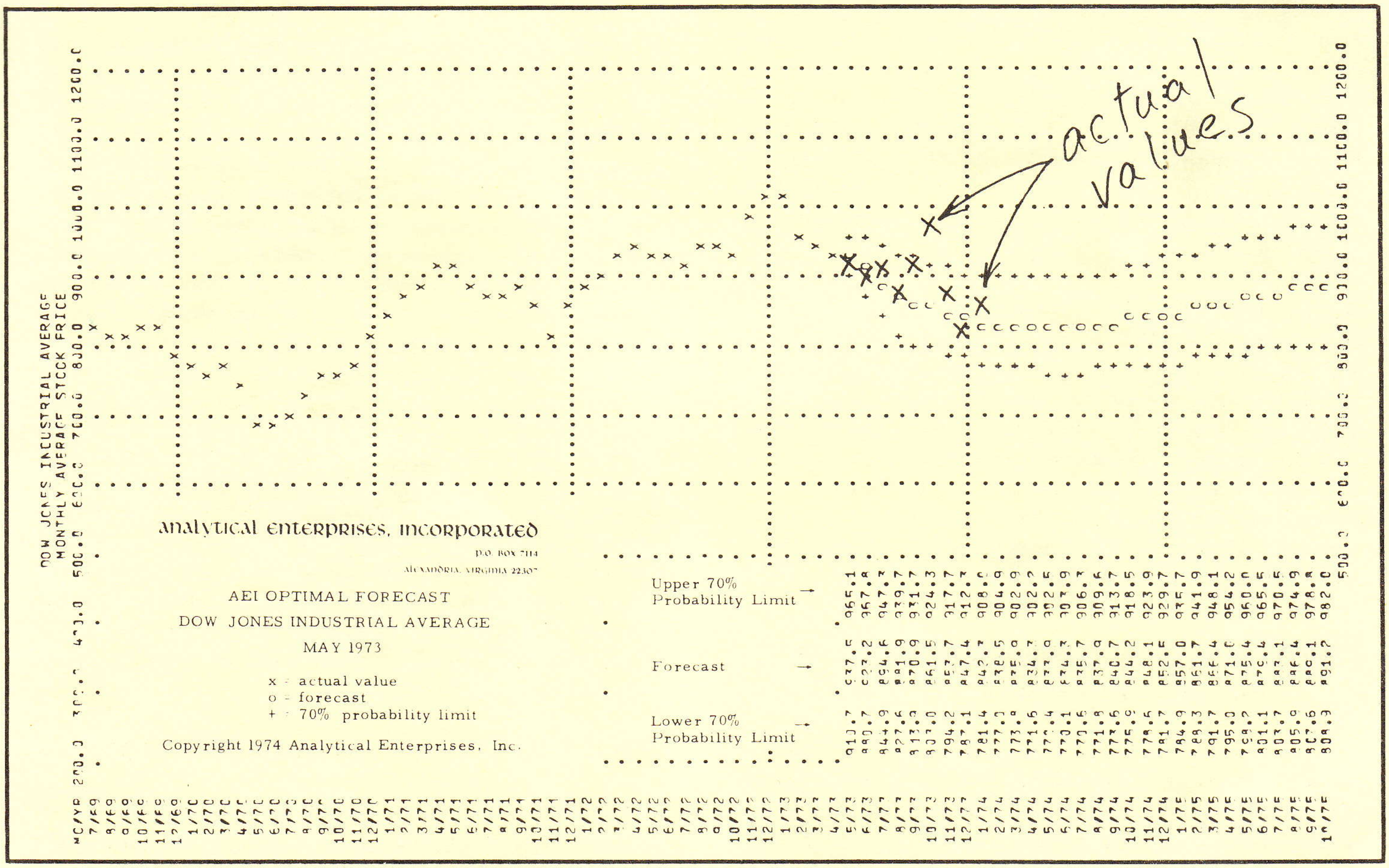
aei

# OPTIMAL FORECASTS




Analytical Enterprises, Incorporated

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Alexandria, Virginia 22307

# AEI OPTIMAL PRICE FORECASTS AND PROBABILITY LIMITS

- 30-month Optimal Forecast of Monthly Average Price
- 70% Probability Limits for All Forecasts
- Forecasts Updated Monthly
- Currently Available for 25 Stocks

## AEI'S FORECASTS PROVIDE SYSTEMATIC INPUTS TO MARKET ANALYSIS

AEI's Financial Services Division introduces an exciting new service to the financial community—optimal forecasts of monthly average common stock prices, with probability limits. Using the most advanced statistical techniques available, AEI has developed models for forecasting monthly price movements and for determining probability intervals around the forecasts. For each stock, a mathematical forecasting model has been developed from past data. The appropriateness of the model to represent the stock's price movements has been thoroughly tested using advanced statistical techniques such as spectral analysis.

AEI's Optimal Stock Price Forecasts provide, for each of a comprehensive selection of stocks, an *objective, consistent, and succinct* assessment of the statistically-likely future behavior of the stock, and of the uncertainty associated with that assessment. Through AEI's forecasting service, the market analyst has access to an *unbiased* source of *processed market information*—not just more raw data or "motivated" recommendations. This information represents a useful input to any systematic approach to stock market analysis, whether "technical," "fundamental," or "index-oriented" in nature.

## MEASUREMENT OF UNCERTAINTY: THE CRITICAL FACTOR IN INTERPRETING FORECASTS

AEI's Optimal Stock Price Forecasts assist the market analyst or portfolio manager in two ways. First, AEI's service provides an indication of a statistically-determined "most-likely" future course of the stock price. Equally important, however, a 70% probability interval is determined for each forecast. These probability limits indicate, around each forecast value, a range within which the actual value is 70% likely to occur when it becomes available.

The forecast range of uncertainty is one of the most valuable pieces of information that an analyst can have. For example, knowing with 70% certainty that the price of a particular stock is going to increase 10%±5% in three months is reassuring information. On the other hand, if the uncertainty range is ±20% rather than ±5%, then the forecast 10% increase is not nearly so interesting.

Of course, the random character of stock prices is such that even with sophisticated models such as those employed by AEI, there is still considerable uncertainty associated with the individual stock forecasts. (Naturally, if AEI's models could predict individual stock prices with certainty, they would never see the light of day, for obvious reasons.) In lieu of forecast certainty, the important thing is to have a correct assesment of the magnitude of the forecast uncertainty, and AEI's probability limits provide this very information. Without consideration of price movement uncertainty, prudent buy-sell-hold recommendations are not possible.

An AEI forecast provides a complete 30-month picture of the predicted course and uncertainty of the monthly average price of a stock. By observing the nature of the forecast over several months' time, an analyst readily sees whether a next-month-up forecast is part of a general predicted price increase, or simply a temporary jump. Continued use of AEI forecasts provides an unbiased, consistent framework within which to assess market behavior. The availability of AEI forecasts for a representative selection of stocks enables comprehensive and systematic comparisons between different stocks.

## FORECASTS CURRENTLY AVAILABLE FOR 25 STOCKS

AEI's Optimal Stock Price Forecasts are published each month for a complete set of 25 common stocks. A list of the stocks for which forecasts are currently available is included later in this brochure. The forecasts are available approximately midmonth following the month from which forecasts are made. In addition to the 25-stock forecasts AEI can arrange to provide forecasts for additional stocks or other quantities of interest, in response to specific requests. We're convinced that AEI's forecast service is the best analytical forecasting service available. Try us . . . we think you'll agree.

# TECHNICAL DESCRIPTION OF AEI'S FORECASTING MODELS

The following paragraphs indicate the technical nature of AEI's forecasting models. The discussion is intended to assist the technical specialist in relating AEI's models to other forecasting techniques that he may have used.

## TECHNICAL COMPETENCE: PREREQUISITE TO SUCCESSFUL ANALYSIS

To date, much of the "research" provided to the financial community has been primitive. Even in the field of economics, the application of sophisticated statistical techniques did not become widespread until the sixties. There is, of course, the everpresent danger of misapplying, or misinterpreting the results of advanced techniques. A well-known example from the past was the unwitting introduction by some economic analysts of fictitious cycles into time series data by the very filtering procedures they used to smooth the data. AEI's Optimal Stock Price Forecasts provide the latest analytical developments, *properly applied,* to the financial community.

## THE BOX-JENKINS MODELS: FLEXIBLE AND POWERFUL MODELS FOR FORECASTING

The econometric model used to represent stock price movement is a multivariable Box-Jenkins time series model. This model is generally regarded as one of the most flexible and powerful mathematical forecasting models available. It is variously called a "distributed lag–correlated disturbance" or "transfer function–correlated noise" model and is a generalization of the standard "linear regression model" used extensively by econometricians in the past. Its very general form allows for adequate representation of a vast range of time series occurring in practice. The Box-Jenkins model is adaptive with respect to all apparent "trend," "seasonal," or other significant price movement characteristics observed in past price data. By allowing for explicit inclusion of previous prices, additional variables, and previous forecast errors, the model combines the best features of both the "technical" and "fundamental" concepts.

The mathematical representation of the multivariable Box-Jenkins model is

$$z_t = \sum_i \delta_i^{-1}(B)\omega_i(B)x_{it-b_i} + \phi^{-1}(B)(\theta_0 + \theta(B)a_t) \qquad (1)$$

where

| | | |
|---|---|---|
| $z_t$ | = | logarithm of average stock price in month t ("average price" is defined as the average of the high and low for the month); |
| $x_{it}$ | = | additional model variables; |
| $a_t$ | = | random ("white noise") residual error term; |
| B | = | backward shift operator; |
| $\delta_i(B)$, $\omega_i(B)$, $\phi(B)$, $\theta(B)$ | = | linear operators (filters, or transfer functions) in B. |

The operators contain the parameters that must be estimated from past data to specify the model (different for different stocks). For example, $\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q$, where the coefficients $\theta_1$ must be estimated. In the above model the a's are uncorrelated with the x's. The noise term $\phi^{-1}(B)(\theta_0 + \theta(B)a_t)$ of the model is called a "mixed autoregressive–moving average" stochastic process.

## ADDITIONAL VARIABLES ALLOW ESCAPE FROM RANDOM WALK REPRESENTATION

It is well-known that the short-term price movement of a stock, given only several previous prices, is essentially a "random walk." For a random walk model, the best forecast of the future price is the current price. AEI has determined additional model variables (the x's) such that, given these additional variables, the price and uncertainty of certain stocks can be predicted more accurately than with a random walk model. What these additional variables are, of course, must remain undisclosed. AEI can reveal the type of model used to produce its forecasts, but not the definition of the additional model variables without compromising proprietary interest. A desired goal in incorporating additional variables into the model is, of course, to find additional variables that are "leading" rather than "coincident" indicators of stock price movements.

## MULTIPLE VARIABLE MODEL PERMITS FORECASTS UNDER ALTERNATIVE ASSUMPTIONS

One advantage of an econometric or "dynamic" model over a purely stochastic one is that the analyst can use the model to answer various "what-if" questions, by specifying alternative values for the additional variables of the model. Such use of econometric models requires careful interpretation, however, since the models are typically developed from data obtained from economic systems that the modeler passively observes rather than actively controls. The specified alternatives examined with the model *must* represent variations in the economic system *operating as it was* when the forecasting model was developed.

Normally, AEI's forecasts are derived using a single "best estimate" for each model variable or parameter. From time to time, however, AEI intends to issue multiple forecasts corresponding to alternative assumptions or model specifications.

## AEI'S MODELS DESCRIBE SHORT-TERM AND LONG-TERM PRICE CHARACTERISTICS

Another reason for including the additional model variables is that the basic single-variable Box-Jenkins model is essentially a *short-term* forecasting model. Except for highly seasonal time series, it is unusual to find a single-variable Box-Jenkins model that describes the short-term behavior of a time series well, and at the same time implies the correct intermediate or long-term forecast uncertainty. Recent prices alone simply do not contain sufficient information about the long-term nature of the price time series. By including the additional model variables, AEI's models are able to adequately represent *both* the short-term behavior *and* the long-term uncertainty of stock prices. Because of the stock market's short-term "efficiency" (rapid adjustment to relevant information), it is variables that relate to the intermediate and long-term, rather than the short-term, that are of practical importance.

## UTILITY OF AEI'S FORECASTS ENHANCED BY AVOIDING RESTRICTIVE ASSUMPTIONS

The high descriptive accuracy possible with a many-variable model is deceptive. Paradoxically, increasing the number of variables in an econometric model may actually *lessen* rather than improve its forecasting utility, because of the large number of attendant assumptions that must hold in order for the forecasts to be valid. With many assumptions, a seemingly objective (and certainly complicated) model may do little more than mirror subjective judgment, thereby subverting its original purpose. To enhance the "robustness" of its forecasts, AEI keeps the number of additional model variables—with their attendant assumptions—as small as is practical.

## ITERATIVE PROCEDURES USED TO ESTIMATE PARAMETERS AND TEST MODEL

To determine the model (1) for a particular stock, past data are used to estimate the model parameters for that stock. This estimation process is complex, since the model is not a "linear statistical model," and iterative estimation procedures must be employed.

Once a tentative model is estimated, it is subjected to a number of tests of its adequacy to represent stock price movements. These diagnostic tests are essentially tests of the "whiteness" of the model residuals (a's). The a's are the one-ahead model forecast errors; in a correct model they are uncorrelated. The importance of testing the adequacy of a tentative model cannot be overemphasized. It is of crucial importance to the development of a good forecasting procedure.

Tests used by AEI include t tests and Hotelling's $T^2$ test of the significance of model parameters, t and chi-squared tests of the significance of the residual's autocorrelation function and individual autocorrelations, and a Kolmogorov-Smirnov test of the significance of the spectral distribution of the residuals.

If any of the tests indicate model inadequacies, the tentative model is modified, and the process repeated until an adequate model is found. The crosscorrelation and autocorrelation functions are the principal guides to tentative model specification and subsequent model modification.

## OPTIMAL FORECASTS AND PROBABILITY LIMITS COMPUTED FROM MODEL

After an adequate model of the form (1) is determined, it is then used to compute optimal forecasts of future prices. The criterion of optimality used by AEI is the standard least-squares criterion. (In mathematical terminology, the forecasts are "minimum-variance linear unbiased estimates" of the log-prices (the z's). Although the procedure used to compute the *forecasts* from the model is relatively straightforward, the presence of the additional model variables (x's) causes computation of the *probability limits* to be somewhat complicated.

# KEY CONSIDERATIONS IN SELECTING A FORECASTING SERVICE

### COST AND QUALITY COMPARISONS DETERMINE THE SELECTION OF A FORECASTING SERVICE

The decision to subscribe to AEI's forecasting service depends, among other things, on a comparison of the cost and quality of AEI's forecasts to the cost and quality of whatever alternatives are available. With regard to cost, there is a definite advantage in subscribing to AEI's service. Considerable expense is involved in developing or leasing the computer programs required to perform the statistical analysis of general Box-Jenkins models; substantial additional expense is required to acquire and support the technical talent required to develop forecasting models using the programs. By specializing in forecasting on a large scale, AEI is able to reduce the marginal cost of each forecast to a reasonable amount.

It would be fortunate indeed if inadequate skill in mathematical forecasting simply resulted in forecasts whose accuracy was not as high as possible, but whose accuracy was nevertheless correctly assessed. The forecast user might regret the lack of creativity of the forecast developer, but at least he would know where he stood with regard to accuracy. Unfortunately, improper application of statistical procedures can result in a much more insidious kind of error, in which the forecast accuracy may be *unknowingly overstated* by a substantial amount. In this case the forecast user has a false impression of the accuracy of the forecasts.

The paragraphs that follow illustrate the importance of technical competence to mathematical forecasting, through several examples that indicate the nature and consequences of some common misapplications of statistical procedures. The examples illustrate analysis errors in all three areas of mathematical forecasting: model selection, model development, and model application.

*Errors in Model Selection.* Sometimes, poor results are simply the result of choosing an inappropriate model, such as a Fourier series (sine-cosine) model to represent cyclical time series exhibiting stochastic rather than deterministic periodicities. (For example, a major computer hardware/software firm utilizes a 12-term sine-cosine model as the basis for its popular seasonal demand forecasting package. Whole books have been written describing the use of various "curve-fitting" and "smoothing" procedures to "forecast" time series.) The best defense against inappropriate model selection is a good insight into the fundamental nature of the price movement phenomenon, and a thorough knowledge of the characteristics of the various mathematical models available.

*Errors in Model Development.* Development of an adequate forecasting model requires considerably more than the perfunctory application of various statistical formulas. In some instances, there is no satisfactory after-the-fact verification of a key model assumption. For example, in the model (1), a critical assumption is that the additional variables (x's) are uncorrelated with the error terms (a's). Unfortunately, however, the validity of this assumption cannot be determined from the data. If the assumption is violated, a totally incorrect model can result, even though the usual statistical estimation and testing formulas have been computed correctly. How this problem is addressed, then, assumes a central role in determining whether a developed model is correct.

Frequently, misapplication of otherwise-valid statistical techniques such as regression models, trends, moving averages, expotential smoothing, and Fourier series representations have stemmed from uncritical "fitting" of these models to data, without subsequently subjecting the fitted model to appropriate tests. The problem is of course one of *forecasting, not fitting,* the price time series. To forecast, a model that *adequately represents the fundamental statistical nature* of the price time series is needed, rather than one that simply "fits" past price data well.

Even the determination of a model that represents the statistical properties of the price time series well is not sufficient, however, to assure accurate forecasting. For example, a regression model that adequately represents price as a very accurate function of other variables is of little forecasting utility, if the other variables are as difficult to forecast as price itself. In other words a good fit, even in a properly developed econometric model, is by itself *no indication* of the forecasting ability of the model.

*Errors in Model Application.* Occasionally, properly developed models are outrageously misused, such as by ignoring the error variability associated with the *forecast* values of the additional variables of the model. A more subtle example of an improper model application is the development of a model from a passively observed system under one set of conditions, and then attempting to use the model to predict the behavior of the system under a different set of conditions. Not surprisingly, the results have not only been disappointing, they have often been totally incorrect. This situation, probably more than any other single factor, accounts for the poor forecasting results that can result from econometric models, even though they may describe historical relationships quite well. This example illustrates a common tradeoff involved in the development of forecasting models: the more accurately the model describes the historical behavior of a variable, the greater may be the number of assumptions upon which its forecasting performance depends.

The main point to the preceding examples is that the application of sophisticated procedures is of little value without a critical evaluation of the (often implicit) assumptions underlying the model: *every model is "adequate" only with respect to particular applications.* Many failures of high-powered theoretical analytical techniques to provide anticipated results of practical value (in all applications areas—not just the stock market) can be traced to failures to demonstrate assumption validity and model adequacy. No model is used by AEI to generate forecasts and probability limits unless its adequacy to represent stock prices is fully demonstrated.

## ASSESSING TECHNICAL COMPETENCE IS A SERIOUS PROBLEM

Unfortunately, the improper application of statistical procedures by unqualified personnel is increasing, owing to the growing availability of statistical computer programs and short courses on the use of statistical tools. Moreover, the user of statistical services has little defense against technical incompetence. The statistical profession does not screen its practitioners—today, *anyone,* textbook and computer program in hand, can call himself a statistician. This "misrepresentation" by itself would be of little consequence, were it not for the extensive misuse of statistical procedures. This situation, of course, hurts the statistical profession as much as its clients.

## AEI FORECASTING MODELS DEVELOPED BY DR. J. G. CALDWELL

AEI's optimal stock price forecasting models were developed by Dr. J.G. Caldwell. Dr. Caldwell has a breadth of practical experience in statistics, econometrics, and operations research. He has provided analytical services to business and government, with particular emphasis in industrial operations research, statistical design and analysis, government sample survey applications, and military systems analysis. He has developed general purpose Box-Jenkins forecasting programs, which have seen numerous applications in industrial, commercial, financial, and defense applications. Dr. Caldwell earned his Ph.D. degree in Statistics from the University of North Carolina, and his B.S. degree in Mathematics from Carnegie-Mellon University.

# FORECASTS CURRENTLY AVAILABLE FROM AEI

The following list indicates the stocks for which AEI Optimal Stock Price Forecasts are currently available. AEI will make availab forecasts of additional stocks or other quantities of interest, in response to specific requests. Please write for quotations; or call 70 360-7165)

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- o Wells Fargo
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- o Tenneco
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- o Crown Zellerbach
- o AT&T
- o IT&T
- o RCA
- o Kraftco
- o PPG Industries
- o Martin Marietta
- o Southern Pacific

## INTRODUCTORY PRICES

A complete set of 25 Optimal Stock Price Forecasts is issued each month. The set is available at the Half-Price Introductory One-Month Subscription Rate of $50.00, or at the Half-Price Introductory Six-Month Subscription Rate of $150.00. Forecasts of individual stocks of the set are available at the Half-Price Introductory One-Month Rate of $5.00 per stock, or at the Half-Price Introductory Six-Month Subscription Rate of $15.00 per stock. Simply fill in the Order Form to begin your subscription immediately. If you wish, send no money now and we will bill you later.

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| Stock | Subscription Term | |
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| Complete Set (25 Stocks) | ☐ 1 mo. ($50) | ☐ 6 mos. ($150) |
| 1. ____________ | ☐ 1 mo. ($5) | ☐ 6 mos. ($15) |
| 2. ____________ | ☐ 1 mo. ($5) | ☐ 6 mos. ($15) |
| 3. ____________ | ☐ 1 mo. ($5) | ☐ 6 mos. ($15) |
| 4. ____________ | ☐ 1 mo. ($5) | ☐ 6 mos. ($15) |
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## OPTIMAL STOCK PRICE FORECASTS AND PROBABILITY LIMITS