than did either of the methods alone. Armstrong (1968) found a slight advantage for the combined approach. However, Armstrong (1978) reanalyzed five existing studies by constructing a combined approach from the single methods reported in those studies and found no clearcut advantage for the combined approach.

In this study two combinations of forecasts are generated. The first is a simple average of forecasts made via double exponential smoothing and the additive econometric model. The second consists of an average of the polynomial regression model and the multiplicative

econometric model. These two combination forecasts are chosen to represent a simple and complex approach. Again, it is hypothesized that the advantages proposed for more complex methods will not be realized.

Hypothesis 20

H : The combination of simple methods yields forecasts
 1 equal to or more accurate than the more complex combination.

H : The combination of complex methods yields more
 0 accurate forecasts than the simple method combination.

To test whether the combination approach to long-term market forecasting is worthy of merit the following hypothesis is offered:

Hypothesis 21

H : The accuracy of the combination approach is greater
 1 than the average error of the individual methods that make them up.

H : The accuracy of the combination approach is equal
 0 to or greater than the average error of the individual methods that make them up.

Overall, these three hypotheses should help shed light on the important issue of whether combinations of forecasts can increase forecast accuracy.

3.3 - THE MEASURES OF FORECAST ACCURACY

Numerous measures exist by which to assess the accuracy of a forecast generated by one of the above methods. These include, 1) the number of "first place" finishes, 2) average rank, 3) mean error (ME), 4) mean absolute error (MAD), 5) mean-squared error (MSE), 6) root mean-squared error (RMSE), 7) percentage error (PE), 8) mean absolute percentage error (MAPE), 9) Theil's U, 10) turning point errors, and R^2 (Schupack, 1962; Armstrong, 1978; Makridakis and Wheelwright, 1978).

In this research, the mean absolute percentage error (MAPE) is employed for the following reasons:

1. Its interpretation is obvious, the percentage by which the forecast missed its mark. Stating that a forecast erred by 20% more clearly communicates the accuracy of that forecast than stating that the MSE was 400, or a root mean-squared error of 200 was found.

2. The MAPE is widely used. This allows for a comparison between the results of this study and others.

3. In general, all the measures of forecast accuracy tend to lead to the same conclusion (Schupack, 1962).

Therefore, the choice of a measure is not crucial to the outcome, and should be made in light of other factors, such as clarity and simplicity (Schupack, 1962).

The MAPE is calculated as follows:

$$\text{MAPE} = \left[\frac{\sum_{t=1}^n \left[\frac{(A_t - F_t)}{A_t} \right]}{n} \right] \times 100$$

where A = actual value of the time series

F = forecast value

n = number of forecasts generated or number of periods in a time-series for which forecasts were generated

The absolute difference between actual and forecast sales is calculated. This difference is then viewed as a proportion of actual sales.

The MAPE has one acknowledged deficiency. Armstrong (1978) notes that forecasts that err on the low side can never result in an MAPE of more than 100%. High side errors, however, can result in a MAPE that ranges to infinity. Therefore, the MAPE is biased in favor of lower than actual forecasts. This bias is most pronounced

in those cases where many, extremely inaccurate forecasts are found. Overall, the advantages of using this measure seemed to outweigh the disadvantages.

The MAPE is used in two ways in this study. In many instances, the MAPE itself is presented as a measure of relative accuracy. In other instances, particularly where the determinants of forecast accuracy are proposed, a dichotomous measure is desired since crosstabulation tables are constructed. Here, the measure of accuracy that tallies the number of first place finishes is used, but it is based on the MAPE. The MAPE's of each forecasting method are compared to one another on a case by case basis, and those cases in which method "A" proves more accurate than method "B" noted. The dichotomous measure is constructed by allocating to one level of the variable those cases where method "A" was most accurate, and to the other those cases where method "B" was most accurate. When crosstabulated with the various determinants of forecast accuracy it is then possible to test whether different forecasting approaches yield different relative accuracies over various applications.

3.5 - THE DETERMINANTS OF FORECAST ACCURACY

In addition to testing the relative accuracy of the Random Walk theory over all applications, comparisons were made on various subsets of the data-series. This offers evidence as to the boundaries of the Random Walk theory.

The independent variables used in this part of the analysis are ten determinants of forecast accuracy that have been proposed in the past literature. Each of these characteristics is discussed below. Hypotheses are offered where appropriate.

3.51 - The Time Horizon of the Forecast

As stated in an earlier section of this chapter, a total of 3240 one-year, 2592 two-year, 1944 three-year, 1296 four-year, and 648 five-year forecasts were generated. Results are always reported separately for each of these time horizons. The centrality of this determinant suggests that "collapsing" over this dimension would not provide meaningful results. This is the only dimension for which this is done. The other determinants are "collapsed" over in many instances.

The first hypothesis regarding the time horizon of the forecast hold that a decrease in accuracy will be observed as the time horizon lengthens, regardless of the method used.

Hypothesis 22

H : As the time horizon of the forecast lengthens accuracy
1 decreases for all forecasting methods.

H : As the time horizon of the forecast lengthens accuracy
0 does not decrease for all methods.

Armstrong (1978) hypothesizes that for longer-range forecasts econometric models will be more accurate than time-series models. For short-term forecasts he hypothesizes no difference in relative accuracy. To test this contention the following hypotheses are offered:

Hypothesis 23

H : In the longer-range forecasts econometric methods
1 provide more accurate forecasts than time-series models.

H : In the longer-range forecasts econometric methods
0 do not provide more accurate forecasts than time-series methods.

Hypothesis 24

H : In the short-term forecasts there is no difference
1 in the accuracy of econometric models versus time-series models.

H : In the short-term forecasts there is a difference
0 in the accuracy of econometric models and time-series models.

For long-range forecasts in might also be hypothesized that the Random Walk model will outperform other time-series methods to a greater degree than in shorter-term forecasts. This might be expected since so many imponderables can affect the long-range trend of marketing time-series, such as new technological developments, competitive efforts, and changes in consumer tastes. The following hypothesis tests this proposition:

Hypothesis 25

- H : The proportion of cases where the Random Walk provides
1 the most accurate forecasts is greater for long-range forecasts than short-range forecasts.
- H : The proportion of cases where the Random Walk provides
0 the most accurate forecasts does not increase for longer-range forecasts.

Overall, these hypotheses will indicate the effect on forecast accuracy of time horizon changes.

3.52 - Data Availability

The length of each of the 98 time-series in the core sample ranged from 10 to 28 years. Table 3.1 shows the length of each series. Since the last five years of data were "held out" and a successive updating procedure was employed, each series in the extended sample contained

from 5 to 27 years of data.

Those series with the least number of observations tended to be relatively "new" product categories, such as microwave ovens, and video recorders and players.

To assess whether the amount of data available is associated with the relative accuracy of a particular method, or the accuracy of forecasts overall, data availability was trichotomized so that approximately one-third of the apparent sample fell into each category. "Few" data were defined as those series containing only five to ten data points. A "moderate" amount of data were defined as those containing 11 through 15 data points. "Many" data were defined as 15 or more observations.

One hypothesis regarding this determinant holds that the overall accuracy of all forecasting methods increases with the amount of data available.

Hypothesis 26

H : The accuracy of all forecasting methods is greater
1 when many data are available.

H : The accuracy of all forecasting methods is not
0 greater when many data are available.

A second hypothesis holds that simple forecasting methods will outperform complex methods when only a few data are available. This hypothesis is motivated by the notion that in such situations the complexity is not warranted.

Hypothesis 27

H : When few data are available simple methods are as
1 accurate or more accurate than complex methods.

H : When few data are available simple methods are
2 less accurate than more complex methods.

Finally, it is hypothesized that in those cases representing a relatively "new" product category, that the exponential growth curve will be most accurate. This is because this method has traditionally proved accurate at the early stages of the diffusion of an innovation.

Hypothesis 28

H : The exponential growth curve is most accurate for
1 "new" product categories.

H : The exponential growth curve is not most accurate
0 for "new" product categories.

Overall, these hypothesis should provide further evidence of the effect on forecast accuracy of data availability.

3.53 - Product-Class Versus Product-Form

All the time-series were categorized as to whether they represented a product-class or product-form. Product-class is the broader definition comprising the sum of the product-forms. That is, automobile or cigarette sales, product classes, are the aggregate of sales for sub-compact cars, luxury cars, low-tar cigarettes, and high-tar cigarettes, product forms. Polli and Cook (1969) contend that product-classes include objects that are substitutes for the same needs, while product forms are finer partitions that represent homogeneous objects (p. 388).

Overall, the series were rather easy to categorize. In those few cases where more than one split was possible, industry standards were used as implied in the manner in which the data were presented in the secondary literature.

Two hypotheses pertaining to this determinant are offered. The first, holds that product forms are more accurately forecast. The second, suggests that the curvilinear regression model, as a surrogate for the

product life cycle, will prove more accurate on product forms than on product classes. Polli and Cook (1969) and Rink and Swan (1979) suggest that this might be so.

Hypothesis 29

H : The average error of all forecasting methods is less
1 for product-forms than for product-classes.

H : The average error of all forecasting methods is greater
0 for product-forms than for product-classes.

Hypothesis 30

H : Curvilinear regression is more accurate for product-
1 forms than for product-classes.

H : Curvilinear regression is not more accurate for
0 product-forms than product-classes.

3.54 - Durable Good Versus Non-Durable Good

While forecasting research has not focused on this possible moderator, Rink and Swan (1979) suggest that this factor might be important in validating the product life cycle. No empirical evidence in either area has been reported. However, economists have observed that "durable goods are subject to violently erratic patterns of demand" (Samuelson, 1973, p. 255). Therefore, in terms of forecasting it might be expected that non-durable goods are more accurately forecast.

Hypothesis 31

H : The average error of all forecasting methods is less
1 for non-durable goods than for durable goods.

H : The average error of all forecasting methods is not
0 less for non-durable goods than for durable goods.

To test Rink and Swan's hypothesis that there is a difference in relative accuracy between these two types, the following hypothesis is offered:

Hypothesis 32

H : Curvilinear regression is more accurate for non-durable
1 goods.

H : Curvilinear regression is not more accurate for non-
0 durable goods.

3.55 - Number of Turning Points

A turning point is a change in the trend of a series. It is something different from instability in a series where short-term fluctuations are observed. At what point a set of same direction changes moves from fluctuations to a trend change is a judgmental decision. In this research, three consecutive same direction changes in a time-series were defined as a trend. Changes that fluctuated more frequently were defined as fluctuations, not trend changes. Using this framework the number of

turning points was counted in each series. Of the 98 series in the core sample, 82 showed no change in the trend, 15 showed 1 trend change, and only one series showed 2 trend changes. This variable was dichotomized into the presence and absence of a turning point.

It is hypothesized here that the curvilinear time-series methods will yield more accurate forecasts than the linear models.

Hypothesis 33

H : Complex time-series methods provides more accurate
1 forecasts than simple models when a turning point is
present.

H : Complex time-series methods provides less accurate
0 forecasts than linear models when a turning point
is present.

A second hypothesis suggests that econometric models will outperform time-series models when a turning point is present. Econometric methods are generally proposed as the better forecasting approach when the goal is to identify turning point errors.

Hypothesis 34

H : Econometric models provide more accurate forecasts
1 than time-series methods when a turning point is
present.

H : Econometric models provide less than or equally accu-
0 rate forecasts than time-series methods when a turning
point is present.

3.56 - Stability in a Series

A judgmental assessment of the stability of each series in the core sample was made by observing the scatter diagrams. Those series that exhibited wide year-to-year swings were judged unstable. Those that seemed to closely follow an underlying trend were judged stable.

Stability is a different notion than a run. It considers not only the frequency of period to period changes but also the magnitude of these changes. This is not considered by merely counting the number of runs. Obviously, forecasting should be more feasible in an environment where the magnitude of the period to period changes are small.

One hypothesis in regard to this determinant suggests that in a highly unstable environment the Random Walk theory would provide the most accurate forecasts.

Hypothesis 35

H : In unstable series the Random Walk theory is the most
1 accurate forecasting method.

H : In unstable series the Random Walk theory is not the
0 most accurate forecasting method.

This first hypothesis really states that as stability in a series increases the ability to forecast with other forecasting methods decreases. However, relative to other forecasting approaches it is hypothesized that simple methods, in particular a simple combination of methods, will yield the most accurate forecasts.

Hypothesis 36

H : Simple time-series models would outperform more complex
1 ones in unstable series.

H : Simple time-series models would not outperform more
0 complex ones in unstable series.

Hypothesis 37

H : A simple combination of forecasts will outperform
1 individual models in unstable series.

H : A simple combination of forecasts will not outperform
0 individual models in unstable series.

3.57 - Number of Runs

Similar to the notion of stability, but more objective in its application, is counting the number of runs in each series of the core sample. A run is a sequence of same direction changes. A series that consistently rises for twenty years has one run. A series that rises the first year, falls the second, rises the third, and so on for twenty years, consists of 19 runs. Of the 98 time-series

examined, the number of runs observed ranged from one to twelve, with a mean of between five and six runs per series. This variable was trichotomized into few, average, and many runs so that about one-third of the sample fell into each group. The following hypotheses are offered:

Hypothesis 38

H : The greater the number of runs encountered the more
1 accurate the Random Walk theory.

H : The greater the number of runs encountered the less
0 accurate the Random Walk theory.

Hypothesis 39

H : Excluding the Random Walk model, simple models will
1 be more accurate when many runs are present.

H : Excluding the Random Walk model, simple models will
0 not prove more accurate when many runs are present.

Financial researchers have relied heavily on the runs test to establish the presence of a random walk in financial markets. A runs test compares the observed number of runs in a series to that expected by chance alone. This provides information on whether the pattern in the data is truly a pattern or merely a sequence of numbers that might have been generated by a chance process. The non-parametric statistical test used here has been provided by Berenson and Levine (1979).

The following hypothesis is offered in regard to the runs test:

Hypothesis 40

- H : The Random Walk model will not provide the most accurate
 1 forecasts when a series contains a number of runs statistically different than that expected by chance.
- H : The Random Walk model will provide the most accurate
 0 forecasts when a series contains a number of runs statistically different than that expected by chance.

3.58 - Autocorrelation

Autocorrelation of the original data indicates the presense of a trend in that data. Autocorrelation of the first differences, period to period changes, rather than the original data, indicates the presence of a pattern in those changes. Both types were calculated. The autocorrelations of the original data were trichotomized into "no" autocorrelation structure, one significant autocorrelation, and two or more significant autocorrelations. The variable for the autocorrelation of the first-differences was dichotomized into the presence and absence of autocorrelation structure.

Hypothesis 41

- H : The less the autocorrelation structure the more accurate
 1 the Random Walk theory.
- H : The less the autocorrelation structure the less accurate
 0 the Random Walk theory.

Finally, the last hypothesis proposes that econometric models will prove more accurate than time-series methods when little autocorrelation is present.

Hypothesis 42

H : Econometric models will outperform time-series methods
1 when little autocorrelation structure is present.

H : Econometric models will not outperform time-series
0 methods when little autocorrelation is present.

Overall, these hypotheses should indicate the boundaries of the Random Walk theory when applied to long-term marketing time-series.

CHAPTER IV

RESULTS

This chapter presents the research findings. First, the evidence regarding the applicability of the Random Walk Theory to long-term marketing time-series is presented, and the related hypotheses tested. Second, the results pertaining to comparisons of other competing forecasting methods are offered. Finally, a delineation of those situations where one forecasting model yields more accurate forecasts than another is presented. The results of hypothesis testing are presented throughout, where appropriate.

4.1 - THE RANDOM WALK THEORY

The Random Walk Theory was tested in two ways. First, the results of the statistical procedures autocorrelation analysis and the runs-test are presented. As noted in a previous chapter, this has been the means by which the theory has been tested in financial applications. Second, and more central to the goals of this research, the results of a direct comparison of predictions made by the Random

Walk model and other competing forecasting models are presented. Again, hypothesis testing is conducted throughout.

4.11 - Statistical Tests

The majority of the long-term marketing time-series tested in this research exhibited suprisingly little autocorrelation structure. This was found for both an analysis of the original data, and for the first differences, or year-to-year changes in the sales levels. This suggests that both past sales levels, and past changes in the year-to-year sales levels, are of only limited value when forecasting future levels of a yearly sales series.

When the analysis was performed on the original data, only 12 of the 98 series contained more than one significant autocorrelation coefficient indicating the presence of a trend, or inertia in the market. Ten of these twelve series were sales of various forms of liquor products, a product category that has shown remarkably consistent trends for the years covered here. These series were defined as possessing an "extensive" autocorrelation structure.

Seventeen series exhibited no significant autocorrelation structure at all. This implies no association between sales in a given year and sales in the past.

The largest number of series, 69, showed only one significant autocorrelation over the twelve time lags tested. In 49 of these cases that autocorrelation was with the previous year. This suggests that sales in a given year are associated with the year directly before, but not sales in years previous to that. This group was defined as series containing "some" autocorrelation.

The first hypothesis strictly defined the Random Walk Theory as the total absence of autocorrelation. Since most of the series contained a slight degree of autocorrelation, the null hypothesis must be accepted, and the Random Walk Theory refuted in its purest form. The majority of long-term marketing time-series exhibit some autocorrelation and can not be judged as purely random.

Hypothesis 1

Accept H : The proportion of series exhibiting "some" or
0 "extensive" autocorrelation is greater than the
proportion of series exhibiting "no"
autocorrelation.

The second hypothesis defines the Random Walk Theory more loosely. It holds that the theory can be supported by the absence of only "extensive" autocorrelation, as opposed to any autocorrelation, on the assumption that only "extensive" autocorrelation indicates the presence of a strong market trend, or inertia in the series. Using this definition the null hypothesis is rejected, and the Random Walk Theory supported.

Hypothesis 2

Reject H_0 ; H_1 : The proportion of series exhibiting "extensive" autocorrelation is equal to or less than the proportion of series exhibiting "some" or "none."

This less strict definition is more consistent with the findings in financial applications. Francis (1976), in a review of this literature, notes that a slight degree of autocorrelation has been found in stock price series, but that it is not enough to overcome the transaction costs required to capitalize on this statistical dependence. Therefore, the slight autocorrelation present in the majority of series studied here does not constitute a negation of the Random Walk Theory as a whole, but the acceptance of a less rigorously defined version.

Finally, autocorrelation of the first differences, or year-to-year sales changes was performed. This analysis detects recurring patterns within a series. Consistent with the above hypotheses, 64 of the 98 time-series tested showed no significant autocorrelation. This suggests that for the majority of the series, knowing that sales increased by X% this year, and some percentage over the last few years, would provide no information as to what next year's change might be.

Overall, the Random Walk Theory must be cautiously supported in light of autocorrelation analysis. Only in its purest form must the theory be refuted since the majority of series exhibit a slight amount of autocorrelation. However, one caveat is in order. By itself, autocorrelation analysis does not provide conclusive evidence as to the viability of the Random Walk Theory on long-term marketing time-series. The series examined here contained, on average, only about 20 data points each. Autocorrelating such small series, especially over a wide range of time-lags, might have failed to detect weak trends in the series.

However, the goal of this research is to build a case for or against the theory using many approaches. The following sections offer additional evidence.

One of the other approaches used to test the theory was the Runs-test. This test observes the "mix" of positive and negative year-to-year changes in the series. It tests for two things, 1) whether the positive and negative changes tend to cluster, an indication of a trend, and 2) whether positive and negative changes are so dispersed in the series that a pattern is present. In both cases observed values are compared to what might be expected by chance. The specific test used was the Wald-Wolfowitz one-sample-runs test as described by Berenson and Levine (1979). Only 73 of the 98 time-series could be tested since 25 of the series did not contain enough positive and negative changes to qualify. In most cases, these series either consistently grew or declined and provided no "mix" to test. It must, therefore, be assumed that a trend is present in each of these cases. Of the 73 series that were tested only 6 indicated a non-chance number of runs. In each of these cases

a trend was indicated. No cases were observed that exhibited too many runs, indicating a pattern. Overall, it must be concluded that the majority of the series showed no trend or pattern when tested via a runs-test.

Hypothesis 3

Reject H_0 ; H_1 : The proportion of series exhibiting a chance number of runs is greater than or equal to the proportion exhibiting a non-chance number.

In sum, the results of the runs-test and autocorrelation analysis suggest that long-term marketing time-series do appear to follow a Random Walk. Next, the results of how predictions made by the Random Walk model compare to predictions made by other models is presented.

4.12 - The Relative Accuracy of Naive Forecasts

As Table 4.1 indicates, predictions made by the Random Walk theory were clearly more accurate than those generated by any other time-series method. This method yielded the lowest overall MAPE relative to the other methods. Therefore, it must be concluded that this theory best describes the process generating the time-series.

TABLE 4.1

THE MEAN ABSOLUTE PERCENTAGE ERROR (MAPE)
OF TIME-SERIES FORECASTING MODELS

METHOD	<u>TIME HORIZON</u>				
	1 YEAR	2 YEARS	3 YEARS	4 YEARS	5 YEARS
NAIVE	13%	19%	26%	31%	36%
DOUBLE EXPONENTIAL SMOOTHING	13	24	29	37	38
TRIPLE EXPONENTIAL SMOOTHING	16	26	35	41	45
LINEAR TIME-SERIES REGRESSION	25	29	34	40	47
POLYNOMIAL TIME-SERIES REGRESSION	20	28	36	45	58
EXPONENTIAL GROWTH	37	49	68	99	153
AVERAGE ERROR	21	29	38	49	63
SAMPLE SIZE (per method)	490	392	294	196	98
AVERAGE ERROR (Naive not included)	22	31	40	52	68

Hypothesis 5

Reject H_0 ; H_1 : Naive forecasts are relatively more accurate than other time-series methods.

Further evidence is offered from a Dunnett's t-test for multiple comparisons. A significant difference (.01) was found in the mean absolute percentage errors of the naive method and the average of the five other time-series methods. This difference was observed for the first four time horizons. The variance in predictions for the five year horizon was so great that a statistically significant difference was not found. Comparisons between individual methods are made throughout the next few sections.

To further corroborate this finding a second measure of forecast accuracy was tabulated by counting the number of cases in which the naive yielded the most accurate forecasts and comparing it with similar tabulations for the other methods. Table 4.2 offers these results and again suggests that the naive performs well. However, double exponential smoothing performed equally well. Neither method was clearly superior. To explain the strong performance of double exponential smoothing it is necessary to look at the specific form of smoothing that best described the time-series.

TABLE 4.2

THE NUMBER AND PERCENTAGE OF CASES IN WHICH EACH
TIME-SERIES METHOD PROVED MOST ACCURATE

* METHOD _____	<u>TIME HORIZON</u>									
	1 YEAR		2 YEARS		3 YEARS		4 YEARS		5 YEARS	
	Count/Percent		Count/Percent		Count/Percent		Count/Percent		Count/Percent	
NAIVE	121	25%	100	26%	66	22%	47	23%	18	18%
DOUBLE EXPONENTIAL SMOOTHING	126	26	83	21	69	23	45	23	26	26
TRIPLE EXPONENTIAL SMOOTHING	90	18	64	16	49	17	30	15	19	19
LINEAR REGRESSION	44	9	44	11	38	13	28	14	14	14
POLYNOMIAL REGRESSION	67	14	52	13	35	12	24	12	12	12
EXPONENTIAL GROWTH	42	8	49	13	39	13	27	13	11	11
SAMPLE SIZE	490	100%	392	100%	296	100%	201	100%	100	100%

*

Ties were allocated to each of the individual methods.

4.13 - The Relative Accuracy of Exponential Smoothing

It seems that double exponential smoothing was able to perform as well as the Random Walk model because of its similarity to it rather than its ability to track some trend in the historical values of the series. In 55% of the series tested in this study an "alpha level" of .9 best described the data. This means that fully 90% of the value of the forecast generated by exponential smoothing was based on the most recently available sales figure. Only 10% relied on historical values. Different weighting schemes resulted in less accurate forecasts on the hold-out sample. Since a naive forecast places 100% of its "weight" on the most recent sales figure and resulted in a lower overall MAPE, it must be concluded that double exponential smoothing was mimicking the Random Walk model to a large extent.

This further supports the contention that the reliance of a forecasting method on past growth rates does not increase forecast accuracy but impairs it. To the extent that an approach to forecasting relies heavily on continued growth, or imminent decline, it will prove less accurate than a simple Random Walk model.

Double exponential smoothing is a flexible approach to forecasting. It can assign "weight" proportionally to the most recent sales figure, and historical values in the series. Had a form of smoothing that assigned a greater proportion of its weight to historical values proved clearly more accurate than the naive it would have to be concluded that the method was capitalizing on historical trends in the data. However, this was not the case. The method assigned most of its weight to the most recent sales figure and provided forecasts similar to the naive.

The relative accuracy of double exponential smoothing is consistent with past research efforts that have found it to be a robust predictor over a wide variety of applications. However, since past research efforts have not generally compared double exponential smoothing with predictions made by the Random Walk theory, this research extends those findings. While smoothing is a robust predictor of long-term marketing time-series, it is not more accurate than a simple Random Walk model.

Hypothesis 7

Accept H : A naive forecast provides forecasts of equal
 0 or greater accuracy than double exponential
 smoothing.

A Dunnett's t-test of multiple comparisons for the two methods was not significant for any of the five time horizons at the .05 level.

Triple exponential smoothing, a more complex method, performed significantly worse than the Random Walk model (.05) for the first four time horizons. Again, due to the extreme variance in the five year predictions, a significant difference was not observed.

Hypothesis 10

Accept H : A naive forecasting method provides forecasts
 0 of equal or greater accuracy than triple
 exponential smoothing.

When double and triple exponential smoothing are compared a less lucid result is observed. While Tables 4.1 and 4.2 indicate that double smoothing 1) provides a lower MAPE for each time horizon, and 2) provides the best forecast in the largest number of cases, the variance in the longer-term forecasts renders such differences statistically insignificant in all but the one year time horizon.

It is clear, however, that the complexities inherent in the triple smoothing model do not yield more accurate forecasts. At best, triple smoothing can be said to provide forecasts no different than those of double exponential smoothing.

Hypothesis 9

Accept H : Double exponential smoothing provides forecasts
0 of equal or greater accuracy than triple
exponential smoothing.

This supports Armstrong's (1978) contention that there is no real advantage to increased complexity in forecasting methods. In fact, double smoothing appeared to offer a more accurate, albeit insignificantly more accurate, forecast.

The ability of triple exponential smoothing to model complex patterns is also an invitation to track "spurious" patterns in a series. Since past data appears to be relatively unimportant to predicting future trends, a method that focuses more intently on patterns in past data might be expected to yield inferior forecasts.

The final two hypotheses deal with the relative accuracy of the two forms of exponential smoothing and the linear and non-linear regression-based extrapolations. The first hypothesis contrasts the accuracy of the two linear models, double exponential smoothing and regression extrapolation. Double smoothing provides a significant (.01) advantage over the regression-based approach for the one year time horizon, but no significant advantage for longer horizons.

Hypothesis 6

Reject H_0 ; H_1 : Double exponential smoothing provides more accurate forecasts than time-series regression.

Hypothesis 6 is rejected only for one year time horizon forecasts. The null must be accepted for other applications. This distinction is important since this form of smoothing allocates an inordinately large percentage of its forecasted value to the most recent sales figure. It would, therefore, be expected that this advantage would prove most valuable for the shorter-term forecasts, since they are temporally closest to this actual figure.

In addition, this form of smoothing can "learn" trend changes faster than trend-fitting regression since it allocates such a large percentage of its forecast to the most recent period. Regression "weights" recent periods equally with historical ones.

Triple exponential smoothing also outperformed its non-linear counterpart in regression analysis for only the one year time horizon (.05). Again, the null is rejected for only this horizon, and accepted for all others.

Hypothesis 8

Reject H_0 ; H_1 : Triple exponential smoothing provides more accurate forecasts than polynomial regression.

In sum, the results in this section indicate that
 1) Long-term marketing time-series appear to rather closely follow a random walk, 2) complex methods will erringly track these random variations as though they were patterns that will repeat themselves in the future.

4.14 - The Relative Accuracy of Regression-based Extrapolations

Tables 4.1 and 4.2 illustrate the relative accuracy of the three regression-based extrapolations that were tested. None of these models was able to outperform the Random Walk model.

Hypothesis 11

Accept H : The naive model provides forecasts equal to or
0 more accurate than the linear regression model.

Hypothesis 13

Accept H : The naive model provides forecasts equal to or
0 more accurate than the polynomial regression
model.

Hypothesis 15

Accept H : The naive model provides forecasts equal to or
0 more accurate than the exponential growth curve.

Not only was no evidence found to support the contention that this widely used approach to long-term market forecasting is more accurate, but considerable evidence to the contrary was observed. The naive method was significantly more accurate (.01) than the linear regression for the one, two, and three year time horizons. Again, the extreme variances in the longer-term forecasts precluded the finding of a significant difference.

In comparison to the polynomial regression, the naive was significantly more accurate (.01) for the first three time horizons, and the four year horizon (.05). The naive proved significantly more accurate than the exponential curve over all five time horizons (.01), even though tremendous variance was present in the longer-term forecasts.

A comparison of the relative accuracy of the linear and non-linear regression-based approaches showed no advantage to using the more complex form.

Hypothesis 12

Accept H_0 : Linear regression provides forecasts equal to or of greater accuracy than polynomial regression.

A Dunnett's t-test for multiple comparisons showed no significant difference for any of the five time horizons tested. Again, this supports Armstrong's (1978) contention that there is no real advantage to complex methods in forecasting. It seems that while linear regression was unable to track strong non-linear patterns, polynomial regression was frequently misled by random fluctuations, which it identified and tracked as changes in the underlying pattern.

The least accurate of the time-series methods was the constant percentage growth curve, or exponential extrapolation model. This result was expected since it is highly unlikely that a market can maintain a constant rate of growth, particularly high growth, over the long-term. A Dunnett's t-test revealed that this method was significantly less accurate over all five time horizons, at the .01 level for the first four years, and the .05 level for the five year horizon.

Hypothesis 14

Reject H_0 ; H_1 : The exponential curve provides forecasts that are less accurate than those of other methods.

The t-test compared the exponential model against the average error of the other time-series methods.

This finding suggests that forecasting future growth rates on the basis of historical rates is a mistake.

In fact, any of the other approaches to long-term forecasting will yield superior results.

4.15 - The Product Life Cycle Versus the Random Walk Theory

As noted in the previous sections, there is no indication that time-series methods will provide more accurate forecasts than a simple Random Walk model. Since time-series methods, by definition, suggest that some underlying pattern is present in long-term marketing data series, and since they are unable to provide more accurate forecasts than the Random Walk theory, which proposes that no set pattern is present, the Product Life Cycle concept can not be supported.

A test of hypothesis 13 indicated that a popular surrogate for the cycle did not yield more accurate forecasts than the naive. In fact, the naive provided significantly more accurate forecasts for most of the time horizons tested.

On the assumption that the average error of three time series methods might prove more effective than any individual method the following hypothesis was tested, and the "null" accepted.

Hypothesis 16

Accept H : The average error of forecasts generated by
0 three extrapolation methods descriptive of
the product life cycle is equal to or greater
than that of the naive model.

While it might be argued that in total the extrapolation methods yielded more accurate forecasts than the Random Walk model, this would constitute an unfair test of the Product Life Cycle. Although when considered jointly the extrapolation methods do fit a larger percentage of the cases tested here, this observation provides the market forecaster with no "apriori" information as to which method to use. The time-series models lead to very different forecasts. Simply observing that as a group they describe long-term marketing data series is of little value in forecasting. What is of value is noting that given no information about the forecasting application at hand, a Random Walk model should be selected since it fits the largest number of cases, and provides the lowest MAPE.

4.16 - The Relative Accuracy of Econometric Models

No evidence was found to support the contention that econometric models provide more accurate forecasts than time-series methods. As Table 4.3 illustrates, neither the additive, nor multiplicative, model was superior to simple time-series methods for any of the five time horizons tested. In fact, the more complex, multiplicative model yielded especially poor predictions. This adds further evidence against the contention that more complex approaches to forecasting results in more accurate forecasts.

Hypothesis 17 (Dunnett's t significant at .01)

Reject H_0 : H_1 : An additive regression model provides forecasts equal to or more accurate than a multiplicative model.

Furthermore, on the subsample of the data tested here, the Random Walk model, and a form of double exponential smoothing closely related to it, again were found to provide the most accurate forecasts. This strongly implies that long-term marketing time-series follow a random walk. The evolution of these series could not be explained by changes in the predictors considered by management to be crucial to future outcomes. Low R^2 could not be blamed since they averaged .84 for the automobile linear models, and .90 for the cigarette series.

TABLE 4.3

THE MEAN ABSOLUTE PERCENTAGE ERROR (MAPE)
OF TIME-SERIES AND ECONOMETRIC MODELS
(AUTOMOBILE AND CIGARETTE SERIES)

<u>METHOD</u>	<u>TIME HORIZON</u>				
	1 YEAR	2 YEARS	3 YEARS	4 YEARS	5 YEARS
NAIVE	10%	16%	20%	23%	25%
D. EXP. SMTH.	9	14	19	18	19
T. EXP. SMTH.	12	21	26	30	27
LINEAR REGR.	16	19	22	23	23
POLY. REGR.	14	20	26	29	33
EXP. GROWTH	48	75	118	188	306
ADDITIVE ECONOMETRIC MODEL	11%	30%	23%	31%	36%
MULTIPLICATIVE ECONOMETRIC MODEL	16%	28%	39%	53%	49%
SIMPLE COMBINATION	10%	21%	20%	23%	26%
COMPLEX COMBINATION	16%	22%	29%	40%	38%
SAMPLE SIZE	75	60	45	30	15
AVERAGE ERROR	16%	27%	34%	46%	58%

One possible reason for the poor performance of these models is the amount of data available. Since this research focused on annual data, the series were relatively short, 18 observations for the cigarette series, and between 13 and 15 for the automobile series. Employing the successive updating procedure shortened the series further still.

A cursory analysis of the MAPE's for the econometric models constructed over varying amounts of data suggested that accuracy decreased when less data was available. However, since the auto series were shorter than the cigarette series this might alternatively be interpreted as; cigarette series respond to econometric models better than do the auto series. That is, the amount of data available is not the key factor, but peculiarities in each industry. A breakout of the MAPE's on this dimension suggests that this might be the case.

To clarify this issue another set of econometric models was constructed, linear form only, for the liquor time series. These ten series were the longest in the sample, possessing 28 observations each. If data

availability is a key factor, the relative accuracy of econometric models should be greater on these series.

Three predictors were identified in the business literature and liquor sales were regressed against them. These predictors were, 1) the number of persons in the liqueur market (age 25-44 years), 2) the ratio of 25-34 year olds over 35-44 year olds, a measure of the relative make-up of the market in terms of age, and 3) a dummy variable distinguishing "baby-boomers" from older liquor consumers.

The average R^2 for these models was .92, implying an excellent predictive potential. However, as Table 4.4 illustrates, the relative accuracy of the econometric models for these series was the worst of all three industries. This suggests that data availability is not the key issue but the specific industry studied. The results in the section "Determinants of Forecast Accuracy" deals with the relative accuracies of forecasting methods under various conditions more directly, and a discussion of this issue is postponed until then.

TABLE 4.4

THE MEAN ABSOLUTE PERCENTAGE ERROR (MAPE)
OF TIME-SERIES AND ECONOMETRIC MODELS
(LIQUOR SERIES)

METHOD	TIME HORIZON				
	1 YEAR	2 YEARS	3 YEARS	4 YEARS	5 YEARS
NAIVE	12%	12%	16%	21%	21%
D. EXP. SMTH.	10	8	11	14	13
T. EXP. SMTH.	10	9	14	17	18
LINEAR REGR.	20	19	21	24	25
POLY. REGR.	14	12	15	19	22
EXP. GROWTH	26	23	28	33	41
ADDITIVE ECONOMETRIC MODEL	58%	45%	112%	103%	187%
MULTIPLICATIVE ECONOMETRIC MODEL	-	-	-	-	-
SIMPLE COMBINATION	31%	22%	56%	51%	92%
COMPLEX COMBINATION	-	-	-	-	-
SAMPLE SIZE	50	40	30	20	10
AVERAGE ERROR	23%	19%	34%	35%	52%

While other criticisms might be offered to explain the poor performance of the econometric approach, these preliminary results suggest that simple econometric models, using independent variables deemed by industry experts to be important in assessing future sales, are not more accurate than simple time-series methods, in particular a Random Walk model.

Hypothesis 4

Reject H_0 ; H_1 : Naive forecasts are relatively more accurate than both other time-series methods and econometric models.

Hypothesis 18

Accept H_0 : The most accurate of the econometric models is not more accurate than the best of the time-series models.

Hypothesis 19

Accept H_0 : The Random Walk Theory yields forecasts equal to or more accurate than the best of the econometric models.

It might reasonably be argued that the single-equation, regression-based models constructed in this research were too simple to be called econometric models, and, therefore, did not adequately test the potential of this approach in long-term market forecasting. Econometric models are generally much more complex than those employed here. Time and data constraints precluded the construction of

the type of models that are generally referred to as econometric models, and no previously constructed models of this type were available to the researcher. As a result, it is not possible to draw inferences regarding the relative accuracy of econometric models in general, but can only be concluded that over a large number of annual, unit sales series, simple models employing the econometric strategy proved less accurate than simple time-series methods.

How the econometric approach would have fared in less restrictive applications is not known. It is certainly possible that more rigorously specified econometric models, applied to longer series, say monthly or quarterly series, would have yielded dramatically different results. However, it is also possible that when forecasting long-term market changes this approach has no advantage over simple time-series methods.

4.17 - Combinations of Forecasts

As Tables 4.3 and 4.4 illustrate, combining the econometric and time-series approaches into a single forecast did not improve the forecast accuracy over the

use of the simple time-series method alone. The relative inaccuracy of the econometric approach on the series studied here seemed to "drag down" the accuracy of the combined approach. Overall, there is no support for the contention that combining forecasts from dramatically different approaches will increase the accuracy of the prediction.

Hypothesis 21

Accept H_0 : The accuracy of the combination approach is equal to or less than the average error of the individual methods.

Consistent with previous findings of this research, combining complex methods leads to less accurate forecasts than combining simple methods. Again, this offers additional support against the value of increased complexity in forecasting.

Hypothesis 20 (Dunnett's t significant at .01)

Reject H_0 ; H_1 : The combination of simple methods yields forecasts equal to or more accurate than the complex combination.

The next section investigates under what conditions a combination of forecasts is of greatest value, as well as, under what conditions other methods are most accurate.

4.2 - THE DETERMINANTS OF FORECAST ACCURACY

The overwhelming superiority of the Random Walk Theory over all other forecasting methods, for all of the five time horizons, does not preclude the ability to forecast long-term market changes in all situations. Rather, the previous analyses suggest that given no information about the specific forecasting situation at hand, a naive method should be selected since odds are that it will best describe that situation. This section presents the results of comparative forecasting efforts for various subsamples of the data that were selected using a priori information available to market forecasters. That is, given certain descriptors of the forecasting situation are known, can forecast accuracy be improved by choosing one method over another? Hypotheses are presented throughout.

4.21 - Time Horizon

As the time horizon of the forecast lengthens, the accuracy of all the forecasting methods tested generally decreased. However, the Random Walk model, and a form of double exponential smoothing closely related to it, ranked as the most accurate methods over all time horizons.

Hypothesis 22

Reject H_0 ; H_1 : As the time horizon of the forecast lengthens accuracy decreases for all forecasting methods.

Overall, the percentage error rates for forecasts generated via time-series methods increased by about ten points for each additional year that the time horizon of the forecast increased. That is, if a one-year forecast erred by 15%, a two-year forecast tended to err by 25%, and a three-year by 35%, and so on. The econometric models showed a less stable increase in error rates but averaged roughly the same as the time-series methods.

No support was found for Armstrong's (1978) hypothesis that econometric models are more accurate than time-series methods in long-range applications. Table 4.5 shows the results of a chi-square analysis testing whether the relative accuracy of these two methods was dependent on the time horizon of the forecast. The findings indicate that it is not.

Hypothesis 23

Accept H_0 : In longer range forecasts econometric methods do not provide more accurate forecasts than time-series methods.

TABLE 4.5

THE RELATIVE ACCURACY OF ECONOMETRIC AND TIME-SERIES METHODS OVER VARYING TIME HORIZONS

	<u>TIME HORIZON</u>		
	ONE YEAR	TWO OR MORE YEARS	
ECONOMETRIC MODELS ARE MORE ACCURATE	5	8	13
TIME-SERIES MODELS ARE MORE ACCURATE	120	242	362
	125	250	375

CHI-SQUARE = .15
NOT SIGNIFICANT AT .05

Overall, it is apparent by looking at Table 4.5 that over all time horizons econometric models performed poorly relative to the time-series methods. Focusing on only the shorter-term forecasts, one and two years, no support was found for Armstrong's contention that in such situations econometric models provided forecasts equal to that of time-series methods. Clearly, time-series methods were superior.

Hypothesis 24 (Chi-square significant at .01)

Accept H : In the short-term forecasts there is a difference
 0 in the accuracy of econometric models and
 time-series models.

Finally, no evidence was found to suggest that the Random Walk Theory was more applicable to long-range forecasts. A chi-square analysis revealed no significant difference in the proportion of cases best described by this model over the five time-horizons.

Hypothesis 25 (chi-square not significant at .05)

Accept H : The proportion of cases where the Random Walk
 0 provides the most accurate forecasts does not
 increase for longer-range forecasts.

In sum, forecast accuracy decreases as the time horizon of the forecast lengthens. Neither econometric models nor the naive, were not found to be more accurate in longer-range forecasts.

4.22 - Data Availability

The amount of data available was not linearly related to changes in forecast accuracy for the series tested. As Table 4.6 shows, the correlations between accuracy, by method, and the amount of data available were very small. Two time-series methods, the regression-based linear extrapolation and exponential growth curve, showed no significant correlations for any of the five time-horizons tested. The other time-series methods, while significantly correlated in a statistical sense, exhibited such small correlations that their value in a practical sense is extremely limited. On average, the amount of data available when forecasting explained less than 2% of the variation in forecast accuracy. Polynomial regression, a non-linear extrapolation model, exhibited the highest correlations. This suggests that this non-linear method can more readily use longer series where turning points, and other changes, are more likely to be encountered. Still, the amount of data available only explains 5% of the variation in forecast accuracy when using this method.

TABLE 4.6

CORRELATION BETWEEN MAPE
AND DATA AVAILABILITY

METHOD	<u>TIME HORIZON</u>				
	1 YEAR	2 YEARS	3 YEARS	4 YEARS	5 YEARS
NAIVE	-.06	-.16*	-.15*	-.15*	-.13
DOUBLE EXPONENTIAL SMOOTHING	-.09*	-.14*	-.22*	-.18*	-.14
TRIPLE EXPONENTIAL SMOOTHING	-.10*	-.19*	-.19*	-.16*	-.08
LINEAR TIME-SERIES REGRESSION	-.04	-.10	-.09	-.08	-.05
POLYNOMIAL REGRESSION	-.13*	-.24*	-.26*	-.26*	-.23
EXPONENTIAL GROWTH	.00	-.06	-.07	-.07	-.08
AVERAGE CORRELATION	-.07	-.19*	-.19*	-.17*	-.15
SAMPLE SIZE (per method)	490	392	294	196	98

*
significant at .05

It appears that more data does not necessarily translate into greater forecast accuracy. Table 4.7 indicates that for the one year forecasts many forecasting methods proved less accurate when "many" observations were available. With the exception of polynomial regression which yielded more accurate forecasts when more observations were present, the other methods showed a decrease in accuracy in such situations. It is as though a minimum amount of data is required to construct the forecasts. After this point, as more observations are considered, the likelihood of encountering an underlying change in the forces affecting the series is increased and the resulting forecast is based on this obsolete and misleading information, and as a result is less accurate. For example, linear extrapolations provide accurate forecasts as long as the pattern in the data is a linear, or close to linear, trend. In longer series this trend is less likely to be observed unbroken. Therefore, in longer series this method might be expected to provide less accurate forecasts. In such instances, MAPE would rise with longer series, and the overall correlation of MAPE with series length would be virtually non-existent since too few and too many data points decrease accuracy, while an amount

TABLE 4.7

THE MEAN ABSOLUTE PERCENTAGE ERRORS OF FORECASTS
GENERATED WITH VARYING AMOUNTS OF DATA

METHOD	<u>DATA AVAILABILITY</u>		
	FEW DATA (less than 11 points)	SOME DATA (11 to 15 points)	MANY DATA (more than 15 points)
NAIVE	16%	11%	13%
DOUBLE EXPONENTIAL SMOOTHING	18	10	12
TRIPLE EXPONENTIAL SMOOTHING	21	13	15
LINEAR TIME-SERIES REGRESSION	28	22	25
POLYNOMIAL TIME- SERIES REGRESSION	26	20	16
EXPONENTIAL GROWTH	38	34	41
* SAMPLE SIZE (per method)	137	198	155

★

Sample includes one year forecasts only.

in between would yield the most accurate forecasts.

The categorization of series used in this research seems to capture this phenomenon well. Ten or fewer data points results in a decrease in accuracy for all time series methods. More than 15 data points resulted in a decrease in accuracy for the linear extrapolation methods, but not polynomial regression which was able to capitalize on this additional information. The linear extrapolations excelled with between 11 and 15 observations.

Hypothesis 26

Accept H : The accuracy of all forecasting methods is not
0 greater when many data are available.

A chi-square analysis of the crosstabulation of data availability and the relative accuracy of "simple" versus "complex" time-series methods shows that simple methods (e.g. linear regression-based extrapolation, and double exponential smoothing) are more accurate when few data are available, while complex methods (e.g. polynomial regression, and triple exponential smoothing) are more accurate when many data are available.

Table 4.8 illustrates these results.

TABLE 4.8

THE RELATIVE ACCURACY OF SIMPLE VERSUS COMPLEX
METHODS WHEN DIFFERENT AMOUNTS OF DATA ARE AVAILABLE

	* <u>DATA AVAILABILITY</u>			
	FEW DATA (LO-10)	SOME DATA (11-15)	MANY DATA (16-HI)	
SIMPLE MODELS ARE MORE ACCURATE	320	291	182	793
COMPLEX MODELS ARE MORE ACCURATE	234	230	213	677
	554	521	395	1470

CHI-SQUARE = 13.77
SIGNIFICANT AT .01

*
includes forecasts generated for all five time horizons

Hypothesis 27 (Chi-square significant at .01)

Reject H_0 ; H_1 : When few data are available simple methods
 are as accurate or more accurate than
 complex methods.

Finally, Table 4.9 indicates that the widely used exponential growth curve, which assumes a constant percentage growth rate, does not significantly predict "new" product categories better than "mature" products, relative to other forecasting methods. In fact, this method was the poorest model tested, on both product types. It best described only 42 of 490 series in one year forecasts. Market forecasters are advised to avoid this method of long-term market forecasting, regardless of the amount of data available.

Hypothesis 28 (Chi-square not significant at .05)

Accept H_0 : The exponential growth curve is not most
 accurate for "new" product categories.

In sum, longer data series are best handled by non-linear methods, while shorter series are best handled by linear models. Econometric models, as discussed in a previous section, appear to depend more on the specifics of the given application, than simply on the amount of data available.

TABLE 4.9

THE RELATIVE ACCURACY OF THE EXPONENTIAL GROWTH
CURVE WHEN DIFFERENT AMOUNTS OF DATA ARE AVAILABLE

		★ <u>DATA AVAILABILITY</u>			
		FEW DATA (LO-10)	SOME DATA (11-15)	MANY DATA (16-HI)	
EXPONENTIAL GROWTH CURVE IS MORE ACCURATE		16	12	14	42
OTHER TIME-SERIES METHODS ARE MORE ACCURATE		121	186	141	448
		137	198	155	490

CHI-SQUARE = 3.3
NOT SIGNIFICANT AT .05

★
includes only the one year forecasts

4.23 - Product-Class Versus Product-Form

Knowing whether a data series constituted sales for a product-class or product-form made no difference in the overall accuracy of the forecasting methods applied, nor the relative accuracy of any individual method. This dimension appears to be unimportant in long-term market forecasting. Neither type of series is inherently more predictable, nor is one type more amenable to a given forecasting method.

The average error of all the time series models tested was essentially the same for product-classes as for product-forms.

Hypothesis 29 (t-test not significant at .05)

Accept H : The average error of all forecasting methods
0 is equal for product-forms and product-classes.

Furthermore, the relative accuracy of econometric models and time-series methods was not dependent on this dimension.

Additional evidence is available on this point by noting that the proportion of the cases best described by the naive, or Random Walk, model was no different for either of the two types of series. This suggests that forecasting is equally feasible for product-forms and product-classes.

The product life cycle literature suggests that this cycle is more appropriate for product-forms than for product-classes (Polli and Cook, 1969; Rink and Swan, 1979). No evidence was found in this research to support that contention. A frequently used surrogate for the product life cycle, the polynomial regression extrapolation, proved no more accurate on product-forms than on product-classes. Table 4.10 shows the results of a chi-square analysis that tests whether this model fits a greater proportion of product-forms. It did not. Neither did combinations of time-series methods that have also been proposed as descriptors of the product life cycle.

Hypothesis 30 (chi-square not significant at .05)

Accept H : Curvilinear regression is not more accurate
0 for product-forms than product-classes.

Furthermore, no time series method, nor econometric model, described one type of series as opposed to the other.

In sum, whether a data series constitutes a product-class or product-form makes no difference in long-term market forecasting.

TABLE 4.10

THE RELATIVE ACCURACY OF A PRODUCT LIFE CYCLE
FORECASTING MODEL ON PRODUCT-FORMS AND CLASSES

	PRODUCT CLASS	PRODUCT FORM	
PRODUCT LIFE CYCLE IS MORE ACCURATE	49	140	189
OTHER METHODS ARE MORE ACCURATE	266	1015	1281
	315	1155	1470*

CHI-SQUARE = 2.41
NOT SIGNIFICANT AT .05

*
includes forecasts generated for all five time horizons

4.24 - Durable Versus Non-Durable Goods

While the product-form/product class typology proved of little value in long-term market forecasting, a durable/non-durable typology was found to be highly associated with forecast accuracy. Regardless of the method or time horizon of the forecast, non-durable goods were more predictable. Durable goods exhibit such highly erratic period-to-period changes in unit sales that forecasting future values is extremely difficult. Non-durables generally followed a more predictable pattern that could be used to ascertain future values.

Hypothesis 31 (t-test significant at .01)

Reject H_0 ; H_1 : The average error of all forecasting methods is less for non-durable goods than for durable goods.

A t-test of the average error of all time-series methods was significantly (.01) lower for non-durables for the first four time horizons tested. While five year forecasts also appeared lower, large variances precluded the finding of a significant difference.

Further evidence on this point can be gleaned from the observation that a larger proportion of the durables were best described by the Random Walk Theory. As Table 4.11 illustrates, 27% of the durable goods

TABLE 4.11

THE RELATIVE ACCURACY OF THE RANDOM WALK
FOR DURABLE AND NON-DURABLE GOODS

	DURABLES	NON-DURABLES	
RANDOM WALK IS MORE ACCURATE	228	124	352
OTHER METHODS ARE MORE ACCURATE	612	506	1118
	840	630	1470*

CHI-SQUARE = 11.12
SIGNIFICANT AT .01

* includes forecasts generated for all five time horizons

were most accurately forecast via the Random Walk Theory. Only 20% of the non-durable series were best described in this way. A chi-square analysis of this contingency table proved significant at .01.

The relative accuracy of econometric models over time-series methods was not found to be related to the durable/non-durable typology.

The product life cycle surrogate was not found to be more accurate on non-durable goods. A chi-square analysis proved insignificant at .05.

Hypothesis 32

Accept H : Curvilinear regression is not more accurate
0 for non-durable goods.

However, double exponential smoothing was significantly more accurate on non-durable goods forecasts, regardless of the time horizon of the forecast (.01). This method proved to be the most accurate means of forecasting for nearly one-third of the non-durable forecasts. No other method was as accurate. Table 4.12 shows the results of the chi-square analysis.

In sum, all time-series methods were more accurate for non-durable goods forecasts, and double exponential smoothing was the most accurate.

TABLE 4.12

THE RELATIVE ACCURACY OF DOUBLE EXPONENTIAL
SMOOTHING FOR DURABLE AND NON-DURABLE GOODS

	DURABLES	NON-DURABLES	
DOUBLE EXPO. SMOOTHING IS MORE ACCURATE	171	174	345
OTHER METHODS ARE MORE ACCURATE	669	456	1125
	840	630	1470 [*]

CHI-SQUARE = 10.45
SIGNIFICANT AT .01

★

includes forecasts generated for all five time horizons

4.25 - Turning Points

The presence of a turning point in a data series greatly decreased forecast accuracy. This was observed for forecasts generated by all methods, over all five time horizons. However, the rate at which forecast accuracy deteriorated was lower for the more complex, non-linear extrapolations than for the linear models. Table 4.13 shows the results of a chi-square analysis that tested the relative accuracy of each type of model on series with and without turning points.

Hypothesis 33 (chi-square significant at .01)

Reject H₀ ; H₁ : Complex time-series methods provide more accurate forecasts than simple models when a turning point is present.

Clearly, when a turning point is present in a series, non-linear extrapolations are superior. They best forecast 72% of those series. However, in those series with no turning point, a simple, linear extrapolation was most accurate. They best described 59% of those series. This finding suggests that market forecasters should select an extrapolation model with this variable in mind. When no turning point is present, simple models should be used. When a turning point is present 1) complex models

TABLE 4.13

THE RELATIVE ACCURACY OF SIMPLE AND COMPLEX MODELS
ON SERIES WITH AND WITHOUT TURNING POINTS

	TURNING POINT	NO TURNING POINT	
SIMPLE MODELS ARE MORE ACCURATE	67	726	793
COMPLEX MODELS ARE MORE ACCURATE	173	504	677
	240	1230	1470*

CHI-SQUARE = 77
SIGNIFICANT AT .01

*

includes forecasts generated for all five time horizons

should be selected, or 2) simple models should be applied to that portion of the data series subsequent to the turning point.

No evidence was found to suggest that econometric models were superior to time-series analysis when a turning point was present. Only 15 data series in the subsamples used to construct the econometric models contained a turning point. All 15 of these series were best forecast by time-series methods. A chi-square analysis was insignificant at .05.

Hypothesis 34 (chi-square not significant at .05)

Accept H : Econometric models provide less than or equally
 0 accurate forecasts than time-series methods
 when a turning point is present.

In sum, the presence of a turning point decreases the accuracy of all forecasting methods. Non-linear models provide relatively more accurate forecasts in such situations. Simple extrapolations are superior when no turning point is present. The relative accuracy of econometric models is not dependent on this variable.

4.26 - Stability

A judgmental assessment of the historical stability of a data series was found to be strongly related to the type of forecasting method that provided the most accurate forecasts. The Random Walk Theory clearly provided the most accurate forecasts for unstable series. As Table 4.14 illustrates, this model best described nearly half of the unstable series, but only about one-fifth of the stable ones. This suggests that by simply viewing the scatter plots of annual sales over time market forecasters can ascertain whether the application of traditional forecasting approaches will outperform a naive model.

Hypothesis 35 (chi-square significant at .01)

Reject H_0 ; H_1 : In unstable series the Random Walk Theory is the most accurate forecasting method.

The more complex, non-linear extrapolations provided especially poor predictions on unstable series. They appeared to confuse random instability with changes in the underlying pattern of the series. Simple models were clearly superior in such instances. However, for

TABLE 4.14

THE RELATIVE ACCURACY OF THE RANDOM
WALK THEORY ON UNSTABLE SERIES

	STABLE SERIES	UNSTABLE SERIES	
THE RANDOM WALK THEORY IS MORE ACCURATE	124	228	352
OTHER METHODS ARE MORE ACCURATE	566	552	1118
	690	780	1470*

CHI-SQUARE = 25.2
SIGNIFICANT AT .01

*

includes forecasts generated for all five time horizons

none of the five time horizons tested did the simple extrapolations outperform the Random Walk when the data-series were unstable.

Hypothesis 36 (chi-square significant at .01)

Reject H_0 ; H_1 : Simple time-series models would outperform more complex ones in unstable series.

Table 4.15 shows the results of this analysis.

There was no evidence found to suggest that combinations of simple forecasts would outperform the individual methods from which they were constructed when the series were judged to be unstable. Unstable series seemed to be relatively unpredictable, regardless of the method used to forecast them, and simple forecast combinations showed no real advantage in such situations.

Hypothesis 37

Accept H_0 : A simple combination of forecasts will not outperform individual methods in unstable series.

In the next section, the moderating effects of the number of runs in the series, a concept similar to that of stability, is considered.

TABLE 4.15

THE RELATIVE ACCURACY OF SIMPLE AND COMPLEX
METHODS ON STABLE AND UNSTABLE SERIES

	STABLE SERIES	UNSTABLE SERIES	
SIMPLE METHODS ARE MORE ACCURATE	328	465	793
COMPLEX METHODS ARE MORE ACCURATE	362	315	677
	690	780	1470 [*]

CHI-SQUARE = 21.3
SIGNIFICANT AT .01

*
includes forecasts generated for all five time horizons

4.27 - Number of Runs

The greater the number of runs contained in a data series the more likely that the Random Walk would provide the most accurate forecasts. Consistent with previous findings in the financial literature, the number of runs in a series was a key indicator of the predictability of that series with traditional forecasting tools. As Table 4.16 shows, the Random Walk best described only 15% of those series containing less than five runs, but almost 30% of those with five or more runs.

Hypothesis 38 (chi-square significant at .01)

Reject H_0 ; H_1 : The greater the number of runs encountered
0 1 the more accurate the Random Walk Theory.

When a statistical test was performed on the number of runs observed in each series to assess whether that number was significantly different than chance, a similar result emerged. As Table 4.17 illustrates, the Random Walk provided the most accurate predictions for only 15% of those series with a non-chance number of runs, series where a trend or pattern was present. However, this model proved most accurate for 33% of those series containing a chance number of runs.

TABLE 4.16

THE RELATIVE ACCURACY OF THE RANDOM WALK THEORY
ON SERIES WITH VARYING NUMBERS OF RUNS

	FEW RUNS (1-4)	SOME RUNS (5-6)	MANY RUNS (7-12)	
THE RANDOM WALK THEORY IS MOST ACCURATE	64	130	158	352
OTHER METHODS ARE MOST ACCURATE	431	320	367	1118
	495	450	525	1470*

CHI-SQUARE = 50.1
SIGNIFICANT AT .01

*

includes forecasts generated for all five time horizons

TABLE 4.17

THE RELATIVE ACCURACY OF THE RANDOM WALK THEORY
ON SERIES WITH A CHANCE NUMBER OF RUNS

	CHANCE NUMBER OF RUNS	NON-CHANCE NUMBER OF RUNS	
THE RANDOM WALK THEORY IS MOST ACCURATE	340	12	352
OTHER METHODS ARE MOST ACCURATE	1040	78	1118
	1380	90	1470*

CHI-SQUARE = 6.42
SIGNIFICANT AT .05

* includes forecasts generated for all five time horizons

The overwhelming preponderance of large numbers of runs in the sample suggests that many long-term marketing series appear to follow a random walk.

Hypothesis 40 (chi-square significant at .05)

Reject H_0 ; H_1 : The Random Walk model will not provide the most accurate forecasts when a series contains a number of runs statistically different than that expected by chance.

Finally, it was observed that simple time-series models significantly outperform complex ones when many runs are present. Again, it appears that complex, non-linear models tend to track the random variation in these series, mistaking it for changes in the underlying trend. Table 4.18 shows the results of a chi-square analysis, and indicates that complex models are most accurate when very few runs are encountered, while simple methods are superior when a larger number are observed.

Hypothesis 39 (chi-square significant at .01)

Reject H_0 ; H_1 : Excluding the Random Walk Theory, simple models will be more accurate when many runs are present.

In sum, when many runs are observed in a data series, the Random Walk Theory will provide the most accurate forecasts. Complex models will perform poorly on such series.

TABLE 4.18

THE RELATIVE ACCURACY OF SIMPLE AND COMPLEX
METHODS ON SERIES WITH VARYING NUMBERS OF RUNS

	FEW RUNS (1-4)	SOME RUNS (5-6)	MANY RUNS (7-12)	
SIMPLE MODELS ARE MORE ACCURATE	209	291	293	793
COMPLEX MODELS ARE MORE ACCURATE	286	159	232	677
	495	450	525	1470*

CHI-SQUARE = 48.7
SIGNIFICANT AT .01

*

includes forecasts generated for all five time horizons

4.28 - Autocorrelation

The Random Walk Theory better described those series that showed no autocorrelation of their first differences, or period-to-period changes. As Table 4.19 illustrates, this model was most accurate in 27% of the non-autocorrelated series, but only 18% of the series that did show some autocorrelation structure. No significant difference in the relative accuracy of the Random Walk was observed when varying levels of autocorrelation of the series themselves were considered. Overall, it was cautiously concluded that the less the autocorrelation structure of a data series the more likely it is that the Random Walk Theory will provide the most accurate forecasts.

Hypothesis 41 (chi-square significant at .01)

Reject H_0 ; H_1 : The less the autocorrelation structure the more accurate the Random Walk Theory.

Finally, no evidence was found to suggest that econometric models are more accurate on series with no autocorrelation structure. The overall poor performance of these models precluded finding any significant difference.

TABLE 4.19

THE RELATIVE ACCURACY OF THE RANDOM WALK THEORY
ON SERIES WITH AND WITHOUT AUTOCORRELATION

	NO AUTOCORRELATION IN THE SERIES	AUTOCORRELATION** IN THE SERIES	
THE RANDOM WALK IS MORE ACCURATE	260	92	352
OTHER METHODS ARE MORE ACCURATE	700	418	1118
	960	510	1470*

CHI-SQUARE = 14.8
SIGNIFICANT AT .01

* includes forecasts generated for all five time horizons

** refers to autocorrelation of the first-differences only

Hypothesis 42 (chi-square not significant at .05)

Accept H : Econometric models will not outperform time-series methods when little autocorrelation is present.

In sum, autocorrelation of the first-differences was found to be related to the relative accuracy of the Random Walk model. The less correlated the series, the greater the proportion of cases in which the Random Walk predicts best. Econometric models were not found to provide superior predictions on uncorrelated series.

In the next chapter the results of this study are summarized, conclusions are drawn from them, and recommendations for possible future research are offered.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter summarizes the findings of this research, offers some generalizations that can be drawn from them, and suggests areas for possible future research.

5.1 - SUMMARY

The explosive growth of strategic planning as a business practice and area of marketing research interest has increased the importance of accurate long-term market forecasts. Strategic planning holds as a basic tenet the identification and prediction of long-term market growth and decline. The overall goal of this research was to aid market planners in assessing how best to estimate market changes. Toward this end, three broad objectives were focused on.

First, this research sought to assess the extent to which the Random Walk Theory explained the evolution of markets. This theory holds that changes in a time-series

are independent of one another; that a series wanders randomly over time. Therefore, any forecasting method that attempts track and project trends or patterns in that series is destined to fail. This theory has received widespread support when applied to many financial time series.

To test the validity of the Random Walk Theory on long-term marketing time-series two procedures were followed. First, a number of statistical tests were performed on the series (i.e., autocorrelation analysis, and runs-tests) that are identical to those that have been used in the financial literature to support the theory. Second, and more central to the goals of this research, direct comparisons between predictions made by this theory and those made by traditional market forecasting tools were made. Since the Random Walk Theory holds that the past values of a series contain no information about future values, it is operationalized via a naive model. This model simply applies the current value of the series as a forecast of future values. The relative accuracy of this method in contrast to

other methods that attempt to capitalize on historical data was used as a measure of the appropriateness of the theory on long-term marketing time-series.

The second objective of this research was to assess the relative accuracy of seven widely-used forecasting methods, and two combinations of forecasts constructed from them. Comparisons were made for one, two, three, four, and five year forecasts on a "hold-out" sample.

The third objective of this research sought to assess how ten descriptors of the forecasting situation affected the relative accuracy of all the methods tested. The result was to provide market planners with a means whereby to tailor the forecasting application with the most appropriate forecasting model. To date, the literature has offered little in the way of empirical evidence on this issue. This research offered a first step in that direction.

In consideration of these three objectives, four specific research questions were formulated and tested.

1. How do predictions generated from time-series methods compare with those of econometric models?

2. Do Complex forecasting methods yield more accurate predictions than more simple ones?
3. How accurate are operationalized versions of the product life cycle in long-term forecasting?
4. Will a strategy that combines forecasts from very different approaches provide superior forecasts than those of the individual methods from which they are constructed?

To answer these research questions, hypotheses were developed and tested.

The sample used to test these hypotheses contained nearly 10,000 forecasts. Ninety-eight time-series representing a wide range of product categories were sampled from secondary data sources. Each series consisted of annual, unit sales. The forecasting methods were applied to the series using a successive updating procedure with the last five years of each series being "held-out." This yielded five one-year, four two-year, three three-year, two four-year, and one five-year forecasts per series, for each of the ten forecasting methods tested. This "extended" sample became the basis for comparing relative forecast accuracy.

Since the econometric models had to be developed specifically for each product category, they were applied only to a subset of the ninety-eight series.

In addition, each series was categorized according to the descriptors mentioned above. This allowed for the matching of the most accurate forecast and the specific type of application, and provided the basis for a number of prescriptive statements regarding the relative accuracy of the methods.

Forecast accuracy was measured using the Mean Absolute Percentage Error (MAPE). This measure was selected due to its inherent clarity of meaning. It represents the percentage by which the forecast differed from the actual outcome as observed in the "hold-out" sample.

Finally, all forecasts were constructed "ex-ante." Only information available to a market forecaster at the time the forecast was constructed was considered. No information subsequent to the current time period of the forecast was incorporated into any of the models.

5.2 - CONCLUSIONS AND RECOMMENDATIONS

This section presents separately, 1) a summary of the results of this research, and 2) a discussion of the implications of these findings with recommendations to market forecasters.

5.21 - Summary of Research Findings

The following points summarize what was found in this research as presented in Chapter IV:

1. The most prominent finding of this research was that the Random Walk Theory received considerable support when applied to long-term marketing time-series. The majority of the series tested showed little auto-correlation structure, and exhibited a number of runs consistent with what might be expected had changes in the series been generated by a chance process.

Forecasts generated by the Random Walk Theory yielded the most accurate forecasts over all series, and all time horizons, when compared with predictions made by nine other forecasting models. Only double exponential smoothing, whose form was very similar to the random walk, provided forecasts nearly as accurate.

2. Excluding the Random Walk Theory, simple models were found to consistently provide forecasts that were more accurate than those generated by complex models. Linear extrapolations outperformed non-linear extrapolations. Additive econometric models were more accurate than multiplicative models. Combinations of simple methods were superior to complex combinations.

3. Econometric models were found to be less accurate than simple time-series methods. While both of the econometric models used in this research were relatively simple single-equation models, the strategy of predicting independent variables deemed by management to be crucial to the evolution of their markets, and using the relationship of these variables with a dependent variable to forecasts future values, did not payoff.

4. The product life cycle, as operationalized via a frequently used surrogate, did not provide very accurate long-range forecasts.

5. A strategy that combined forecasts from the econometric and time-series approaches provided more accurate forecasts than the average error of the individual methods from which it was constructed, but did not outperform a simple time-series model alone.

In regard to determinants of forecast accuracy the following results emerged:

1. As the time horizon of the forecast increased, the accuracy of all forecasting methods steadily decreased. No method appeared to be relatively more accurate for long-term forecasts as opposed to shorter-term forecasts.

2. More data did not necessarily translate into greater accuracy. Simple time-series models proved most accurate when few data were available, while the more complex versions were superior when many data were available.

3. The classification of series as product-classes and product-forms did not affect the accuracy of forecasts generated by any method, for any time horizon. Neither type of series was inherently more predictable.

4. Durable goods proved significantly less predictable than non-durables. The Random Walk Theory was more likely to best describe durable goods series than non-durables.

5. Series with a turning point were best handled by non-linear time-series methods. Series without a turning point were best handled via simple time-series

methods. Econometric methods were observed to yield relatively more accurate forecasts when a turning point was present in the series.

6. Unstable series were most accurately forecast by the Random Walk Theory. Complex methods performed especially poorly on such series.

7. Series with many runs, or a chance number of runs, were most accurately forecast via the Random Walk Theory. Complex methods were also observed to offer very poor predictions on these types of series.

8. Series with meager autocorrelation structures were best forecast by the Random Walk Theory.

5.22 - Implications and Recommendations

The following implications and recommendations were drawn from the research findings presented in Chapter IV:

1. The Random Walk Theory has been found to apply not only to short-term changes in financial time-series (e.g., stock and bond prices, interest rates, commodity prices, and corporate earnings) but to annual changes in a large number of unit sales series. This implies that the applicability of this theory is far more

pervasive than previously thought.

One possible reason for the pervasiveness of the Random Walk Theory is that long-term sales are determined in much the same way as short-term stock prices. Whereas changes in stock prices are greatly influenced by the random occurrence of "news" events, year-to-year changes in sales series are heavily influenced by changes in a host of exogenous variables. These variables, even if identifiable, affect the series in a manner that probably changes over time. That is, new factors enter the picture (e.g., interest rates on car sales), other factors decrease in their importance (e.g., styling of automobiles), and the combined, and cumulative effect on sales is difficult to quantitatively specify. The result is that the time-series appear to wander and are best described as a Random Walk. The future does not seem to evolve according to generalizable patterns.

The reliance on ever more complex forecasting methods, in the hope of capturing these complexities, has not paid off because any increase in the theoretical efficiency of the method is more than compensated for by practical problems in specifying the model. In other words,

complex models end up compounding errors due to mis-specification, and measurement error.

The recommendations of this research are, given no information about the specific characteristics of the forecasting situation, except that the series consists of annual unit sales data, a naive forecasting method should be employed to predict future values of the series. On average, this method will yield the most accurate yearly forecasts.

The use of the Random Walk model is strongly recommended when the series at hand represents sales of an unstable durable good, with few runs in the data, and a limited autocorrelation structure. In these cases, period-to-period changes appear random. Durable goods tend to be 1) more expensive, 2) purchased less frequently, and 3) more susceptible to changes in economic conditions, which are themselves highly unpredictable.

The less similar the characteristics of the forecasting situation are to those described above, the greater the likelihood that traditional forecasting approaches will prevail.

The validity of the Random Walk Theory in many long-term market forecasting applications will be hard for marketers to accept. It suggests that the future does not evolve from the past in an orderly, and identifiable pattern. This runs counter to the notion of planning for an expected future, and strongly implies that management's ability to foretell the future state of its markets is severely limited. Marketers, like people in general, will be reluctant to accept their limitations.

Forecasting by analogy, marketers might be expected to respond to the Random Walk Theory in a manner similar to financial analysts. In stock market applications the theory has been embraced almost solely by academics. Practitioners have largely rejected the theory even though it is strongly supported by a voluminous body of empirical literature. It has probably been rejected for two reasons. First, stock price forecasting is an integral part of their business; to acknowledge the frailty of their estimates would be tantamount to questioning their existence in that business. Second, it is psychologically

unpalatable to accept that there are some things that no matter how deeply you study them are inherently unknowable. Most likely, marketers will respond in a similar manner. The emergence of strategic planning as a business practice relies heavily on market forecasts. How can a firm invest in "growth" markets, and divest from "declining" markets in a random walk?

Marketers will also continue to rely on new and traditional market forecasting tools because they firmly believe in the "technological fix." The application of high technology, in particular computer gadgetry, has proven successful in other areas of their business. It seems only reasonable that the advent of cheap, high-speed digital computers, and the accompanying advances in statistical and mathematical forecasting methods should lead to similar advances in forecast accuracy.

Marketers are surely not dissuaded from this view by the advocates of complex market forecasting techniques. On the contrary, they are encouraged to employ the latest approach.

Forecasters also seem to believe strongly in the "technological fix." They have generally focused ever more intently on the development of ever more complex forecasting models. Rarely have they sought to assess the feasibility of long-term market forecasting in an objective fashion.

Forecasters generally view the forecasting problem from the narrow perspective of model-building. Proponents of time-series methods view the future as a continuation of some pattern that can be identified from past data. This deterministic view implies a certain degree of inevitability in the future. The key to the future is to find the correct pattern in past data. Economists focus on the interrelationships among many aspects of the market. The key to econometric forecasting is to understand the structure of these relationships, hope they do not change, and be able to forecast certain elements of the system.

In sum, marketers will not readily concede that the future is largely unpredictable. They will continue to embrace the latest method (e.g., cross-impact, MARMA, state-space) in search of the holy grail of forecasting. To do otherwise would be to admit their limitations in a world where uncertainty is viewed like the plague.

2. Recent research efforts have suggested that simple methods of long-term forecasting are more accurate than complex methods (e.g., Armstrong, 1978). This research generally concurs on this point. In fact, the simple methods that have been proposed may not be simple enough. This study found that a naive method of applying the current periods sales figure as a forecast for future periods was most accurate. This method generally provided forecasts more accurate than simple extrapolations and simple econometric models. This implies that previous research efforts have been observing a random walk in long-term series, since they did not test this method.

Complex extrapolations can only be recommended when many data are available, and those data contain a turning-point. The use of complex econometric models can not be recommended in any situation.

Simple extrapolations, and to a lesser extent simple econometric models, are recommended over the Random Walk Theory when the series to be forecast is a stable, non-durable good, possessing some autocorrelation structure, with no turning point present.

3. Only with caution can generalizations regarding long-term forecasting via econometric models be made. With this approach it was possible that alternative explanations for the relatively poor performance are valid. The industries selected might not have been representative. Important factors may have been omitted, or poorly forecast. Possibly not enough data was used. However, it is also possible that econometric models simply do not provide more accurate forecasts than simple time-series methods.

Concluding that this last point is correct, it can not be recommended that econometric models, especially multiplicative models, be used in any situation. No generalizable situations were observed where this approach proved more accurate.

4. The strong support found for the Random Walk Theory suggests that market forecasters should not rely on operationalized versions of the product life cycle as forecasting tools. If viewed as competing theories, the Random Walk better describes the pattern followed by marketing time-series. These series generally showed

little or no evidence of trends or patterns. The fact that a model that postulated sales would remain the same outperformed one that assumed a continuing trend suggests that a series at any given point in its history might subsequently rise, or fall. The explanatory power of a concept that has little predictive power must be questioned.

5. The strategy of combining forecasts from the econometric and time-series approaches can not be supported. The use of simple time-series methods alone will yield more accurate forecasts. It is not recommended that this method with great intuitive appeal be used in any situation over simple time-series methods, or a naive method.

In Conclusion, the findings of this research should be considered in light of the following caveats and observations.

First, although the econometric models proved to be poor predictors of annual, unit sales series, their ability to explain variation among industry variables might serve some ancillary purpose. In other words, the value of an econometric model can not simply be

judged to be predictive, but also in its ability to aid in the understanding of the market, or economy. While philosophers of science might argue that a theory or model that does not predict can not also possess any explanatory power, the Power Paradox argument, econometric models are frequently used as a means of obtaining an intuitive, if not scientific, understanding of the market, or economy. Econometric models of the U.S. economy, such as the Wharton and Chase models, appear to provide a greater understanding of the dynamics of the economy than their predictive power would imply. This explanatory power, in spite of a weak predictive record, can greatly aid marketers and economists, and might result in more accurate versions of the model being developed in the future.

Second, the relative accuracy of these models might have greatly been affected by the unit of analysis selected. Had monthly, or quarterly, data been used, as opposed to annual data, shorter-term variations such as seasonality would have played a much more dominant role than they did in this research, and more complex models that

excel at identifying such patterns might have yielded more accurate forecasts. Many of the complex forecasting methods mentioned in this dissertation, such as Box-Jenkins, are advocated as very short-term forecasting tools. Since such methods would be able to identify the components that dominant short-term series, and more data would be available for applying these methods, complex methods might prove more accurate than simple methods, including the Random Walk, when a more micro-level unit of analysis is employed. However, previous research has indicated that complex models show no advantage in such situations.

It is clear from this research, however, that the Random Walk Theory was most accurate. The lack of dominant fluctuations in annual data might explain the relative accuracy of the Random Walk. It would be interesting to see how this model performs with quarterly, or monthly, versions of the same set of series.

Third, many of the forecasting models tested in this research are subsets of one another. Double exponential smoothing is a special case of triple exponential

without the curvilinear factor. Similarly, linear regression is a special case of polynomial regression, containing no curvilinear trend either.

Most importantly, the dichotomy between exponential smoothing, a time-series method, and the econometric models is not a perfect one. Some authors have replaced the lagged forecast value in the exponential smoothing model with lagged sales, thus using exponential smoothing as a form of econometric model.^{*} Therefore, it might be argued that exponential smoothing is a form of econometric model.

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This distributed lag model was developed by Koyck, L.M., Distributed Lags and Investment Analysis, (Amsterdam: North-Holland, 1954). It was first applied in marketing by Palda, K.S., The Measurement Of Cumulative Advertising Effects, (Englewood Cliffs, N.J.: Prentice-Hall, 1964).

5.3 - RECOMMENDATIONS FOR FUTURE RESEARCH

This research found considerable evidence that many long-term marketing time-series follow a random walk. Possibly this was due to the time frame of the forecasts; many relied on pre-1975 data to predict sales in subsequent periods. This was a turbulent time in the United States. An oil "crisis" and recessionary economy were dominant factors at that time. Many series may have been essentially unpredictable only for this period (e.g., automobile sales, durable goods). Further research focusing on other time periods would shed additional light on whether these series generally follow a random walk, or what was observed here was merely an aberration that might not be expected in the future.

Other possible areas of future research might focus on the effect of measurement error in the series studied and the conclusion that they follow a random walk. If the secondary data sources used were replete with inaccurate data, then the reported data might appear to follow a random walk, but the actual series might contain a strong trend or pattern. Forecasts based on different data bases are strongly encouraged.

Finally, further research aimed at matching the forecasting situation with the most appropriate method should be encouraged. The potential benefits from this relatively unexplored avenue of research are many. It would help delineate those situations where forecasting is feasible, and where it is not. It would allow market planners to choose a forecasting method best suited to their specific application. Eventually, such efforts might result in a theoretical framework for forecasting research.

It is not recommended that forecasting researchers focus more intently on the development of complex methods. Rather greater emphasis should be placed on comparing the relative accuracy of simpler methods. The very nature of the long-range forecasting problem implies that seeking to capture the inherent complexities that affect long-term market growth and decline is a treacherous task that has, and probably will continue to have, a limited payoff.

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