SIMSTOCK: computer simulation of securities markets

James E. Abbott

The University of Montana

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SIMSTOCK: COMPUTER SIMULATION
OF SECURITIES MARKETS

By

James E. Abbott

B.A., Lake Forrest College, 1963

Presented in partial fulfillment of the requirements
for the degree of

Master of Business Administration

UNIVERSITY OF MONTANA

1971

Approved by:

[Signature]
Chairman, Board of Examiners

[Signature]
Dean, Graduate School

Date: June 7, 1971
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CHAPTER I

THE PURPOSE OF SIMSTOCK

This project was designed to test the feasibility of developing a computer model to simulate a cross-section of a stock market. The ultimate goal is a model sophisticated enough to provide sufficient realism for use as a supplement in investment education. Necessary ingredients of such a model would include offering the participants a cross-section of the diverse options available to real investors and generating the type of information necessary to formulate rational investment decisions. Decision-making information would consist of at least some general econometric news and certain aggregate statistics of the stock and bond markets.

The purpose of this project, then, is to outline the basic design of such a model, to specify significant features of it, and to propose some stochastic simulation mechanisms which could generate meaningful stock market and economic data to describe a hypothetical but realistic environment.

Investment Education

This research originated during an investment seminar conducted in 1968 at the University of Montana's Malmstrom Program. A typical learning method employed in investment
courses is to require each student to invest a hypothetical amount of money in securities at the beginning of the course. Each student "manages" his portfolio for the duration of the course, and reports at the conclusion on his portfolio's performance against whatever goals were chosen at the onset.

Theoretically, this method will get students "involved in the market": they will visit brokers, scan current investment news, and familiarize themselves with investment decision criteria. In practice, however, the method seems largely ineffective in developing any well-rounded knowledge of investment alternatives or strategies. Its primary weakness is the short amount of time involved which directly limits the scope of the student: invariably, he will tend to concentrate on a "long" position in some common stock or stocks which appear to offer short-term stability or growth.

Also, during short periods of time, securities markets will not normally demonstrate any large movements of prices. Some dramatic exceptions are always a possibility, but even in periods of rapid change, movements will be all positive or all negative. A sound investment education should include exposure to enough situations so that omni-directional movements can be experienced by the student.

The goals of the educational method just discussed are correct, but the method is inadequate to meet those goals. Questions may be raised concerning the necessity for "exposure" or "experience" in investment education: a wealth
of historical data and price theory is available to the stock market student, and it might appear that these alone are sufficient for educational goals to be met. However, a quick look at the rapidly expanding field of business gaming would reveal that education is increasingly making use of simulation when decision-making under uncertainty is studied. The growth in computer simulation applications is easy to comprehend: experience can aid the decision-maker operating under uncertainty, but actual experience may be both time-consuming and expensive (the latter especially, in the stock market). Simulation models have been developed in recent years to fulfill needs of this type.

Computer Simulation as an Educational Supplement

Interest in computer simulation techniques led to consideration of employing a "realistic" dynamic model as a supplemental device in investment education. Realism, in the context of simulation, is a qualitative characteristic implying a close relationship between the model and the system it represents. This relationship may be highly superficial, but the reaction of a "realistic" model to certain stimuli should approximate the response typical of the real world under similar circumstances. A model is an imperfect learning tool due to the errors in its approximations and the loss of reality arising from oversimplification. Models
of complex systems can only be constructed by allowing some generalizations. Therefore, the model-builder is confronted by a series of choices when constructing a model.

If a somewhat realistic model could be developed, a powerful—albeit imperfect—learning tool would be available to supplement actual experience and to expand the student's understanding of the real world (the stock market). The computer's ability to "compress" time would allow numerous "pictures of the market which would only occur over a period of several months or years in the real world. A basic tenet of this project is that involvement during the educational period is indispensable to anyone who would desire a meaningful knowledge of investing. The psychological and emotional problems of dealing with the vagaries and complexities of the marketplace can only be understood and (hopefully) surmounted by experience.

Design of the Project

One reason simulation models are developed is to promote learning. Initially, computer simulation models were developed by and for practiced and experienced professionals for advanced special studies in their respective fields. Computer models were not used extensively for purposes of formal education. The rapid growth of computer installations in colleges and the increasingly earlier introduction of students to these facilities are tending to erase this
developmental "lag", but much more research and application work is required to fully utilize the excellent potential of the computer in formal education. This project is oriented toward helping to fulfill this objective.

Computer program segments shown in this paper have been written in a version of the FORTRAN II language known as AFIT KINGSTRAN. This language version was adopted from the University of Toronto's KINGSTON FORTRAN II, and is a two-pass system designed for the IBM 1620 computer. Translation to any other FORTRAN language version would be relatively simple.

Modular construction was deemed most appropriate for facilitating adaptation to a wide array of computer systems with varying storage capabilities. Therefore, extensive use was made of subroutines and common storage of data. Structure criteria was imposed by the system available to the researcher, an IBM 1620 Model I of 40,000-bit core storage and card input/output.

**Organization of the Project**

Various stock market theories and concepts are examined, and the empirical evidence concerning these theories is

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1Faculty of Applied Science and Engineering, University of Toronto, KINGSTON FORTRAN II: Language Specifications, ed. by P.I.P. Boulton; and Mathematics Department, Air Force Institute of Technology, Operations Manual: AFIT KINGSTRAN.
reviewed. Basic to any model are its underlying postulates, reflections of the model-builder's conclusions or hypotheses about the real world. Theories of the market and an empirical appraisal of these theories are presented in Chapter II.

A stock pricing mechanism and its underlying rationale are developed in Chapter III. Functional relationships within the SIMSTOCK model and significant indicators and operating features are also outlined in this chapter.

A structure is suggested for the model in Chapter IV which will fulfill the requirements previously discussed. The structure consists of three passes, or independent programs. This chapter also explains the simulation mechanisms which form the SIMSTOCK economy and market environment, or "Pass Two", which is operational. Completion of this particular segment of the model fulfills the objective of this project; however, work will be continued to develop SIMSTOCK into the type of model described earlier. Some additional work has already been accomplished toward this goal, and is partially presented herein.

Results of the study, some conclusions, and additional research requirements are reviewed in Chapter V.

The complete FORTRAN source program for Pass Two, a glossary of variable names, some notes on the random generator employed, and a sample test result are included in Appendices.
CHAPTER II

THEORIES AND EMPIRICAL APPRAISALS
OF STOCK MARKET PRICE MOVEMENTS

"To put its market advice on a truly scientific footing, a brokerage house acquired a huge computer and pumped in all the market tops and bottoms, prices, volume, the latest data on sunspots, lammings [sic], and the moon. As tape spun through the machine, the partners gathered around watching the lights blink. After much buzzing, the typewriter clickety-clacked its answer: Buy low—sell high. (A popular "Street" joke.)" ¹

Theories about price movements are almost as numerous as the number of issues traded on the exchanges, but most fit into one of four broad, slightly overlapping categories—fundamental, technical, psychological, and scientific. Before discussing each of these groups, some definitions are necessary to avoid semantic ambiguities. For instance, many Wall Street professionals claim that the first truly "scientific" study of the market began with Charles Dow and his celebrated theory. Dow, however, marked the beginnings of what is referred to in this paper as the technical approach. Likewise, professional traders refer to

¹Quoted in William Gordon, The Stock Market Indicators, p. 143.
the scientific approach (somewhat disparagingly) as the "academic" or "academician's view" of the market. Needless to say, this group of theories is not given much respect on Wall Street. Reference to this group as a "cult of ignorance" is a milder sample of the responses it invokes from many members of the investment community.

One must comprehend the basic differences of this latter approach to fully understand its unacceptability to the investment community. Dow started the technical movement before the turn of the century, and fundamental analysis predated even Dow. Anyone observing the vicissitudes and inconsistencies of price movements over time can quickly recognize a prevalent catalytic "psychology" at work in the marketplace. Thus the first three categories of theories—fundamental, technical, and psychological—have some history or some visible underlying logic. A common thread of interdependency links these three groups despite the conflicts between their adherents. The scientific approach is radically different: it starts with the premise that price series are composed of independent elements. In other words, prices have no memory.\(^1\) Today's price is independent of yesterday's, and tomorrow's price is independent of the price today. This concept is called the random walk theory: a price series will exhibit the properties of a stochastic

\(^1\)Adam Smith, (pseud.), *The Money Game*, p. 148.
variable, wherein each element is independent of previous elements. No matter what else is said, this serial independence of price changes is the crux of disagreement between proponents of a random walk theory and all other groups of theory. All others are based, to some extent, on price dependency.

One must also remember that the investment community derives a substantial portion of its income from advising and forecasting. If the idea circulates that a handful of darts thrown at a list of stocks can advise just as well, then this community will naturally feel threatened—especially when the cost of darts is compared to advisory service fees.

Random walk theory really does not ascribe to darts, though, but so much animosity exists that distortions are rampant. The random walk theorists equate technical analysis with astrology and necromancy, while analysts lampoon random walk theory as the "know-nothing approach of selection." These four categories of theories are briefly explained in this chapter. Some of the empirical evidence is presented, and the chapter is concluded by a discussion

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2Krow, Stock Market Behavior, p. 16.
of factors suggesting rapprochement between the investment community and the newer theory of random price movements.

**Fundamental Analysis**

"Don't gamble! Take all your savings and buy some good stock and hold it till it goes up, then sell it. If it don't go up, don't buy it. . . .Will Rogers, October 31, 1929."¹

**The search for value**

Fundamental analysis has determination of "value" as its goal. In the nineteenth century, a firm's assets were thought to be a good indication of value: whatever the company owned, the stockholder owned, in proportion to his shares.² But bankruptcies proved that corporate assets lost considerable value in liquidation, while disparities between similar corporations' earnings-to-assets ratios were also difficult to ignore. The amount of corporate debt also proved to be misleading in later years when borrowing became a respectable activity. Companies began requiring a higher percentage of external funds, and borrowing had the appeal of increasing leverage, maintaining stockholder control, and gaining more favorable tax treatment. The rise in corporate debt was accelerated in the late 1960's because convertible

¹The Autobiography of Will Rogers, ed. by Donald Day, quoted in Gordon, Indicators, p. 43.

²Ralph Bellemore, Investments, p. 105.
bonds were used to acquire stock during mergers and acquisitions.\(^1\) Therefore, one company could be carrying much more debt than another, and yet be profiting handsomely.

Fundamentalists then left the balance sheet in favor of the income statement. Therein lay the key to value: what the company could earn! Since "...an investment is the purchase of future economic performance,"\(^2\) the capitalization of earnings was justified and practiced. The primary question, "What does it pay?" was answered by calculating the present value of expected future dividends. "The tenet is that a common stock is worth the present value of all future dividends."\(^3\) John Burr Williams described the theory in 1938 (The Theory of Investment Value), but Nicholas Molodovsky refined the application of the theory in several important ways. Molodovsky's most important contributions were substituting earnings-per-share for dividends and recognizing and formulating stages of earnings-growth related to the company's development.\(^4\)

Business cycles and stock prices

The wavelike movements characteristic of macroeconomic activity have been under intensive study for

\(^1\)Karen Kidder, Wall Street Before the Fall, p. 5.
\(^3\)Cohen and Zinbarg, Investment Analysis, p. 222.
several decades. Research has identified enough uniformity
in these movements—despite varying characteristics—to
describe the phenomena of "business cycles"; and the National
Bureau of Economic Research, the Bureau of the Census, and
other organizations have developed a number of economic
series. These series are grouped as leading, lagging, or
coincident indicators of economic activity. One of the
leading indicators is invariably some aggregate measure of
stock market prices, because most of these studies have
indicated that stock prices anticipate economic activity
by approximately four or five months.

Three explanations of this leading relationship
have been advanced: (1) investors have good foresight and
act on the basis of their foresight; (2) investors act on
current developments, but these developments are precursors
of general economic activities; or (3) market movements
cause economic activity, post hoc ergo propter hoc (after,
therefore because of). The last explanation, (3), has
been generally discredited, but (1) and (2) are both still
widely accepted.

1 Badger, Guide to Analysis, p. 166.
2 Brealey, Risk and Return from Common Stocks, p. 32.
3 Cohen and Zinbarg, Investment Analysis, p. 37.
4 Ibid., p. 461; and Greiner and Whitcomb, Dow
Theory, p. 76.
Six extended downtrends of stock prices have occurred in the last two decades—1953, 1956-57, 1959-1960, 1962, 1966 and 1969-70. Most of these downward spirals preceded slumps in business activity, and ended before the recovery phase of the economy began. However, no corresponding drop in business activity followed the 1962 market drop, although that decline averaged twenty-three percent.\(^1\) A similar erosion of stock prices, also around twenty-three percent, occurred in 1946 without an accompanying business slump.\(^2\) The other downtrends referred to above, although accompanied by business slumps, were not proportional in magnitude to the business downturns.

These disparities have confounded fundamental analysts. Many serious investigators have hypothesized that stocks do predict business activity, but only as accurately as investors can foresee the future. Thus stock price changes have a dual causation: "A real cause is a change in actual economic conditions. A psychological cause is a change in men's attitude of mind toward actual economic conditions."\(^3\)

Recent analysis has uncovered some startling new insight to this whole relationship hypothesis. Work conducted by the Econometrics Research Program of Princeton

\(^1\)Cohen and Zinberg, *Investment Analysis*, p. 459.
\(^2\)Gordon, *Indicators*, p. 5.
\(^3\)Greiner and Whitcomb, *Dow Theory*, p. 70.
University in the early 1960's has indicated a much weaker correlation between stock prices and various business cycle components. These studies have raised questions, but have not yet resulted in any disproof of the contention that stock prices as a whole precede macro-economic activity.

"Standard method" of valuation

The 1962 edition of Graham, Dodd, and Cottle's classic text, Security Analysis, defines the "standard method of valuation" as "capitalizing the expected future earnings and/or dividends at an appropriate rate of return." William Kurtz elaborated on the capitalization-of-earnings approach. He reasoned that a stock would still have value even if earnings were sometimes zero or negative, and that prices reflect some "residual" value plus some "multiple" of earnings. Refinements of his theory have been the determination of residual value as the last bear market low or as a capitalization rate applied to normal earnings. A growth factor and a quality factor are then thrown into the equation for good measure.


3Rolo, Wall Street, p. 148.
Other factors

The fundamentalist does not determine value in a vacuum; he is a relativist. He assesses the state of the market, the industry, the economy, and the political scene. He employs business indicators, market statistics, experience, and intuition. He attempts to quantify his analysis whenever possible by including present value calculations concerning dividends and earnings, and by reviewing price-earnings ratios and earnings-growth rates between both individual companies and their corresponding industries.¹

The fundamental approach is considered more conservative than any other, and most investment literature is written from this viewpoint.² Despite its widespread acceptance, fundamental analysis nevertheless receives its share of criticism. Most of this criticism arises over the several "judgement" factors fundamental analysis requires. The analyst must judge the quality and depth of management, the probability that past information is a reliable indicator of future performance, and the exogenous factors of government and politics. Even past information offers no certainty of accurate portrayal due to variations in accounting methods.

²Krow, Stock Market Behavior, p. 4.
A Forbes magazine article once presented an actual company's income statement—disguised as the "Golden Fleece Manufacturing Company"—under both conservative and liberal accounting policy, and computed respective earnings-per-share figures of $1.99 and $3.14 for the same year.¹

Those of technical theory persuasions accuse the fundamentalists of disregarding the laws of supply and demand. Technical theorists agree that those factors studied by fundamentalists certainly do have an effect on prices, but that changes in prices are caused by a much broader set of variables. These complex causative factors do not yield to analysis, but since their effects can be seen in price and trading statistics, then these resulting statistics can be analyzed. They also contend that shares may sometimes be overpriced relative to any "value" calculation, but may still continue to appreciate and yield a gain due to strong demand or weak supply. A final, and most important, criticism is timing. A fundamental approach identifies over and under-valued situations and assumes a subsequent price adjustment, but the timing of the adjustment is ignored because the fundamentalist really has no tools for this work. Timing, however, is most important in the stock market, and it is one of the cornerstones upon which technical theories have been erected.

Technical Analysis

"October. This is one of the peculiarly dangerous months to speculate in stocks. Others are November, December, January, February, March, April, May, June, July, August, and September. ...Mark Twain." 1

Dow Theory

Charles Dow founded his theory on the premise that "It is always safe to assume that values determine prices in the long run." 2 Instead of attempting to discern value directly as the fundamentalist does, Dow sought to analyze the market by the use of stock averages which would reflect the general trend of stock prices. He concluded that these averages would "discount the future" because they would reflect the consensus of market opinion about value.

Dow Jones and Company began publishing a daily average consisting of twelve stocks in May, 1896. The number of stocks was increased to twenty in 1916, and to thirty in 1928. 3 Although this number has remained at thirty, many substitutions have been made over the years to keep stocks in the list that represent actively traded shares of leading companies. 4 Adjustments for stock splits and replacements

1Quoted in Gordon, Indicators, p. 25.
3Educational Service Bureau, The Dow Jones Average.
4Frederick Amling, Investments, p. 448.

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are made by changing the divisor. This average has become known as the Dow Jones Industrial Average. The Dow Jones Railroad Average, started in October of 1896, initially consisted of twenty railroad stocks. On January 2, 1970, it was modified to include other forms of transportation, and renamed the Dow Jones Transportation Average.\(^1\)

The Dow Theory attributes all fluctuations of the averages to three continuous and often concurrent movements—the primary trend, the secondary reaction, and daily fluctuation.\(^2\) The primary trend is the broad pervasive movement referred to as a bull or bear market. Secondary reactions are the shorter reversals against the primary trend, and they last from three weeks to three months. Daily fluctuations are considered unimportant and misleading.\(^3\)

Bullish trends are recognized when the averages succeed in establishing new highs and do not decline below previous lows. Bearish trends are noted conversely. Both the Industrial and Transportation Averages must confirm a trend to avoid the false signals which one average alone might generate.

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\(^1\)"Dow Jones Averages," Educational Service Bureau.
\(^2\)Greiner and Whitcomb, Dow Theory, p. 51.
Volume is used to supplement Dow Theory. Basically, bull markets end in excessive volume, and bear markets end in lower volume.

Dow Theory is a general method for determining the investment climate, or state of the market. It assumes that most individual stocks will follow the trend of the averages. Selection of individual issues is the concern of other technical methods. Several of these methods are a direct result of Dow's major premises applied to a single issue.

Common stock rates of return

In 1958, the Center for Research in Security Prices was established at the University of Chicago's Graduate School of Business under fund grants from the firm of Merrill, Lynch, Pierce, Fenner and Smith, Incorporated, and the National Science Foundation. The purpose of the Center was to conduct exhaustive research on refined measurements of performance of stocks listed on the New York Stock Exchange. Preliminary results of initial work was presented in the Journal of Business issue of January, 1964, and more comprehensive results were reported in the same publication in July, 1968.¹ These results are summarized below to familiarize the reader with them. They are subsequently used as a yardstick for measuring Dow Theory results.

¹Extracted from a brochure entitled "Rates of Return on Investments in Common Stocks (1926-1965)," printed and distributed by Merrill, Lynch, Pierce, Fenner & Smith, Inc.
The Center's file of price and dividend data is considered 99.44 percent accurate, and it goes back to January, 1926, thus including the 1929-1932 stock market crash. The most significant investigation sponsored by the Center so far has been Professor Lawrence Fisher's study of random investments on the NYSE. Professor Fisher computed the results for every possible combination of month-end purchase and sale dates for every stock listed on the Exchange throughout the thirty-five year period of 1926-1965. For each stock, this represented 87,900 monthly combinations, and a total of 56,557,538 transactions for the whole Exchange. The study determined these results for an issue chosen at random and purchased and sold at randomly-selected dates between 1926 and 1965:

(1) The investor would make a profit 78% of the time;

(2) The median return, assuming reinvestment of all dividends and payment of 1% commissions, was 9.8% per annum, compounded annually;

(3) Risk of losing as much as 20% a year was one in thirteen, while gains of 20% a year had a probability of one in five;

(4) If small groups of stocks had been randomly selected instead of just one, the risk of loss would have been reduced and the probability of a larger profit considerably improved.
Of 210 overlapping time periods on file, positive rates of return occurred in 199 periods—95 percent of the total.¹

Measuring Dow Theory performance

Foremost among the collection of assumptions called Dow Theory is the one concerning volume: "bull markets terminate in a period of excessive activity."² But a comprehensive study covering the period of 1921 to 1966, on a weekly basis, contradicts this assumption. "Not once in this forty-five-year period did the Dow Jones Industrial Average terminate a bull market in the "heaviest" volume of the cycle!"³ This study found that the week of climactic activity usually occurred about halfway through the cycle. The same study also reviewed the ninety-year period from 1877 to 1966, covering eighteen bull markets. The volume highs ranged from a lead time of zero months (January 1906 and November 1916) to twenty-four months (January 1951), with an average time of nine months. The tenet about lower volume marking bear market bottoms was more generally true, but the 1946, 1958, and 1962 bear markets were marked by a bottom of very high volume.⁴

¹Also extracted from the previous brochure.
⁴Ibid.
The same study determined that, by Dow Theory, an average market cycle was three years and seven months, composed of an average bullish trend lasting two years and two months and an average bearish trend of one year and five months. An annual rate of increase was calculated by totaling the percentage profit from buy to sell signal and dividing the total by the sum of the time periods. An annual rate of 18.1 percent, when invested, was the result.¹

Dow Theory adherents have always been quick to point out the amount of gain from buy signals to bull market peaks. These gains are of course overstated because the market must decline a certain amount before a sell signal is generated. Nevertheless, the 18.1 percent rate mentioned above overcame these objections by using sell signals instead of market tops. In addition to this impressive figure, the study included a computation for gains of holding short positions from sell to buy signals. These gains averaged ten percent. Both of these figures must be adjusted before they can be compared with a buy-and-hold strategy. The over-all per annum rate for the 69-year period studied was 14.39 percent. However, this figure is compounded periodically, and not annually; it has not been adjusted for dividend reinvestment; and no reductions were made for brokerage commissions. Compared to the 9.8 percent reported by the Fisher study,

¹Ibid., p. 22.
the figure still seems impressive. Comparability is still not possible, however, without additional adjustments.

Comparative Dow Theory results

A brief comparative study on Dow Theory results and Fisher's findings was conducted which yielded some unexpected results. All of the data used was drawn from the two references previously mentioned except as noted below in this section. Dow results were based on closing prices of days generating buy or sell signals, and were adjusted for commissions of one percent of transaction amounts. All results were translated by a computer program into annually compounded rates of return.

For the seventy-year period of 1897 to 1967, the Dow Theory generated a rate of return of 9.31 percent for both long and short positions, and a 7.69 percent return for only long positions. A comparison was also made for the 1925-1965 period covered by the Fisher study. The Dow rate of return was 8.36 percent for long and short positions versus the 9.8 percent reported by Fisher. The Dow return is net dividends, however, and it therefore far exceeds the 9.8 percent indicated for a random buy and hold strategy. But the problem which persists throughout this comparison is that the Average is always composed of leading, successful companies. The Average never includes a company which flounders; such an issue is eliminated and replaced with another healthy one.
In almost all cases, issues in the Average are industry leaders in terms of size, stock distribution and prestige. The unexpected results occurred when two subsets of the seventy-year period were considered. These results are shown below:

<table>
<thead>
<tr>
<th></th>
<th>DOW Long and Short</th>
<th>DOW Long Only</th>
<th>DOW Short Only</th>
<th>Fisher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1897-1929</td>
<td>13.31%</td>
<td>9.13%</td>
<td>3.75%</td>
<td>*</td>
</tr>
<tr>
<td>1932-1967</td>
<td>6.81%</td>
<td>7.25%</td>
<td>-0.38%</td>
<td>15.9%</td>
</tr>
</tbody>
</table>

*Not available

Again, all of the above data is expressed in annually-compounded rates of return, and Dow results do not include the reinvestment of dividends assumed in Fisher's work. The unexpected results were twofold: (1) the large proportion of pre-1929 Dow gain from short positions, and the negative gain from shorts since 1932; and (2) the low post-1932 rate of return of the Dow Theory compared to Fisher's results.

The gulf between the Dow and Fisher returns since 1932, 8.65 percent, cannot be accounted for by any rational assumption concerning dividends. Moreover, the return computed by Fisher is for any listed stock chosen at random.

---


Recent studies conducted at the Center for Research at Chicago indicate that rate of return dispersion decreases rapidly with some diversification, although diminishingly as diversification is continued:¹

<table>
<thead>
<tr>
<th>Number of Stocks in Portfolio</th>
<th>Reduction in Dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>40%</td>
</tr>
<tr>
<td>8</td>
<td>80%</td>
</tr>
<tr>
<td>16</td>
<td>90%</td>
</tr>
<tr>
<td>32</td>
<td>95%</td>
</tr>
<tr>
<td>128</td>
<td>99%</td>
</tr>
</tbody>
</table>

This brief comparison is not a rigorous disproof of Dow Theory, but it does point up an apparent decrease in its relative effectiveness over the last three and one-half decades. Perhaps this may be attributed to a changing market environment arising from different investor practices, better and faster communications, or a host of other factors. Nevertheless, the Dow Theory has not performed as advertised. A poor post-1933 record for the Theory has also been noted by other researchers.²


Confidence Index theory

Barron's Confidence Index, published weekly since 1932, is computed by dividing the yield on Barron's 10 High-grade Bonds by the Dow Jones 40 Bond Index. The latter index consists of supposedly lower-quality issues whose prices will go down faster than high-grade bonds as confidence wanes. Since bond yield is inversely related to price, relative price erosion of lower-grade bonds will increase their yields and subsequently decrease the level of the Index.

A basic tenet of Index adherents is that this indicator portrays the movement of "smart money": the bond market is dominated by professional money managers who have primary access to economic and business information and who are consequently superior to the average investor in evaluating future conditions. Most adherents claim the Index to be one of the few leading indicators of stock prices, and a few claim that it can predict the magnitude as well as the direction of future stock price movements.

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1 Badger, Guide to Analysis, p. 84.
2 Donald E. Vaughn, Survey of Investments, p. 385.
Confidence Index results

Joseph E. Granville, one of the staunchest supporters of the Confidence Index theory, has stated that changes in the Index forecast market movements two to four months in advance. Furthermore, he implies a direct correlation between the magnitudes of these movements.\(^1\) The history of this indicator from its inception in 1932 until 1966 bears no resemblance to his description of it. Major market tops have occurred from four months before to sixteen months after Index highs, while market bottoms have occurred from eight months before to five months after Index lows. Index changes of 6 points have corresponded to Dow Jones Industrials' changes of 105 percent, while changes of 8 points have corresponded to Dow movements of 19 percent.\(^2\)

The Index is constructed in such a manner that it should really not work at all. The group of high-grade bonds whose yields appear in the Index numerator are all rated AAA; but of the bonds composing the denominator—the so-called lower-grade liens—two are issues appearing in the numerator, fourteen are also rated AAA, and another eight are rated AA. All of the rest of the "low-grades" are still A-rated except for some railroad issues. Indeed,

\(^1\)Krow, Stock Market Behavior, p. 136.
critics feel that these rail issues are the source of Index fluctuations, but rather than indicating the movement of "smart money," these fluctuations may just be reflections of the rapidly changing situation in the railroads today.¹

Moving Average Theory

Identification of the trend of an individual stock can be accomplished by computing the direction of a moving average line. No general agreement exists on how many elements should comprise the moving average except that a larger number of elements provides fewer false signals and a lower profit expectancy.

More recently, "filters" have been used with fewer elements in a moving average to simultaneously reduce false signals and obtain a more responsive trend line. When a price movement penetrates some percentage filter, then a buy or sell signal is given. Again, the percentage is a matter of personal choice, but the filter size correspondingly reduces the responsiveness of the moving average line; larger filters decrease profit expectation while smaller filters increase risk.

Monthly moving averages

A study utilizing data-tapes from the University of Chicago's Center for Research tested monthly moving average

¹Krow, Stock Market Behavior, p. 140.
theory. The study employed a simulation model to compare trading based upon a two percent filter rule against a simple buy-and-hold policy. Only two of the forty runs made resulted in any superiority of the filter rule significant at the five percent level of significance, and none were significant at the one percent level. The buy and hold strategy was far superior than the moving average method, and produced a better return, especially in cases where adjustments were made for dividends. Even better results were obtained for buy-and-hold when short positions were allowed between moving average sell and buy signals. These additional gains were mostly attributable to the loss of dividends for the moving average policy when a long position was not held (and the payment of such dividends when a short position was maintained). ¹

Advance-decline theory

An advance-decline statistic is generated by starting with some arbitrary constant such as 10,000. Each day, the number of issues closing at a higher price are added to this constant while those declining in price are subtracted. An alternate approach is to divide the difference between advances and declines by the number of issues traded to

form a ratio. This ratio eliminates a dependency of the statistic on the number of issues listed on the exchange.

An overbought-oversold index is constructed by taking a ten-day moving average of advance-decline ratios. All of these advance-decline statistics are an attempt to supplement the lack of breadth in the Dow Jones Averages, to develop some measure of disparity between the averages and the general market, or to confirm or deny the validity of other market aggregates such as Standard and Poor's 425 Industrials.

Advances and declines

Standard and Poor's 425 Industrials was correlated to advance-decline line values on a daily and weekly basis. Coefficients of correlation were computed for time lags from -15 to +15 time periods; and for both sets of data, the highest coefficient was obtained for a lag time of zero (at coincidence). The study also determined that correlation coefficients of changes in the averages and the line appear to behave as a random variable as lag or lead time is varied. Additionally, peaks and troughs of the line were maximally correlated with the average at coincidence.²

¹Gordon, Indicators, p. 57.
Psychological Indicators

"I find more and more that it is well to be on the side of the minority, since it is always the more intelligent. ...Goethe" 1

Contrary opinion

Investor behavior is the subject measured by the so-called psychological indicators. Although these indicators are often construed as technical indicators, they are mostly the result of "contrary opinion" theory which assumes that "all information is imperfect and all human judgement is fallible." 2 Although some of the indicators in this group seem to imply that the general public is almost always wrong, the basic theory is not quite so oversimplified. Instead, the theory recognizes that intelligent decision-making by individuals deteriorates when the individuals become a crowd. Therefore, the "contrarian" is reluctant to indulge in the speculative sprees of bull markets or the "panic" selling of bear markets. He attempts to develop a skeptical attitude toward popular sentiments. His favorite indicators tend to erase some of these distinctions, however, and oversimplify his position.

1Quoted in Gordon, Indicators, p. 61.
Odd-lot statistics

Odd-lot transactions (those involving less than one hundred shares) are considered to be the domain of the small investor, and therefore represent the opinions of the general public. Contrary to widely-held beliefs, historical data reveals that the odd-lot investor is usually right. His tendency is to be wrong only on reversals of trend. However, because of this characteristic of missing trend reversals, it is difficult to imagine any meaningful use of odd-lot statistics except as a lagging indicator of trend change. Additional discredit of odd-lot statistics arises from the decreasing odd-lot participation in the market. In recent years, odd-lot participation has accounted for a decreasing percentage of the activity on the New York Stock Exchange. The percentage odd-lot volume of total volume set an historic low for the Exchange of 10.46 in 1967, yet it dropped again in 1968 to 9.12. The percentage value of odd-lot to total transactions is decreasing at an even faster pace, from 12.36 in 1967 to 10.69 in 1968. Rising affluence in our society may mean that many so-called small investors are now showing up in round-lot statistics. Mutual funds, or other investment media, are undoubtedly absorbing some of the former odd-lot

1Cohen and Zinbarg, Investment Analysis, p. 512.
population. These structural changes must be analyzed before any validity can be claimed for odd-lot statistics today.

**Short sales indexes and ratios**

A short sale is defined as "any sale which is consummated by delivery of a security borrowed for...the seller."¹ The selling antedates the buying. The "short interest," the number of shares sold short and not yet repurchased, is related to total transactions on the New York Stock Exchange by dividing the total short interest in all shares on the Exchange by the average daily volume for the month. The resulting figure is called the Short Interest Ratio, and it represents the number of average-volume trading days which would be required for all short sales to be liquidated (covered). Theoretically, a high Ratio accompanies market bottoms, and a low Ratio indicates peaks.² Measurement of support, or potential demand, is attributed to this indicator because each short position always requires a future purchase.

**Short Interest Ratio**

Late in 1967, the "bullish" level of a short interest in excess of eighteen million shares was stressed by many


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advisory services. Yet a close examination of the current short positions maintained in all NYSE stocks at that time indicated some 75% of these positions were affected in one way or another by arbitrage transactions. "In 1940, only 140 mergers or acquisitions were reported by the NYSE; by 1967, the number had grown to more than 2800." Such an environment can greatly reduce the meaningfulness of the Short Interest Ratio.

Suggestions have recently been made to substitute the short positions and the volume statistics for the thirty Dow Jones Industrials into the computations of the Short Interest instead of using total Exchange figures, but opponents argue that such a substitution will weaken the "breadth" of the Index.

**Short interest results**

Thomas H. Mayor, of the University of Maryland, applied regression techniques to the short interest level and an aggregate measure of stock prices (Standard and Poor's 500 stock index), and also compared the performance of short traders with a chance model. He concluded that the short interest level is not a predictor of future price, and that

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2 Ibid., p. 107.
short traders do not outperform a chance model. The latter conclusion is beset with difficulties, however, since no methods were employed to correct for seasonality (tax motivations) or specialists' activities (arbitrage).

Random Walk Theory

Serial independence

Market imperfection is implied by both technical and fundamental analysis. Both of the methods also imply optimism about discovering and profiting from these imperfections. Use of the indicators gauging investor sentiment likewise imply imperfect action in the stock market. Random walk theorists envision a perfect or near-perfect market, however, and reason that recognition of imperfections would lead to actions which would tend to eliminate these imperfections as prices adjust to the consensus of expectations. Dow Theory says much the same thing: "The fluctuations of the ...averages afford a composite index of all the hopes, disappointments, and knowledge of everyone who knows anything of financial matters, and for that reason, the effects of coming events are always properly anticipated in their movement."2


2 Greiner and Whitcomb, Dow Theory, p. 50.
But the random walk theorist reaches a different conclusion than the technician: "In a perfect market, no opportunity for profit based upon past price movements or any other past data should exist; stocks are always at their proper price except for purely random fluctuations."¹ Price series tend to exhibit little serial correlation,² and differences in price appear as results of a chance model.³

Although most of the work on the random walk theory is of recent origin, research has already produced a large amount of empirical evidence which will be outlined below. Before examining this research, some further explanation of the random walk theory is necessary.

This theory's beginnings can be traced to mathematical studies of price movements. Except for Bachelier's notable work at the turn of the century, little serious work was done until Professor Holbrook Working (Stanford University) demonstrated in 1934 that a random walk series will look very much like a stock price series.⁴ Professor Working, Arthur

⁴Cootner, ed., Random Character of Prices, p. 3.
Okun (Yale University), and Mr. Alfred Cowles have also shown that a positive serial correlation will be introduced when averages of periodic elements are employed even though the original series is random.\(^1\)

Initially, research was confined to commodity markets. Price series obtained at fairly close intervals behaved like wandering series. The random changes from one term to the next were so large that any systematic tendency was swamped.\(^2\) Later research centered on the stock market itself, most notably the New York Stock Exchange. Researchers tested chance models which employed normally-distributed changes in price and produced price series whose graphs contained the "patterns" significant to technical analysis.\(^3\)

Most investigators of the random walk theory agree that the evidence implies normally-distributed changes of the natural logarithms of price. This assumption agrees with many independent observations that price changes are proportional to price levels,\(^4\) and it has been referred to as "geometric


Brownian motion."¹ Mathematically, the relationship may be expressed as follows:

Prices denoted sequentially with respect to time as \( P_t, P_{t+1}, \ldots, P_{t+k} \) are related such that,

\[
Z_{t+1} = \frac{P_{t+1}}{P_t}
\]

or

\[
\log_e(Z_t) = \log_e(P_{t+1}) - \log_e(P_t)
\]

where

\[
Z_i [i=t, t+1, \ldots, t+k]
\]

is log-normally distributed.

Differences of logarithms of price are therefore normally-distributed, with a consequent expectation that "values for price itself...increases, with increasing time interval, at a rate of three to five percent a year, with increasing fluctuation, or dispersion."²

Causes of price movements

Critical appraisals of random walk theory usually end with the reflection that randomness flies in the face of reason. The word random is an unfortunate choice in this respect, and increases misinterpretation of what the theory is really saying. Random means haphazard, without definite method or specific pattern. But the theory only implies

² Cootner, ed., *Random Character of Prices*, p. 100.
randomness with respect to previous prices. It does not imply that price movements are unrelated to anything. The underlying rationale is that prices are future-oriented, discounting known events, and that they tend to adjust to new information as it becomes disseminated. So dependency on exogenous factors is not denied by the theory, although no attempt is made to define these factors or their relationship to prices. Finally, the theory states that, whatever the relationships are, their effects are statistically equivalent to a random model with properly chosen parameters.

Distribution of prices

Several different distributions of prices or price changes would be consistent with random walk theory. Several researchers have disagreed with any position advocating Gaussian assumptions about the distribution. Very significant work was done in this area by Benoit Mandelbrot. He applied Paretian distributions to cotton prices and other speculative markets with very good results.¹ Later investigation utilizing listed daily common stock prices has tended to confirm Mandelbrot's hypothesis.²

¹Benoit Mandelbrot, "The Variation of Certain Speculative Prices," Random Character of Prices, p. 328.
More important, however, are the environments in which the random walk theory would be valid:

(1) Information available to market participants is random in its effects on market price;¹

(2) Effects of news are not random, but all participants are immediately apprised of all new information and any statistical dependencies inherent in the information; or

(3) Participants operate at different levels of information, and just enough well-informed traders are enticed by profit to eliminate any systematic tendencies in price changes.²

The third environment has become known as the "modified" random walk hypothesis, and is probably the most widely-held viewpoint because of its similarities to the real world. Very recent research about frictions and lags in the information-generating process has raised questions about the basic random walk concepts of independence and market perfection.

¹This theory was first introduced by Professor Paul A. Samuelson in the Industrial Management Review, Spring, 1965, 41-50.

Areas of Compromise

Unexplained relationships

In 1960, Alfred Cowles found some evidence of price trends in common stock price indexes, but he concluded that these trends seemed fragmentary and not well-linked to the flow of new information.¹ Eugene Fama, a significant contributor to the random walk field, has noted the weakness inherent in statistical tests of dependence—serial correlation only checks for dependencies present throughout the data—and he has uncovered some empirical dependencies on magnitude of adjacent stock price changes in a series.² A 1966 study also indicated that volume and price are dependent, and, furthermore, the conditional probability of a daily rise (fall) in price is greater given a rise (fall) in price on the previous day.³

A very recent attempt to predict the six-month performance of a stock based on earnings-price and earnings-change ratios has proved somewhat successful, although the model is not as good at identifying low performers as it is high performers.⁴ Several new methods have also been

¹Cowles, "A Revision," p. 139.
²Fama, "Stock-Market Prices," p. 86.
developed in the field of technical and fundamental analysis which have not yet been rigorously evaluated. Some of these are laudable efforts by people cognizant of the older fallacies and pitfalls surrounding market analysis, and their work has been directed toward the discovery of causal and symptomatic relationships.

One such method is the "dual-market" principle of Kenneth B. Smilen and Kenneth Saffian which they developed in the early 1960's. The market, according to their principle, is a collection of sub-markets, each a grouping of issues based upon factors which influence earnings. Their basic premise is that issues within a particular group are in competition for the same capital as other issues in the group.¹ A study of the 1952-1960 period by Richard Brealey of Keystone Funds, Inc., has identified common influences in price changes which seem to lend support to Smilen and Saffian. He identified influences attributable to the market, the industry, the sub-group, and the individual firm. The identifiable sub-group influence was by far the largest factor affecting price change. These sub-groups were structured upon earnings factors.²

²Brealey, Risk and Return in Common Stocks, p. 59.
Even within the framework of the random walk assumption, meaningful relationships may exist: "...distributions of stock returns which appear to conform to the laws of random motion can hide a significant amount of internal structure."^1

Modified random walk: "reflecting barriers"

Several researchers have commented on the evidence of some dependencies in price series, but they have generally tended to minimize these inconsistencies and stress instead the randomness of price changes. Paul H. Cootner, Professor of Finance at the Sloan School of Management, has advanced a theory which recognizes these inconsistencies and undertakes an explanation for their existence.

Cootner visualizes a market which is imperfect due to the varying degree of knowledgeability of its participant. At one end of this "knowledgeability" spectrum are the bulk of the participants who accept prices as rough approximates of true value and make their choices mainly on the basis of risk. When they attempt to predict the future, they are as often wrong as right. At the other end of the spectrum are the market specialists who have some idea of future events,


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but whose profits cannot be realized until prices deviate enough to yield an adequate return.

These more knowledgeable traders will buy or sell when deviations occur which are sufficient to guarantee their profits. Their actions set up the "reflecting barriers." Between these barriers, the actions of the less knowledgeable group force prices to prescribe a random walk pattern. The spread between the barriers will be limited by competition among the professionals, and movements of these barriers will also occur over time as professionals adjust their expectations in the face of new information.

An interesting corollary of Cootner's hypothesis is that stock prices over a substantial period of time will "be composed of a random number of trends, each of which is a random walk with reflecting barriers." Any statistical analysis of series such as these would have to grapple with the implicit non-stationarity of the sequences.

Theoretical confluences

If stock prices are statistically equivalent to a series of random trends, then the possibility exists that some sufficiently powerful analytical method could be employed to identify the onset of a new trend and to make

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some estimate of its ultimate expectation. Such an over-
simplification may not exist, and even if it does, inherent
difficulties could render analysis impossible. Oversimplifi-
cation may be a blatantly inept term to describe a non-sta-
tionary process, but it is used here because any definitive
model such as Cootner's would bring some clarity to the
present morass of theories.

Cootner's theory has undergone some testing, and the
results are supportive.¹ This reference may have a subtle
bias, however.²

The model also raises some significant questions
about conventional market and security analysis. According
to Cootner, the "model is perfectly compatible with much of
what I interpret Wall Street chart reading to be all about."³
"Like the Indian folk doctors who discovered tranquilizers,
the Wall Street witch doctors, without the benefit of scien-
tific method, have produced something with their magic, even
if they can't tell you what it is or how it works."⁴

Although Cootner never mentions fundamental analysis directly,

¹William Steiger, "A Test of Nonrandomness in Stock

²Ibid., p. 253; this paper was based on Steiger's
Master's thesis submitted to the School of Industrial Manage-
ment. The thesis advisor was Professor Cootner.


⁴Ibid.
his model implies that prices would have trends influenced by some expectation of value, and the expectations of professionals would produce boundaries. Thus three disparate viewpoints may evidence some relationships to one another.

Only one thing is certain. Gross defects have been discovered in the older traditional views of the stock market, and recent research on the random walk theory has evidenced phenomena unexplainable by many rational assumptions lying within the context of the theory.

Other assumptions consistent with random walks might be made. The subject of the next chapter concerns some of the relationships which were chosen for the SIMSTOCK model, and the price philosophy which these relationships encompass.
CHAPTER III

THE RATIONALE OF SIMSTOCK

An attempt to develop a pricing theory for the model is undertaken in the first part of this chapter. Previously cited work has stressed the random characteristics in stock price data while minimizing observed deviations from the theory. Most researchers have accepted log-normally distributed ratios of successive prices as the most appropriate distribution to describe price series—despite some notable exceptions—because of two inherent advantages this distribution offers. First, it is non-negative; and second, changes in prices would be proportional to price levels, a feature that is characteristic of stock prices. A price mechanism with characteristics similar to log-normality will be


3Benoit Mandelbrot, "Variation of Certain Speculative Prices,"; and Eugene Fama, "Mandelbrot and the Stable Pareto Hypothesis."

presented which possibly circumvents the Mandelbrot objection to Gaussian distributions.

An outline of the functional relationships in the model is presented in the second part of this chapter. No two analysts will necessarily agree with these choices, but neither would the same two analysts necessarily agree with each other's specific vision of the marketplace. The reasoning behind the selections made is purely that of the researcher, and is a composite reflecting his own perusal of the literature and his opinions concerning it. A more detailed explanation of the model's parameters will be presented in Chapter IV. The section in this chapter is intended only as a brief outline of the basic relationships.

The indicators and features discussed in Chapter II which are necessary to the model are dealt with in the third part of this chapter.

Price Philosophy

"Most economic processes are blatantly non-stationary. In certain cases, however, this non-stationarity does not appear to take on an extreme form; rather it is of a slowly altering nature. In fact, for restricted time periods, one can apparently assume stationarity and then, as the time period shifts, imagine that the parameters of the process evolve in a regular manner."¹

Random walks

The researcher has chosen the random walk theory as the most realistic approach to a price philosophy. The heavy weight of evidence rationalizes such a choice. The modified random walk with "reflecting barriers" advanced by the Cootner model in Chapter II assumes non-stationarity. A non-stationary process raises serious analytical difficulties, but it presents a logical approach to a stock pricing mechanism. If a random generator were employed to produce stock prices, the expected value of a future price would be merely a function of the mean of the distribution. A capital gain (loss) would be expected for a positive (negative) mean value. However, stock price expectations tend to change over extended periods of time, and it would seem to be a very difficult task indeed to expect that some distribution with constant parameters could be found to explain a price series over several time periods.

Random walk theory has dealt extensively over the past several years with the log-normal distribution. The distribution was investigated during this project, but was rejected for several reasons which will be mentioned below.
Log-normal distribution

For simulation purposes, the output of a random generator, \( \text{RAND}(-1.) \), which produces random normal deviates, \( X_i \), can be transposed to a normal distribution, \( N(U, SD) \), by the following:

\[
X_i = \text{RAND}(-1.) \times SD + U; \text{ where } U \text{ is the mean and } SD \text{ the standard deviation.}
\]

An additional transformation can be made to yield log-normally distributed values for \( X_i \):

\[
X_i = e^{(\text{RAND}(-1.) \times SD + U)}.
\]

The parameters of the resulting log-normal distribution, \( U' \) and \( SD' \), are then functions of the parameters \( U \) and \( SD \) of the underlying normal generator:

\[
U' = e^{(U + \frac{1}{2}SD^2)};
\]

and

\[
SD' = e^{(2U + 2SD^2)} - e^{(2U - SD^2)}.1
\]

A computational problem is encountered in choosing appropriate values for \( U \) and \( SD \) to yield the desired parameters \( U' \) and \( SD' \) of the log-normal distribution. This problem becomes even more acute if non-stationarity is introduced. To effect a change in the log-normal mean only, values must be chosen so that \( U' \) changes by the desired amount while \( SD' \) remains constant. Little mention has been made of non-stationarity.

\[1\text{Claude McMillan and Richard F. Gonzalez, Systems Analysis, p. 260.}\]
except by Fama. His conclusions rejected non-stationary parameters of the log-normal distribution as a possible explanation of the excessive dispersion stock prices exhibit over that amount expected if the distribution was followed.¹

In addition to the inadequacies of a log-normal model found by Fama and the computational problems in using the log-normal distribution, a purely deductive objection arises. Investor expectations are expressed by price levels. Investors express their expectations by making buy and sell decisions. Their actions are made known through changes in price, however, and these actions are also formulated through comparisons of price levels, or differences in prices. It would seem logical, therefore, to base a price model on changes in price rather than absolute levels of prices.

The SIMSTOCK price mechanism for stocks

SIMSTOCK employs a price mechanism which is based upon a normal generator which yields normally-distributed percentage changes in price. In other words, the mean and standard deviation are cast as percentages of the current price. For a mean of U and a standard deviation of SD, the price in period t, Pₜ, would be given by:

\[ Pₜ = Pₜ₋₁ + \Delta Pₜ; \text{ where } \Delta Pₜ = R \times SD \times Pₜ₋₁ + U \times Pₜ₋₁ \]

and R is a random normal deviate of mean=0.0 and standard deviation=1.

¹Fama, "Mandelbrot and the Stable Paretian Hypothesis,"
So \( P_t = P_{t-1} + R \times SD \times P_{t-1} + U \times P_{t-1} \);

or \( P_t = P_{t-1} \times (1 + R \times SD + U) \).

Both individual common stocks and market aggregates (Dow Jones Industrials and Standard and Poor's 500) are priced by this method. The difference between the process for the individual stocks and the process for the aggregates is in the selection of the parameters. Individual issues have non-stationary means and constant standard deviations, while the aggregates are non-stationary in both parameters. The logic of this choice is amplified below.

Investor expectation for a given issue will change over time. One would expect to see this change reflected in the mean price change. This change will be an aggregate of several factors which affect the fortunes of the issuing company, however. If the market is generally rising, this trend will have its effect on investor's attitudes toward a given stock. Likewise, high long-term interest rates will have adverse effects on the stock of a company that extensively employs long-term financing. The mean of the price distribution may thus be thought of as a composite, or sum, of various factors relating to stock price.¹ Other research has used partial correlation techniques to isolate effects

on price by factors both endogenous and exogenous to the stock market. The same research has also indicated that degree of risk is a persistent characteristic over time for a given issue.\(^1\)

The mean price change for individual issues is determined periodically by a pre-determined relationship each issue has to certain factors influencing price such as industrial production, inflation, cost of capital, general market movements, and the earnings of the issuing company. Since the mean is viewed as expectation, it is treated as a partitionable variable, equal to the arithmetic sum of the events which influence stock price. The model treats standard deviation as a measure of risk. Since a given level of risk tends to persist over time, the standard deviation is constant.

The mean change in value of the market aggregates is functionally related to expectations as expressed by a cyclical trend factor effecting the index of leading barometric indicators, and to a measure of Federal Reserve Board policy. The standard deviation also changes with the mean because aggregate market risk is not a constant factor.

These pricing mechanisms will be more fully explained in Chapter IV. However, one point should be clarified at this

time. Since the distribution parameters are really percentages of the current price, they are actually continuously non-stationary. For purposes of reference, the term "constant" has been used. It should be remembered that "constant," in this sense, does not imply constant arithmetic value, but rather a constant percentage value.

Functional Relationships

Econometric motivation

The primary motivating forces of the SIMSTOCK market are the econometric parameters generated by the model. Values are determined for a diffusion index of leading barometric indicators, the Federal Reserve Board Index of Industrial Production, the Consumer Price Index, a prime rate of interest, the rate on four to six-month prime commercial paper, and the composite yield on Moody's Aa Corporate bonds.

Figure 1 presents the functional relationships between these parameters. The barometric index is a stochastic variable containing an induced trend. The FRB Index is directly related to the previous quarter's values of the barometric index. Consumer prices are related to divergences in the prime rate from an arbitrary stable rate, and to a random element. Changes in the prime rate only occur when an imbalance condition is detected in the simulated economy. A change factor is generated whenever an imbalance is discovered. The subsequent prime rate change is determined
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Function of</th>
</tr>
</thead>
</table>
| 1. Index of leading barometric indicators (BAR) | A. Moving average of last four values  
B. Random element  
C. Cyclical trend element |
| 2. Federal Reserve Board Index of Industrial Production (FRB) | A. Barometric index, latest quarter and latest month  
B. Random element  
C. Prime rate divergence from "stability" |
| 3. Consumer Price Index (CPI) | A. Random element  
B. Prime rate divergence from "stability" |
| 4. Prime Rate (RATE) | A. Value of change factor (or "correction" variable)  
B. Random element  
C. Difference between growth rates of FRB and CPI |
| 5. Prime Commercial Paper Rate (COMCL) | A. Prime rate  
B. Federal Reserve Board policy factor |
| 6. Moody's Aa Bonds | A. Prime rate  
B. Rate on prime commercial paper  
C. Random element |

Fig. 1.--Econometric Relationships.
by a discrete probability distribution dependent upon the sign and magnitude of the change factor. The rate on prime commercial paper is viewed as a short-term interest rate measurement related to changes in the prime rate and an index measuring Federal Reserve Board policy, while the yield on Moody's Aa Corporates is a long-term interest rate indicator related to a random element, the prime rate, the commercial paper rate, and the cyclical trend element of the barometric indicators.

Responses of the market environment

The SIMSTOCK market environment includes aggregate measures which are related to the above econometric parameters. Figure 2 illustrates the functional relationships involved.

Two of the common stock averages— the Dow Jones Industrials and Standard and Poor's Five Hundred Average— are randomly-generated variables whose parameters are non-stationary functions of the cyclical trend element of the barometric index and changes in the prime rate. The Dow Jones Transportation Average, the third stock index, is merely a function of the Dow Industrials and a random element. The frequency of parameter changes is influenced by changes in the prime rate and changes in the sign of the barometric index trend factor.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Function of</th>
</tr>
</thead>
</table>
| 1. Mean Price Change, Common Stock Averages (excluding Transportation Index) | A. Current change in prime rate  
B. Cyclical trend factor, leading barometric index |
| 2. Standard Deviation, Common Stock Averages (excluding Transportation)  | A. Mean price change parameter  
B. Length of current trend in months |
| 3. Issues Listed, NYSE                                                   | A. Monthly growth factor  
B. Random element |
| 4. Volume, NYSE                                                         | A. "Normal" daily volume factor  
B. Issues listed, NYSE  
C. Corresponding percentage change, Standard and Poor's Stock Average |
| 5. Advance-Decline Ratio                                                 | A. Sign of corresponding Standard and Poor's Stock Average change  
B. Random elements  
C. Issues traded, NYSE |
| 6. Issues Traded, NYSE                                                  | A. Issues listed, NYSE  
B. Sign and magnitude of Standard and Poor's Stock Average  
C. Random element |
| 7. Bond Yields                                                           | A. Moody's Aa Corporates  
B. Current prime rate change  
C. Random element |
| 8. Bill Yields                                                           | A. Prime commercial paper rate  
B. Random element |

Fig. 2.—Market Relationships.
The number of issues listed on the New York Stock Exchange is computed and reported monthly, and is an arithmetic progression increasing at an historic rate. New York Stock Exchange volume is related directly to the number of issues listed, multiplied by a "normal" daily volume factor, and influenced by the latest corresponding percentage change of the Standard and Poor's Index. Advance-decline-unchanged-statistics are randomly-generated percentages of the number of issues traded which, in turn, is a random function of the number of issues listed. The sign of advances minus declines is the same as the sign of the corresponding change in Standard and Poor's Average.

Other aggregate measures of the market include the current yields on the Dow Jones Forty Bonds, Barron's Ten Hi-Grade Bonds, five-year Treasury bonds, and six-month Treasury bills. The first two of these measures are related to Moody's Aa Corporates, and will normally straddle this value. Treasury bonds are also directly related to corporate bond yields, but will always carry a lower yield. Treasury bills are treated as short-term debt instruments, and therefore yields on these bills are functionally related to short-term rates as expressed by the rate on prime commercial paper.
SIMSTOCK Features and Indicators

Variable time periods and options

The model includes an option concerning the amount of time to be simulated in a particular cycle. Simulation time periods are variable to allow the flexibility of increasing the number of investor decisions during the periods of rapid change. When relative stability prevails, the participants can then switch to fewer decisions by lengthening the simulation period per cycle.

A basic purpose of this model is to provide an educational experience. The model will therefore contain as many options as possible consistent with the actual market. Both short and long positions will be allowed, as well as margin account privileges. Bonds and government securities will be offered as alternative investments, as well as warrants and option contracts (puts and calls). In addition, brokerage fees will parallel actual rates.

Decision-making information

An attempt has been made to provide the participants with enough information to enable them to formulate rational investment decisions. Although the random walk theory has been incorporated into the model, features relevant to both technical and fundamental analysis have been included to facilitate the use of these tools.
Technical analysis is probably the farthest departure from the SIMSTOCK model that could be employed for analytical purposes. Nevertheless, the model includes features which permit the use of this method. The Dow Jones Industrial Average, the Dow Jones Transportation Index, daily and monthly New York Stock Exchange volume statistics, and Barron's Confidence Index (computed from the Dow Jones Forty Bonds and Barron's Ten Hi-Grade Bonds) were included in the stock market reports generated by the model. Technicians will also find advance-decline statistics rendered on a daily basis. However, none of these features influence stock prices generated by the model.

Fundamental analysis is more closely related to the model due to the fact that price parameters are functionally related to econometric factors of earnings, interest rate levels, real production, and leading barometric indicators. The model provides a monthly report on the current values of the Consumer Price Index, the Federal Reserve Board Index of Industrial Production, a diffusion index of leading barometric indicators, and the rate on prime commercial paper. For each common stock, the model includes information concerning current earnings and dividends. Gross National Product is computed quarterly, and is reported in current dollars. Changes in the prime rate or rediscount rate are reported in the week of occurrence.
The economy and market environment sections of the model have been constructed and tested (Pass Two). In the next chapter, the structure and operation of these sections are explained in detail, and a brief presentation is also afforded other sections of the model (Pass One and Pass Three).
CHAPTER IV

STRUCTURE AND OPERATION OF THE SIMSTOCK ECONOMY AND MARKET ENVIRONMENT

The SIMSTOCK model is presented in this chapter. The proposed structure is outlined first with accompanying system flowcharts illustrating subprogram relationships. An operating sequence envisioned for the full model is presented in the same section. The rest of the chapter is devoted to a more specific explanation of the portion of the model which is currently operational (Pass Two).

The FORTRAN source deck for this operational portion is listed in Appendix I. Appendix II contains a glossary of the variable names shown in the Pass Two source deck and the flow charts below. The random generator chosen for the model is evaluated in Appendix III, and the results of one simulated five-year test period are presented in Appendix IV.

Structure

Operation of the model

Structural recommendations outlined in this section are based on the requirements dictated by an IBM 1620 Model I system. Three programs--hereafter referenced as Pass One,
Pass Two, and Pass Three—will compromise the full model. Other computer systems may be capable of accommodating the whole model in a single program, or may at least be able to process the whole model in one pass by referencing sub-routines stored on tape or disc devices.

Some division into parts was necessitated by the limited capacity of the computer available. Pass One is the broker operation, and provides processing routines for order execution and trading account supervision. Pass Two determines all of the factors relevant to price computation and determines the value of stock market aggregates. Pass Three determines the prices of individual securities based upon data provided by Pass Two, and provides reports to players on the economy, the market, and their individual portfolios.

A full cycle, one time period, is accomplished by running all three passes in numerical order. The simulation period may be varied from one to twelve weeks per cycle. One week is the basic simulation period. The simulation "calendar" consists of five days per week, four weeks per month, and twelve months per year. Two hundred and forty trading days are simulated in an annual period, a figure very close to reality despite the artificial method by which it is produced.¹ As few as four or as many as forty-eight player

decisions are possible each annual period by varying the number of weeks in a cycle. Player decisions are made at the end of a cycle.

The reader will note a considerable amount of card input/output in some of the flowcharts in this chapter. Again, different computer systems will dictate varying constraints. The most expeditious method for handling data on the 1620 system was to reproduce the data deck on each pass. Then after each program of the model is executed, the punched card output from that run can be placed behind the next pass as the data deck. The output from Pass Three will likewise be the data deck for Pass One the following cycle.

Pass One

An abbreviated flowchart of the program structure envisioned for this pass is presented in Figures 3a and 3b. Sections of the program are referenced below by the letter labels shown in parentheses on the flowchart.

(A) The value of LOOP is always from one to twelve, and is the number of weeks to be simulated for the current cycle. An option exists to intervene during execution via sense switch one and change this value.

(B) As the data cards containing the information about specific issues are read, the current price of each issue is extracted and placed in the array PRICES. These prices represent the last closing price computed (Friday
Fig. 3a.--Pass One, Part One.
Fig. 3b.—Pass One, Part Two.
closing, last cycle). All players will buy and sell at these prices. Price per issue will also be constant despite the order size.

(C) As the arrays of econometric and market data are read, the current percentages for initial margin, maintenance margin, and Federal Reserve Board margin for government securities will be extracted and stored in array XARGIN.

(D) The account cards for all players will be read and placed in on-line storage.

(E) Decision cards will be processed for one player at a time. The first card will contain the number of sell orders and buy orders. When these numbers are non-zero, the respective subroutine will be called to execute the number of orders. Sell orders are handled first so that proceeds from sales will be available for subsequent purchases made during the same cycle.

(F) Upon completing all order processing for a particular player, his account will be reviewed and updated. If the account is deficient, a margin call will be made which must be satisfied at the beginning of the next cycle. Margin calls will be generated when account balance falls below a percentage maintenance margin specified in the input data.

Figure 4 outlines Subroutine Sell. For each of the NSELL orders, a card is read which includes the issue identity, ID, the type of sell order, IO, and the number of units, NS (shares, warrants, bonds, etcetera). If the security is not
Fig. 4.—Subroutine Sell.
a stock, a check is made of the portfolio to ensure that the order can be fulfilled. The same check is made to liquidate a long position in a stock. Statement 45 is an error message which is generated if these conditions are not met. When the order is deemed executable, Subroutine CHARGE is called to determine brokerage fees. These fees are determined in accordance with the rates specified by the New York Stock Exchange. The cash in the player's account is then augmented by the net proceeds from the sale. If the order code, 10, indicates that this order is not to liquidate a long position, then a short position is assumed if the player's account contains sufficient collateral, and cash exists to meet brokerage fees. In addition to the flowcharted routines, another check will be made to determine if a margined position is being liquidated, and, if it is, the subroutine will retire the debt before posting the sale proceeds to the account.

Subroutine BUY is analogous to the above subroutine in structure, and it is also called to liquidate a short position. Subroutine CHARGE is again used to determine commissions. An additional feature of the buying sub-program will be a percentage figure on the data card showing the percentage amount of the purchase price not being paid at execution. This amount will represent margin, and the player will be charged simple interest at one percent per annum above the current prime rate until the debt is retired. If a percentage is not shown on the data card, zero margin (one hundred percent
cash order) will be assumed. A buy order is not considered valid unless the account contains sufficient cash to meet the unmargined purchase price plus commission. An initial margin constraint will be contained in the input data, as well as a margin for Federal securities.

Subroutine CHARGE will compute commissions in accordance with the "Formulas for Minimum Commissions" developed by Standard and Poor's Corporation. These formulas do include an odd-lot differential. When the total transaction price is under one hundred dollars, a flat commission rate of five percent of the amount involved will be charged. Bond commissions will be a flat rate of ten dollars per bond. No other taxes or fees will be levied on transactions involving long positions.

Pass One is terminated upon the completion of processing all orders.

Pass Two

This program represents the main simulation running for a period of one to twelve weeks as determined by the variable LOOP. For each week simulated, it determines daily market statistics for the following: Dow Jones Industrial Average, Standard and Poor's Five Hundred Stock Composite,  

New York Stock Exchange daily volume, number of issues traded, number of issues advancing, number declining, and number unchanged. It also computes a daily advance/decline statistic. Each month it calculates the latest econometric information, and it periodically changes the parameters of the distributions of the stock aggregates. The program is a collection of thirteen subroutines and two functions whose relationships are outlined in Figure 5. Two of these subprograms, ECONMY and ENVIRN, are merely supervisory subroutines which control execution routing through their respective subordinate subroutines. The first group comprises the econometric model, and the second group is the stock market model. A discussion of these subprograms appears in the latter part of this chapter. Figure 6 illustrates the execution sequence of the main program.

Pass Three

The final program will read the starting date of the current cycle and then advance this date through LOOP weeks while processing the data provided by the previous program. On each weekly pass, a weekly report on the market is given to each player. If the current week ends a month or quarter, the appropriate report on the economy will be rendered. Also during each of these weekly passes through the main program loop, a subroutine will be called to determine the daily closing prices for each individual issue in the model.
Fig. 5.--Pass Two Subprogram Relationships.
Fig. 6.--Pass Two, Main Loop.
Although all prices will be carried as floating-point values, a subprogram will convert these prices to the nearest fractional point in eighths.

Option contracts to be offered during the next cycle will be determined prior to the termination of Pass Three. The option price is based primarily on expectation as measured by the parameters of the particular price distribution. Option contracts will be written only for common stocks listed on the New York or American Exchange. During periods of rapid price fluctuation, option offers may be sparse or even non-existent.

_The SIMSTOCK Economy_

**Program Execution**

Subroutine ECONMY, illustrated in Figure 7, controls the execution of the econometric portion of the SIMSTOCK model. Control is passed back to the main program immediately if the current week being processed is not the end of a month. The variable I is held in common storage, and represents the number of the week currently being processed. The array NRPT(I) carries the values of one, two, three, or four to indicate that week I marks the end of a normal week, a month, a quarter, or a year, respectively. This array is calculated in Subroutine UPDATE at the beginning of Pass Two execution.
Fig. 7. -- Subroutine ECONMY.
Subroutine PRIMRT

This subprogram determines changes in the prime rate and rediscount rate. It is referenced during normal routing only on an annual basis, but may be called by three other subroutines (dotted connecting lines on flowchart in Figure 7) as necessary to attempt corrections to the economy through Federal Reserve Board action. This action is called upon when industrial production, measured by the Federal Reserve Board Index of Industrial Production, falls below an annual growth rate of two percent or has a negative growth rate during the most recent quarterly period. The prime rate program is also called when the Consumer Price Index exceeds an annual growth rate of seven percent or a quarterly growth rate in excess of two percent, or when the rate on prime commercial paper is nine percent or greater. Changes in the prime rate are a function of the variable NT, and are related directly to the sign and magnitude of this variable. The annual review of the prime rate will result in change only if the annual growth rate of the Consumer Price Index exceeds that of the Index of Industrial Production by two percent or more.

The prime rate will not necessarily change every time the subprogram is called for a non-zero value of NT. A change is dependent upon the elapsed time since the last change and the magnitude of NT (see statement 23 of program listing).
Subroutine GNPROD

Gross National Product is computed in current dollars. The model takes the grossly oversimplified approach that inflation is perfectly represented by the Consumer Price Index (CPI) and real growth is perfectly represented by the Index of Industrial Production (IIP). Therefore, since Gross National Product in current dollars is the result of production and inflation, the increase in Gross National Product is then computed quarterly by adding the latest quarterly growth rates of these two factors and their cross-product, and applying the resulting percentage to last quarter's GNP:

$$\Delta \text{GNP}_t = \left( \frac{\Delta \text{CPI}_t}{\text{CPI}} + \frac{\Delta \text{FRB}_t}{\text{FRB}} + \frac{\Delta \text{CPI}_t}{\text{CPI}} \times \frac{\Delta \text{FRB}_t}{\text{FRB}} \right) \times \text{GNP}_{t-1}.$$ 

Subroutine BARMTR

A diffusion index of leading barometric indicators is the motivating force in the model, and is produced by this subroutine. Values returned by this subprogram always are between zero and one. A value of one-half indicates neutrality: as many leading indicators are rising as are falling. A uniformly-distributed random generator, RAND(0), is used to calculate the index. Motion is dampened by using a moving average containing five elements, the previous four values of the index and a number from the random generator. A bias element, W(30), is also introduced into the computation to provide trends (see statement number 10 of program listing).
The subroutine also controls the amount and duration of bias. A simplified flowchart is provided in Figure 8. W(31) is a counter which indicates the number of months the bias factor has maintained the current sign. Changes in the prime rate effect changes in the bias factor during the month of occurrence to a slight degree, and one month after occurrence by a much greater degree. The absolute value of the bias is raised slightly after the third month since a sign change, and is then gradually decreased each month by fifteen percent plus a random amount until either a change in sign occurs or twelve months have elapsed.

After the calculations concerning the bias are accomplished, a new value for the current diffusion index (W(20)) is determined. The random element added to this moving average is also smoothed by taking three uniformly-distributed numbers and dividing by three. The value must lie between zero and one. If this condition is satisfied, the array of diffusion index values is shifted one month, and the oldest value is dropped from the data file.

**Subroutine FRBIND**

The Index of Industrial Production is a function of the prime rate, the latest quarter's values for the leading barometric index, and a random element:
Fig. 8.---Subroutine BARMTR.
\[ \text{IIP}_t = \text{IIP}_{t-1} \times (1. + \frac{(\text{difference in prime rate from } 6.8\%)}{1200} + \frac{((\text{latest three values, barometric index} + \text{latest value}) - 2.)/300}{\text{(uniform random element/125)}}). \]

A "normal" prime rate of 6.8 percent is envisioned for the model. The average monthly growth rate for the Federal Reserve Board Index between 1950 and 1970 was 0.403 percent per month. If the expected prime rate is in effect, and if the barometric indicators are neutral, then an average growth rate of 0.4 percent per month will result from the random element in the equation (0.5/125).

A change in prime rate will be requested (always a negative change) when growth becomes retarded. Unemployment is also calculated by this subroutine as a function of the latest change in the Industrial Index, but it is limited to values between 2.5 and 4.5 percent.

**Subroutine CPINDX**

From 1963 to 1969, the Consumer Price Index has shown an average monthly growth rate of 0.258 percent. Since 1966, this growth has been at an abnormally high rate of 0.351 percent per month. The subroutine computes the latest monthly value of the Index from the following:

\[ \text{CPI}_t = \text{CPI}_{t-1} \times (1. + \frac{(\text{difference in prime rate from } 6.8\%)}{2000} + \frac{\text{(uniform random element)}}{160}). \]
A growth rate of .3125 percent a month will thus result when the prime rate is 6.8 percent, while a growth rate of .3275 will result when the prime rate is 6.5 percent. These rates are a good approximation of actual recent growth of consumer prices.

A change in prime rate will also be requested by the subprogram when growth rates of the Consumer Price Index exceed the limits mentioned earlier.

**Subroutine MONIES**

An abbreviated flowchart of this subroutine is provided in Figure 9. The subprogram computes both the rate of prime commercial paper (W(19)) and the value of Moody's Aa Corporate index (E(13)). The former is a function of business expansion over the latest quarter as measured by the Index of Industrial Production, the amount of expansion or contraction in monetary policy (W(13)), and a random generator uniformly-distributed over the range of ±.25. A decrease in prime rate is requested if the rate on paper exceeds nine percent. The Moody Index is merely an average of .714 points above the prime paper rate.

In addition, the subprogram monitors the length of time that monetary policy has been contracting or expanding, and will attempt to change the policy when the time exceeds an annual period.
Fig. 9.—Subroutine MONIES.
The SIMSTOCK Market Environment

Program execution

Execution of subprograms providing market information is controlled by Subroutine ENVIRN. There are four of these subsidiaries, one which is called every month, and three which are referenced weekly. The three weekly subprograms will be presented first.

Subroutine DJONES

Five daily closing prices of stock market aggregates for each week simulated are provided by this subroutine in conjunction with a function subprogram called Prices. Besides fulfilling this basic purpose, the Dow subroutine has access to parameter change procedures in another subroutine whenever the prime rate has changed. It also retains high and low values of the Dow Jones Industrials for the current month, and maintains a record of percentage advance or decline of the Dow Industrials and Standard and Poor's Averages for the current year. Figures 10a and 10b contain the program flowchart.

The arguments X and Y, transmitted to the function PRICES by the dummy variable Z, are set initially each week to a fair coin toss of plus or minus. Function PRICES will then compute a new value for Z following each iteration which is the sign of the last price change, ±1. Price changes have
Fig. 10a.—Subroutine DJONES.
Fig. 10b.—Function PRICES.
a fifty percent chance of being either positive or negative due to the random generator, but the addition of the variable Z creates a seventy-five percent chance that adjacent price changes will have the same sign. Therefore, in accordance with Ying’s findings, the conditional probability of adjacent price changes having the same sign is greater than fifty percent.¹

The Dow Jones Transportation Average, contained in array RR, is computed by formula from the corresponding day’s Dow Industrials’ quotation. This formula resulted from a regression analysis of daily historical data on these two indicators over the period of late 1966 through the first half of 1968, a period of 19 months. A random factor was added to the equation to approximate the standard error of the estimate found in this analysis. For any given day, the Transportation Average, RR, is given by:

\[ RR = \frac{(DJIA + 14.7)}{3} + 3 \times RAND(-1.) \]

where DJIA is the corresponding Industrials’ quotation and RAND(-1.) is a normally-distributed variable of mean = 0 and standard deviation = 1.

Subroutine VOLUME

For each simulated trading day, the volume subprogram computes the following: Daily NYSE (New York Stock Exchange)

¹Ying, "Stock Market Prices and Volume of Sales," 677.
volume, \( V \), in millions of shares; the number of issues traded daily, \( RR \); the number of issues advancing, \( SP \); the number declining, \( DJ \); and the latest value of a moving advance-decline ratio, \( AD \). The program glossary is confusing because of the utilization of some array names used previously in connection with market aggregates. Computer memory constraints required these usages, however.

Volume is a function of the latest daily percentage change in the S & P Index (Standard and Poor's Five Hundred Stock Composite), \( YX \), a first approximation of the number of issues traded, \( ZZ \), and a "normal daily volume factor," \( E(11) \). \( ZZ \) is determined as a percentage of the total number of listed NYSE issues, \( E(8) \), such that

\[
.9 \times E(8) \leq ZZ \leq 1.0 \times E(8),
\]

and an expected value of approximately

\[.96 \times E(8)\].

Then volume is computed as

\[
V = \frac{E(11) \times ZZ}{100,000} + 100 \times YX + 1.5 \times \text{RAND(-1.)},
\]

(A) \( \pm \) (B) \( + \) (C)

where \( V \) is in millions of shares.

The determination of \( E(11) \) will be covered below, but it can be given an arbitrary value of 600 for illustrative purposes. Then \( A = .006 \) of the issues traded, \( B \) is in the range \(-1 < B < +1\), and \( C \) has an expected value of 0.
The final value for issues traded, RR, is ZZ plus or minus a random variable of mean = 0 and standard deviation = 5 plus 3 times the volume in excess of 8 million shares, measured in millions.

Advance-decline statistics are related to the S & P Index, but not the Dow Industrials, because the former provides a more pervasive view of market activity. A variable L is set equal to 1, 2, or 3 for negative, zero, or positive daily changes in the S & P Index. When L=1, the number of issues declining will be greater than those advancing. The opposite occurs when L=2,3. A variable X is chosen such that X≤2, and this value represents the percentage of issues remaining unchanged. In periods of rapid price movements, as measured by the mean parameter of the S & P Index, X will be correspondingly smaller. X is then changed to

\[ X = (1.-X) * RR \]

so that X becomes the number of issues advancing and declining. Random variables Y and Z are then chosen so that \( Y + Z = 1 \). Then, for L=1, the number of issues declining becomes the maximum of \((Y,Z)\) multiplied by X, and the minimum of \((Y,Z)\) times X becomes the number advancing. The opposite result occurs for L = 2,3.
Subroutine MOODY'S

Composite yields for Barron's Ten Hi-Grade Bonds, Moody's Aa Corporates, the Dow Jones Forty-Bond Index, six-month Treasury bills, and five-year Treasury bonds are calculated weekly by this subprogram. Components of the monthly Confidence Index computation are also gathered as simple summations of the weekly statistics.

A variable \( X \) is computed as the growth of the Industrial Production Index in excess of its expected growth rate, unless a change occurred in the prime rate during the weekly iteration. Then \( X \) is set equal to the change in the prime rate. \( Y \) is a value of a uniform random generator. \( Z \) is usually a positive value between zero and one, but becomes negative for highly positive values of the leading barometric index's bias factor.

Yields for the Dow Jones Forty Bonds, \( E(15) \), and Barron's Ten Hi-Grade Bonds, \( E(14) \), will always be spread a minimum of two basis points unless \( Z \) is negative. A negative value for \( X \) can result in Confidence Index values greater than one, but very infrequently. Such an event would have a low probability, and would only occur when excessive optimism and speculative activity exist in the bond market. Both of these composite yields are functionally related to Moody's Aa Corporates, and bracket it. Treasury bills, \( E(25) \), are a function of the current prime paper rate, while Treasury
bonds, \( E(24) \), are related to Moody's Aa Corporates.

**Subroutine MTHLY**

This subroutine is the largest one in the stock market model. It is referenced monthly by normal routing procedures contained in Subroutine ENVIRN, but it can also be called at any time by the stock composite subroutine, DJONES.

During normal execution, routines are processed which determine the number of issues listed on the NYSE for the coming month, \( E(11) \), and the "normal daily volume factor," \( E(8) \); the short interest ratio, \( E(16) \), and the Confidence Index, \( E(23) \), are also computed for the month just completed. Parameters of the composite stock indicators' distributions can also change during normal processing, but only due to an abnormally long period of stationarity resulting in dramatic price changes or the absence of price changes.

Figure 11 presents a flowchart of the normally executed segments, and Figure 12 depicts one of the parameter change routines available to the DJONES subroutine. The particular one shown is for changing the Dow Industrials' parameters, but the routine used for changing the parameters of the S & P 500 distribution is directly analogous.

The number of issues listed on the NYSE, \( E(8) \), is computed monthly by the increasing random percentage change function shown below:
Fig. 11.—Subroutine MNTHLY (partial).
Fig. 12.—Dow Jones parameter change routine (Sub-routine MNTHLY).
\[ E(8) = E(8) + (2 \cdot R - 1.2 \cdot R)/100, \mod (1). \]

where \( R \) is a uniformly-distributed random variable.

Therefore, \( E(8) = E(8) \cdot (1 + 0.008 \cdot R), \mod (1), \)

and \( \text{Exp} \ (E(8))_t = 1.004 \cdot E(8)_{t-1}. \)

Values in the equation were chosen on the basis of historic growth rates for the number of issues listed on the NYSE. The average monthly growth rate from 1963 to 1969 was approximately 2.8 percent per year which is comparable to a compounded monthly rate of .4 percent.\(^1\)

The "normal daily volume factor" referred to earlier was derived by dividing annual average daily volume, measured in tens of thousands of shares, by the annual average number of issues listed on the NYSE for the years 1960 to 1968.\(^2\) The resulting values evidenced an annual growth of 66.75 points. Therefore, \( E(11), \) the volume factor, is computed as

\[ E(11) = E(11) + 3. \cdot \text{RAND(-1.)} + 5.5, \text{ so that } \]

\[ \Delta E(11) \text{ has a mean of } 5.5 \text{ and a standard deviation of } 3. \]

The expected annual growth is then \( 12 \cdot 5.5, \) or 66. \( E(11) \) is multiplied by the number of listed issues to provide a daily volume statistic.

The short interest ratio, \( E(16), \) is computed as a function of the mean of the S & P 500 distribution (see

\(^2\)New York Stock Exchange Fact Book; 1969, pp. 68, 76.
statement #12, Subroutine MNTHLY) when the mean is non-zero. For zero values of the mean, the bias factor of the barometric index, \( W(30) \), is used. The ratio is always forced to satisfy the condition that \( 0.5 E(16) \leq 2.85 \), which are historic limits for this indicator.

Parameter changes are effected for the composite stock indicators' distributions whenever the combined period of stationarity of both indicators is greater than eight months (see statement #7, Subroutine MNTHLY). These changes are functions of the bias factor of the barometric index, \( W(30) \). Changes may also be effected when the percentage advance-decline counters (\( E(17) \) and \( E(18) \)) for either indicator exceed some specified limit. The amount of change is controlled by the magnitude of the variable \( NT \), and is designed to alleviate the condition triggering the change. The parameter change routines are at the beginning of the subroutine, and are the same ones referenced by Subroutine DJONES. Routing is controlled in such a way that negative changes always occur first to the S & P Index parameters, and positive changes always occur first to the Dow Industrials' parameters. Dow stocks generally recover first after downward market movements, and often show a positive divergence from the market prior to downward movements.
Infrequent changes in the mean $X'$, are of the form

$$X' = \frac{(W(30) + .15 \pm R)}{1500},$$

where $R$ is a normally-distributed variable of mean $= 0$, and $W(30)$ is the barometric bias factor.

The changes called for by Subroutine DJONES are of the form

$$X' = X' + \frac{(NT + R - .8 \times R)}{1000};$$

or $\Delta X' = \frac{(NT + .2 \times R)}{1000}$, where $R$ is a uniformly-distributed random variable with an expected value of .5.

Both of these formulas contain a very small amount of positive bias. For the first, this is $.5/1500$, or .0001; and in the second, although the bias is random, it still has an expected value of .0001. In terms of wealth ratios, over an annual period of 240 trading days, this bias could be expected to impart a factor of 1.03, or a secular rate of 3 percent when compounded daily.

Operating Constraints

The Pass Two portion of the model, as listed in Appendix I, requires 38,729 bits of core storage. Very little room is left for expanding data dimensions. Current dimensions indicated in the source deck listing were chosen solely to test the program and were therefore made correspondingly small. The inability to expand these dimensions and thereby increase the number of securities in the model is a severe constraint.
Another problem which has not been resolved is the failure of the program to give the same results on identical runs. Many difficulties were encountered with the computer system used during the construction of the model, and these alone may be responsible for the varying results. On some occasions, a total failure to execute successfully has occurred. Yet the same data and random seed can be used subsequently to provide a successful run. Since the results are not constant, the computer system seems to be the most likely difficulty, but confirmation of the problem is lacking.

Despite these problems, some test runs were conducted, and are briefly discussed in Chapter V. The project is also summarized in the next chapter, and some conclusions are presented.
CHAPTER V

EVALUATION AND CONCLUSIONS

Testing performed on the main simulation model, Pass Two, is presented briefly in the first section of this chapter. The limitations of the model are discussed in the second section of the chapter. The project is summarized and conclusions are offered in the third part, and the final part contains some suggestions for further study.

Evaluation of SIMSTOCK

Five-year test runs were conducted for Pass Two by altering the program to loop continuously for twenty consecutive twelve-week cycles. Computer availability has limited testing to only five of these runs.

The maximum five-year gains for Gross National Product, Federal Reserve Board Index of Industrial Production, and Consumer Price Index, were 53.6 percent, 21.2 percent, and 27.1 percent, respectively. Respective lows registered were 19.3 percent, 6.1 percent, and 9.2 percent. Results were highly dependent upon the state of the economy as described by the starting parameters although significant variations were achieved by changing only the random seed. These results were deemed compatible with historic data.
insofar as econometric reaction was considered. Results were fair to poor for interest rates and yields. Not only did yields of corporate bonds increase to unaccountably high levels, but comparable yields for indexes such as the Dow Jones Forty Bonds and Moody's Aa Corporates were spread by as much as three percent. These problems can no doubt be solved, but machine failures and inconsistencies experienced during this project have delayed some of these corrections.

Only three of the five runs referred to above were fully executed. The other two resulted in execution failures, although the runs were repeated with the same data and subsequently executed successfully.

Limitations

At the end of the previous chapter, mention was made of a size restriction encountered in working with the IBM 1620 Model I system. Pass Two will be the largest of the three programs comprising the full model, but data arrays cannot be expanded in any of the programs beyond the extent of the allowable size in Pass Two. The only solution to such memory constraints would be program subdivision, but then more passes would considerably lengthen computer execution time.

The whole problem rapidly diminishes if tape or disc capabilities are available. The program may then be executed in segments, thereby compensating for memory limitations.
Nevertheless, on a card-oriented system without these peripheral devices, such as the one available for this project, the model will be slow to execute, and the number of issues and players permissible will be limited. Perhaps even an abbreviated version of the model would be necessary before its use on such a system could be justified.

Conclusions

Stock market theory and historical price data were reviewed for the purpose of outlining the requirements necessary for a stock market simulation model. The model suggested by this research was presented as a business gaming device oriented toward investment education at the graduate or undergraduate level of formal business training. A proposed structure for this model was also presented, but it was specifically oriented to a particular computer system. Several specific simulation devices for the model were developed during this project and presented in this paper. These devices form a portion of the model which is an independent program and which was tested at the completion of the project.

Although the testing conducted was very limited in scope, the results provided information sufficient for several conclusions to be reached:
1. The AFIT KINGSTRAN/1620 system is inadequate for a model of this size and scope.

2. After four years—and on approximately one run in five, after two or three years—the model demonstrated some instability in bond yields and interest rates. The instabilities noted were tendencies toward abnormally high rates, sometimes over ten or eleven percent.

3. Aggregate measures of stock prices—specifically, the Dow Jones Industrial Average and Standard and Poor's Five Hundred Stock Composite—appeared to be realistic, but did not lead economic activity by as great a time period as was expected.

4. The model should be able to function effectively with minor changes if it is used in conjunction with a different computer and programming system.

Additional Requirements and Research

Several features could be added to the model structure outlined in this paper which would enhance its usefulness.

First, a tax rate could be carried in the data file for each player, and net performance could be calculated and included in account reports. This would create an additional constraint on the player's decisions, and would familiarize him with the tax implications of selecting various investment vehicles.

Second, a very realistic market could be created if industry codes were used in the model. A great deal of price
movement grouping is formed by industry association. This addition would require changes in both the SIMSTOCK economy and market so that information could be generated by industry categories as well as for the general state of the economy. Even if these changes could be effected without any increase in program size, however, the effort would not be justified unless a larger number of issues could be included in the model. No doubt a disc capability would be mandatory for this undertaking.

The feature of weighting the mean price change parameters of individual issues by the factors effecting issue price—general market buoyancy, money rates, real economic growth, earnings, and inflation—was presented earlier in this paper. Testing is still in progress to properly define this process so that the translation of events into parameter changes can take place.

1Brealey, Risk and Return, p. 63.
APPENDIX I

SIMSTOCK, PASS 2

COMMON W(60),E(30),NRPT(13),DJ(5),SP(5),RR(5), IV(5),AD(5),INT,LOOP
CALL UPDATE(1)

C MAIN LOOP
DO 50 I=1,LOOP
NT=0
CALL ECONMY
CALL ENVIRN
IF(NRPT(1)-2)50,55,55

C MONTHLY OUTPUT
55 PUNCH,(W(K),K=1,60)
PUNCH,(E(K),K=1,30)
DO 49 J=28,30
49 E(J)=0:
W(15)=E(1)
W(16)=E(1)
CONTINUE

C PUNCH PLAYER CARDS
CALL UPDATE(2)

100 STOP

END

SUBROUTINE UPDATE(KLM)
COMMON W(60),E(30),NRPT(13),DJ(5),SP(5),RR(5), IV(5),AD(5),INT,LOOP
DIMENSION IDATE(3),A(16),B(3),C(5)
GO TO (10,11),KLM

C READ PARAMETER CARD
10 READ 1,NPLYRS,NSTOCK,NWRNTS,NBONDS,NOPTNS,LOOP
1,(IDATE(K),K=1,3),RA
1NDOM
1 FORMAT(812,14,F9.8)

C STARTING DATE, THIS CYCLE
PUNCH,(IDATE(K),K=1,3)
READ,(W(K),K=1,60)
READ,(E(K),K=1,30)

C DETERMINE NEW RANDOM SEED FOR NEXT CYCLE
RANDOM=RAND(RANDOM)
J=213.*RAND(RANDOM)*RANDOM
10 FLOAT(IDATE(2)*IDAT
1E(1)+3))
PAGE 2 -- SIMSTOCK, PASS 2

C CYCLE RANDOM GENERATOR
DO 5 K=1,J
5 RANDOM=RAND(0.), RANDOM=RAND(-1.), RANDOM=ABS(RANDOM-FLOAT(INT(RANDOM)))
C DETERMINE COMPLETION DATE FOR THIS CYCLE, AND REPORT DUE
DO 25 I=1,LOOP
NRPT(1)=0
IDATE(1)=IDATE(1)+1
IF(IDATE(1)-4)12,12,15
12 NRPT(1)=1
GO TO 25
15 IDATE(2)=IDATE(2)+1
IDATE(1)=1
DO 17 KK=1,10,3
IF(IDATE(2)-KK)18,19,17
17 CONTINUE
18 NRPT(1)=2
GO TO 20
19 NRPT(1)=3
20 IF(IDATE(2)-12)25,25,21
21 IDATE(3)=IDATE(3)+1
IDATE(2)=1
NRPT(1)=4
25 CONTINUE
M=LOOP+1
DO 30 K=M,13
30 NRPT(K)=0
C PUNCH NEW PARAMETER CARD
PUNCH 1,NPLYRS,NSTOCK,NWRNTS,NBONDS,NOPTNS,LOOP
1P,(IDATE(K),K=1,3),R
RANDOM
PUNCH,(NRPT(K),K=1,13)
JJJ=2+NSTOCK+NWRNTS+NBONDS+NOPTNS
DO 2 KL=1,JJJ
READ 3,(A(MM),MM=1,16)
2 PUNCH 3,(A(MM),MM=1,16)
3 FORMAT(16A5)
RETURN
C READ PLAYER CARDS
C PUNCH PLAYER CARDS
11 DO 4 I=1,NPLYRS
READ 6,(B(K),K=1,3),(C(K),K=1,5),K1,K2,K3,K4
PUNCH 6,(B(K),K=1,3),(C(K),K=1,5),K1,K2,K3,K4
4 FORMAT(3A5,2F12.2,3F10.2,3I3,12)
6 FORMAT(3A5,2F12.2,3F10.2,3I3,12)

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JJJ=K1+K2+K3+K4
DO 4 KL=1, JJJ
READ 3, (A(MM), MM=1,16)
4 PUNCH 3, (A(MM), MM=1,16)
RETURN
END

SUBROUTINE ECONMNY
COMMON W(60), E(30), NRPT(13), DJ(5), SP(5), RR(5),
1V(5), AD(5), INT, LOOP
IF(NRPT(1)-1)8,8,5
5 DO 4 J=9,11
4 W(J)=FLOAT(INT(W(J)))+1.
W(14)=W(14)+1:
9 GO TO (8,3,2,1), NRPT(1)
1 CALL PRIMRT
E(17)=0.
E(18)=0.
2 CALL GNPROD
3 CALL BARMTR
CALL FRBIND
CALL CIPIND
CALL MONIES
8 RETURN
END

SUBROUTINE PRIMRT
COMMON W(60), E(30), NRPT(13), DJ(5), SP(5), RR(5),
1V(5), AD(5), INT, LOOP
IF(NT)1,40,1
1 IF(W(11)-1)40,23,2
23 IF((.95+.1*ABS(FLOAT(NT)))-RAND(0.))2,60,60
2 NNT=NT+4
Y=W(13)
GO TO (3,4,5,40,5,4,3), NNT
3 X=W(8)+.25*FLOAT(NT+INT(3.*ABS(RAND(-1.))*)RAND(1.0))
SAVE=(1.5*RAND(0.))*(X-W(8))
12 W(12)=W(12)+SAVE
W(13)=SIGN(SAVE)*50.
14 IF(SIGN(W(13))-SIGN(Y))15,6,15
15 W(14)=0.
GO TO 6
4 X=W(8)+FLOAT(NT)*.25
W(13)=W(13)+10.*X
GO TO 14
5 IF(RAND(0.))-.5)40,40,4
6 IF(X-.10.)7,8,8
7 IF(X-.4.)9,9,10

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8 X=X-.25
9 X=X+.25
10 IF(X-W(8))21,61,21
21 DO 11 J=6,10
11 W(J)=W(J+1)
12 W(8)=X
13 W(11)=0.
S=W(8)-W(7)
TYPE 75,S
PUNCH 75,S
75 FORMAT(5HPRIME,F10.3)
RETURN
40 IF(W(11))44,60,44
44 IF((STAT(W,45,57,1)-STAT(W,32,44,1))-.02)60,45
W(12)=W(12)-.25
16 W(12)=W(12)+.25
NT=1
50 GO TO 1
60 NT=0
RETURN
61 W(30)=X-7.
RETURN
END
SUBROUTINE GNPROD
COMMON W(60),E(30),NRPT(13),DJ(5),SP(5),RR(5),
1V(5),AD(5),I,NT,LOOP
BASE=STAT(W,1,5,3)
W(5)=W(4)+W(5)
DO 5 J=4,2,-1
5 W(J)=W(J-1)
X=STAT(W,32,35,1)
Y=STAT(W,45,48,1)
W(1)=BASE*(X+Y+X*Y)
RETURN
END
SUBROUTINE BARMTR
COMMON W(60),E(30),NRPT(13),DJ(5),SP(5),RR(5),
1V(5),AD(5),I,NT,LOOP
W(31)=W(31)+1.
1F(W(30))107,106,107
106 W(30)=.00001
C  HAS PRIME CHANGED (CURRENT MONTH)
107 IF(W(11))5,4,5
  4 W(30)=W(30)+.5*(W(7)-W(8))
  GO TO 104
C  HAS PRIME CHANGED (LAST MONTH)
  5 IF(W(11)-1::104,84,104
  84 W(30)=W(30)+1.5*(W(7)-W(8))
  W(11)=1:1
103 IF(W(31)-3::10,10,104
104 SAVE=W(29)
C  LATEST BIAS
  W(30)=W(30)-W(30)/ABS(W(30))*(.15*W(30)+.25*ABS(RAND(-1:)))*(SIGN(W(31))-.5)
C  HAS SIGN OF BIAS CHANGED
  IF(W(30)/ABS(W(30))-SAVE/ABS(SAVE))2,85,2
  2 W(30)=W(30)+W(30)/ABS(W(30))*ABS(RAND(-1:))
  W(29)=W(30)/ABS(W(30))
  W(31)=0
  GO TO 10
85 IF(NRPT(1)-3)10,6,10
  6 IF(W(31)-12::10,7,7
  7 DO 8 KL=29,31
  8 W(KL)=0.00000001
  175 SAVE=(STAT(W,25,28,3)+((RAND(0.)4RAND(0.)4RAND(0.:))/3.)+W(30))/5.
  96 IF(SAVE)11,11,12
  11 W(30)=.5+W(30)
  SAVE=SAVE+.1*RAND(0:)
  GO TO 96
  12 IF(SAVE-1::15,14,13
  13 W(30)=W(30)-.5
  14 SAVE=SAVE-.05*RAND(0:)
  GO TO 12
  15 DO 16 J=28,21,-1
  16 W(J)=W(J-1)
  W(20)=SAVE
  RETURN
END
C  SUBROUTINE FRBIND
COMMON W(60),E(30),NRPT(13),DJ(5),SP(5),RR(5),
  IV(5),AD(5),NT,LOOP
C  IS ANNUAL RATE OF FRB INDEX UNDER TWO PERCENT
  IF(STAT(W,32,44,1)-.02)15,15,5
C  WAS RATE OF INCREASE NEGATIVE LAST QUARTER

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5 IF(STAT(W,32,35,1))10,25,25
10 NT=1

C UNEMPLOYMENT
W(60)=W(60)+(RAND(0.5)+RAND(0.5))/2;
GO TO 20
15 NT=2
20 CALL PRIMRT

C SHIFT FRB INDEX ARRAY
25 DO 30 J=44,33,-1
30 W(J)=W(J-1)

C DETERMINE FRB INDEX FOR NEW MONTH
W(32)=W(32)*(1+(6.5-W(7))/200.4RAND(0.)/125.
1+(STAT(W,23,25,3)+W(123)-2.)/300.5
IF(Abs(W(32)-W(33))-8)33,33,32
32 W(32)=W(32)+SIGN(W(32)-W(33))*1.01*RAND(0.2)
33 W(60)=W(60)-SIGN(W(32)-W(33))*RAND(0.2)/20.
40 IF(W(60)-4.5)45,35,35
45 IF(W(60)-2.5)46,46,47
47 RETURN

END

C SUBROUTINE CPINDX
COMMON W(60),E(30),NRPT(13),DJ(5),SP(5),RR(5),AD(5),I,N,T,LOOP
C WAS LATEST ANNUAL INCREASE IN CPI GREATER THAN 5 EVEN PERCENT
10 IF(STAT(W,45,57,1)-.07)10,20,20

C WAS LATEST QUARTER GREATER THAN TWO PERCENT
10 IF(STAT(W,45,48,1)-.02)30,15,15
15 NT=1
20 GO TO 25
20 NT=2
25 CALL PRIMRT

C SHIFT CONSUMER PRICE INDEX ARRAY
30 DO 35 J=57,46,-1
35 W(J)=W(J-1)

C DETERMINE CONSUMER PRICE INDEX FOR NEW MONTH
W(45)=W(46)*(1+(6.8-W(7))/200.4RAND(0.)/160.
1)
40 IF(Abs(W(45)-W(46))-8)45,40,40
45 RETURN

END

C SUBROUTINE MONIES

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COMPUTE ANNUAL AND QUARTERLY CPI CHANGES (PERCENTS)

DETERMINE COMMERCIAL PAPER RATE, DEP UPON BUS EXPANSION, CURRENT QUARTER

C HAS THERE BEEN MORE THAN 12 MONTHS OF RESTRAINT/EXPANSION

SUBROUTINE ENVIRN

SUBROUTINE MONTLY
\[
X = \frac{(\text{FLOAT}(NT)+\text{RAND}(0.;+8\times\text{RAND}(0.)))/1000.}{\text{IF}(\text{NT})1,3,2}
\]

**PARAMETER CHANGE, STANDARD AND POORS 500 COMPOSITION**

1. IF (E(26)) 101, 102, 101
   
   101 E(6) = E(6) - E(26)*X
   
   E(26) = 0;
   
   E(2) = E(2)/2.
   
   GO TO 103

2. IF (E(20) - 2.1) 109, 107, 107
   
   107 E(6) = E(6) + X
   
   E(26) = NT

3. IF (E(7) = E(6) * (1+\text{ABS}(\text{RAND}(-1.;))/1.5)
   
   TYPE 761, E(6), E(7)

761 FORMAT (/3HS-P, 2F10.6/)

4. RETURN

**PARAMETER CHANGE, DOW JONES INDUSTRIALS AVERAGE**

1. IF (E(26)) 104, 105, 104
   
   104 E(2) = E(2) + E(26)*X
   
   E(26) = 0;
   
   E(6) = E(6)/2.
   
   GO TO 106

2. IF (E(19) = 2.1) 110, 108, 108
   
   108 E(2) = E(2) + X
   
   E(26) = NT

3. NT = 0
   
   E(19) = 0;
   
   E(3) = E(2) * (1+\text{ABS}(\text{RAND}(-1.;))/1.5)
   
   TYPE 762, E(2), E(3)

762 FORMAT (/3HDJA, 2F10.6/)

4. RETURN

**NUMBER OF ISSUES LISTED, NEW YORK STOCK EXCHANGE**

3. E(8) = \text{INT}(E(8) * (0.55 + (2.1*\text{RAND}(0.;)-1.5*\text{RAND}(0.))/1)

**VOLUME FACTOR**

1. E(11) = E(11) + 0.55 + 3.1*\text{RAND}(-1.;)

**BARRONS CONFIDENCE INDEX**

1. E(23) = E(28)/E(29)

73. E(19) = E(19) + 1;

E(20) = E(20) + 1.

**SHORT INTEREST**

1. IF (E(6)) 12, 13, 12
   
   12 E(16) = E(16) - E(6)*E(30)*1.75+\text{RAND}(0.;)/10.
   
   GO TO 14

302
110

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13 \( E(16) = E(16) - \text{SIGN}(W(30)) \times \text{RAND}(0.) + \text{RAND}(0.) + \text{RAND}(0.) / 2 \)

14 IF \((E(16) - \text{ABS}(E(16))) \leq 31\), 31, 32

31 \( E(16) = E(16) + 5 \times \text{RAND}(0.) \)

GO TO 14

32 IF \((E(16) - 2.85) \leq 34\), 34, 33, 33

33 \( E(16) = E(16) - \text{RAND}(0.) / 5 \)

GO TO 32

34 PUNCH \( B_3, E(23), E(16) \)

83 \( \text{FORMAT}('5HC0NF>,F10.7,5HSH0RT,F10.5') \)

7 IF \((\text{RAND}(0.7) - (0.05 \times (E(19) + E(20) - 4.))) \geq 17\), 17, 15, 15

C PARAMETER CHANGE, DJIA AND S-P

17 \( E(19) = 0. \)

18 \( E(20) = 0. \)

DO 8 \( J = 2,6,4 \)

39 IF \((E(J+1) - \text{ABS}(E(J))) \leq 62\), 62, 62

40 IF \((E(J+1) - \text{ABS}(3.6 \times E(J))) \leq 8,8,41\)

41 \( E(J+1) = E(J+1) - 5 \times \text{ABS}(E(J)) \)

GO TO 40

62 \( E(J+1) = 2.6 \times E(J+1) \)

GO TO 39

8 CONTINUE

TYPE 763, \( E(2), E(3), E(6), E(7) \)

763 \( \text{FORMAT}('4HBOTH,4F10.6') \)

GO TO 18

C CHECK PERCENTAGE ADVANCE/DECLINE OF MARKET AGGREGATES

15 IF \((E(17) - \text{ABS}(E(17))) \geq 2\), 10, 10, 9

9 IF \((E(18) - \text{ABS}(E(18))) \geq 42\), 42, 11, 11

10 \( \text{NT} = 2 \)

42 \( \text{IF}(E(26)) \leq 16, 18, 16 \)

16 \( \text{NT} = \text{E}(26) \)

51 \( \text{E}(26) = \text{SIGN}(E(17)) \)

GO TO 19

52 \( \text{E}(26) = \text{SIGN}(E(18)) \)

GO TO 19

18 RETURN

END
SUBROUTINE DJONES
COMMON W(60),E(30),NRP,T(13),DJ(5),SP(5),RR(5),
V(5),AD(5),I,NT,LOOP

C DID PRIME RATE CHANGE THIS MONTH
IF(W(11))2,1,2
1 NT=4*W(7)-W(8)
E(26)=0
CALL MNTHLY
2 X=RAND(0.5)-RAND(0.5)
Y=RAND(0.5)-RAND(0.5)

C COMPUTE DAILY PRICES FOR MARKET AGGREGATES, CURRENT WEEK
DO 3 J=1,5
1 IF(J-1)5,5,4
4 X=STAT(DJ,J,J-1,2)/ABS(STAT(DJ,J,J-1,2))
Y=STAT(SP,J,J-1,2)/ABS(STAT(SP,J,J-1,2))
5 DJ(J)=PRICES(E(1),E(2),E(3),X)
SP(J)=PRICES(E(5),E(6),E(7),Y)
3 RR(J)=(DJ(J)+14.7)/3+3*RND(-1.)

C INCREMENT PERCENTAGE ADVANCE/DECLINE COUNTERS
E(17)=E(17)+(DJ(5)-E(1))/E(1)
E(18)=E(18)+(SP(5)-E(5))/E(5)

105 PUNCH,(DJ(J),J=1,5),(RR(J),J=1,5),(SP(J),J=1,5)
106 E(4)=RR(5)
1 IF(ABS(E(2))=.006)9,9,8
8 E(2)=E(2)/2
E(3)=1.5*E(2)
9 IF(ABS(E(6))=.006)11,11,10
10 E(6)=E(6)/2
E(7)=1.5*E(6)

C RETAINING MONTHLY HIGH AND LOW FOR DJIA
11 W(15)=MAX(W(15),DJ(1),DJ(2),DJ(3),DJ(4),DJ(5))
1
W(16)=MIN(W(16),DJ(1),DJ(2),DJ(3),DJ(4),DJ(5))
1

6 RETURN
END

SUBROUTINE VOLUME
COMMON W(60),E(30),NRP,T(13),DJ(5),SP(5),RR(5),
V(5),AD(5),I,NT,LOOP

L=SIGN(SP(1)-E(5))+2
YX=(SP(1)-E(5))/E(5)
E(1)=DJ(5)
E(5)=SP(5)
ZZ=(.9+30.5*ABS(E(6)))*E(8)
11 IF(ZZ-E(8))1,1,12
12 ZZ=ZZ-20.*RND(0.5)
GO TO 11

1 DO 8 J=1,5

C DETERMINE DAILY VOLUME, NYSE
   V(J)=E(11)*Z/1.55+SIGN(RAND(-1))*1.5*ABS(Y)
   1X+1.5*RAND(-1))

C COMPUTE ISSUES TRADED DAILY, NYSE
   RR(J)=ZZ+SIGN(RAND(-1))*10*rand(0.2)+3*(V(J))
   1-8)
   IF(RR(J)-E(8))102,102,101
   101 RR(J)=E(8)-5*RAND(0.2)
   102 IF(J=5)9,10,10

C VOLUME IN MILLIONS OF SHARES TRADED (MONTHLY SUM
   MATION)
   10 E(30)=E(30)*V(J)
   101 IF(E(6)<0.004)2,2,3
   2 X=RAND(0.2)
   101 IF(X=.2)4,4,2
   3 X=.0002/(ABS(E(6))+.001*RAND(0.2))
   4 X=RR(J)*(1-X)
   5 Y=RAND(0.2)+RAN(0.2))/.2
   6 Z=1-Y
   GO TO (5,6,6),L

C DECLINES GREATER
   5 DJ(J)=MAX(Y,Z)*X
   10 SAVE=MIN(Y,Z)*X
   GO TO 7

C ADVANCES GREATER
   6 SAVE=MIN(Y,Z)*X
   101 DJ(J)=MIN(Y,Z)*X
   7 IF(J=5)17,16,16
   16 SP(J)=SAVE
   17 L=SIGN(SP(J)+1)-SP(J))+2
   101 IF(ABS(E(6))-0.001)16,21,21
   21 L=SIGN(E(6))+2
   16 SP(J)=SAVE
   17 L=SIGN(AD(J)+1)-AD(J))/RR(J)
   8 E(12)=AD(J)

106 PUNCH(RR(J),J=1,5),(V(J),J=1,5),(SP(J),J=1,5)
   1, (DJ(J),J=1,5),(AD(J)
   1),J=1,5)

C SUBROUTINE MOODY'S
   COMMON W(60),E(30),NRPT(13),DJ(5),SP(5),RR(5),
   1V(5),AD(5),1,INT,LOOP

C DID PRIME RATE CHANGE THIS MONTH
C PREVENT ADDITIONAL FLUCTUATIONS DUE TO THIS CHANGE

W(11) = .01
GO TO 6
5 X = 5 * (STAT(W, 32, 33, 1) - .0035)
TYPE, 5
6 Y = RAND(0.)
TYPE, 6, W(30)
Z = W(30)/10.
TYPE, 6, 1, E(15)
TYPE, 6, 3, E(13)
TYPE, 6, 1, Z
E(14) = E(13) + (RAND(0.0) + RAND(0.0) + RAND(0.0))/10.
TYPE, 34, E(14)
E(15) = E(13) - (RAND(0.0) + RAND(0.0) + RAND(0.0))/10.
TYPE, 6, 2, E(15)
34 IF (Z) 32, 9, 31
31 IF (E(14) - E(15) - .02) 9, 9, 10
9 E(14) = E(14) + .015
TYPE, 9
E(15) = E(15) - .015
GO TO 31
32 IF ((E(15) - E(14))/Z) 33, 10, 10
33 E(15) = E(15) + RAND(0.0)/3.
TYPE, 33
E(14) = E(14) - RAND(0.0)/3.
GO TO 32
10 IF (E(13) = E(14))/13, 13, 11
11 IF ((E(13) - E(14))/5) 14, 14, 12
12 E(13) = E(13) - .5*RAND(0.0)
TYPE, 12
GO TO 10
13 E(14) = E(14) + .1*RAND(0.0)
TYPE, 13
14 X = E(14) - E(15)
TYPE, 14
E(13) = E(15) + AMAX((Y*X), ((1:-Y)*X))
TYPE, 14, 1
E(24) = E(13) - (RAND(0.0) + RAND(0.0))/1.5 + 5.*((1:-E(2
13))
TYPE, 14, 2
E(25) = W(19) - RAND(0.)
TYPE, 14, 3

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IF (ABS (E(24) - E(25)) - 1.255) < 24,24,21
21 IF (E(24) - E(25)) > 22,24,23
22 E(24) = E(24) + RAND(0.) / 5.
   TYPE, 22
   E(25) = E(25) - RAND(0.) / 5.
   TYPE, 22, 1
   GO TO 24
23 E(24) = E(24) - RAND(0.) / 5.
   TYPE, 23
   E(25) = E(25) + RAND(0.) / 5.
   TYPE, 23, 1
24 E(28) = E(28) + E(14)
   TYPE, 24
   E(29) = E(29) + E(15)
   TYPE, 24, 1
782 FORMAT (/2F7.2, 7F7.2, 2F8.2/) 481
RETURN 482
END

FUNCTION PRICES (PR, TMU, SD, Z) 484
NORMALLY-DISTRIBUTED PERCENTAGE CHANGE IN PRICE,
DP
   DP = RAND(-1.) * SD + TMU
   IF (RAND(0.) - .5) < 5, 10, 10
5   DP = DP * Z
10   PRICES = PR * (DP + 1)
RETURN 488
END

FUNCTION STAT (X, M, N, JJ) 491
DIMENSION X(60)
GENERAL-PURPOSE FUNCTION FOR ARRAY CALCULATIONS
GO TO (5, 10, 15), JJ
C
PERCENTAGE INCREASE/DECREASE
5   STAT = (X(M) - X(N)) / X(N)
RETURN 494
C
DIFFERENCE
10   STAT = X(M) - X(N)
RETURN 497
C SUMMATION OVER N-M ELEMENTS
15 STAT=0
DO 20 K=M,N
20 STAT=STAT+X(K)
RETURN
END
APPENDIX II

GLOSSARY

**Econometric Data**

The list below identifies the elements of array \( (W(K), K=1,60) \):

<table>
<thead>
<tr>
<th>Value of K</th>
<th>Identity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Current quarterly increase in Gross National Product</td>
<td>billions of current dollars</td>
</tr>
<tr>
<td>2</td>
<td>Quarterly increase in Gross National Product, one quarter ago</td>
<td>billions of current dollars</td>
</tr>
<tr>
<td>3</td>
<td>Quarterly increase in Gross National Product, two quarters ago</td>
<td>billions of current dollars</td>
</tr>
<tr>
<td>4</td>
<td>Quarterly increase in Gross National Product, three quarters ago</td>
<td>billions of current dollars</td>
</tr>
<tr>
<td>5</td>
<td>*Actual Gross National Product, one year ago</td>
<td>billions of current dollars</td>
</tr>
<tr>
<td>6</td>
<td>Prime rate, two changes ago</td>
<td>**percent</td>
</tr>
<tr>
<td>7</td>
<td>Prime rate, last change</td>
<td>percent</td>
</tr>
<tr>
<td>8</td>
<td>Prime rate, current</td>
<td>percent</td>
</tr>
<tr>
<td>9</td>
<td>Time since ( W(6) ) determined</td>
<td>months</td>
</tr>
<tr>
<td>10</td>
<td>Time since ( W(7) ) determined</td>
<td>months</td>
</tr>
<tr>
<td>Value of K</td>
<td>Identity</td>
<td>Units</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>11</td>
<td>Time since W(8) determined</td>
<td>months</td>
</tr>
<tr>
<td>12</td>
<td>Federal Reserve Board, discount rate</td>
<td>**%</td>
</tr>
<tr>
<td>13</td>
<td>Federal Reserve Board index of restraint</td>
<td>units</td>
</tr>
<tr>
<td>14</td>
<td>Arithmetic sign of W(13)</td>
<td>t1</td>
</tr>
<tr>
<td>15</td>
<td>High, Dow Jones Industrial Average, current month</td>
<td>units</td>
</tr>
<tr>
<td>16</td>
<td>Low, Dow Jones Industrial Average, current month</td>
<td>units</td>
</tr>
<tr>
<td>17</td>
<td>Not currently used</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Not currently used</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Four - six month prime commercial paper rate</td>
<td>**%</td>
</tr>
<tr>
<td></td>
<td>BAROMETRIC DIFFUSION INDEX</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(t in months)</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Value for month t+3</td>
<td>**%</td>
</tr>
<tr>
<td>21</td>
<td>Value for month t+2</td>
<td>percent</td>
</tr>
<tr>
<td>22</td>
<td>Value for month t+1</td>
<td>percent</td>
</tr>
<tr>
<td>23</td>
<td>Value for month t (current month)</td>
<td>percent</td>
</tr>
<tr>
<td>24</td>
<td>Value for month t-1</td>
<td>percent</td>
</tr>
<tr>
<td>Value of K</td>
<td>Identity</td>
<td>Units</td>
</tr>
<tr>
<td>-----------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>25</td>
<td>Value for month t-2</td>
<td>percent</td>
</tr>
<tr>
<td>26</td>
<td>Value for month t-3</td>
<td>percent</td>
</tr>
<tr>
<td>27</td>
<td>Value for month t-4</td>
<td>percent</td>
</tr>
<tr>
<td>28</td>
<td>Value for month t-5</td>
<td>percent</td>
</tr>
<tr>
<td>29</td>
<td>Arithmetic sign of bias factor</td>
<td>±1</td>
</tr>
<tr>
<td>30</td>
<td>Bias factor</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Time since change of sign, W(29)</td>
<td>months</td>
</tr>
</tbody>
</table>

FEDERAL RESERVE BOARD INDEX OF INDUSTRIAL PRODUCTION

<table>
<thead>
<tr>
<th>Value for month t (current month)</th>
<th>units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value for month t-1</td>
<td>units</td>
</tr>
<tr>
<td>Value for month t-2</td>
<td>units</td>
</tr>
<tr>
<td>Value for month t-3</td>
<td>units</td>
</tr>
<tr>
<td>Value for month t-4</td>
<td>units</td>
</tr>
<tr>
<td>Value for month t-5</td>
<td>units</td>
</tr>
<tr>
<td>Value for month t-6</td>
<td>units</td>
</tr>
<tr>
<td>Value for month t-7</td>
<td>units</td>
</tr>
<tr>
<td>Value of K</td>
<td>Identity</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>40</td>
<td>Value for month t-8</td>
</tr>
<tr>
<td>41</td>
<td>Value for month t-9</td>
</tr>
<tr>
<td>42</td>
<td>Value for month t-10</td>
</tr>
<tr>
<td>43</td>
<td>Value for month t-11</td>
</tr>
<tr>
<td>44</td>
<td>Value for month t-12</td>
</tr>
</tbody>
</table>

**CONSUMER PRICE INDEX**

<table>
<thead>
<tr>
<th>Value</th>
<th>Identity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>Value for month t (current month)</td>
<td>units</td>
</tr>
<tr>
<td>46</td>
<td>Value for month t-1</td>
<td>units</td>
</tr>
<tr>
<td>47</td>
<td>Value for month t-2</td>
<td>units</td>
</tr>
<tr>
<td>48</td>
<td>Value for month t-3</td>
<td>units</td>
</tr>
<tr>
<td>49</td>
<td>Value for month t-4</td>
<td>units</td>
</tr>
<tr>
<td>50</td>
<td>Value for month t-5</td>
<td>units</td>
</tr>
<tr>
<td>51</td>
<td>Value for month t-6</td>
<td>units</td>
</tr>
<tr>
<td>52</td>
<td>Value for month t-7</td>
<td>units</td>
</tr>
<tr>
<td>53</td>
<td>Value for month t-8</td>
<td>units</td>
</tr>
<tr>
<td>54</td>
<td>Value for month t-9</td>
<td>units</td>
</tr>
<tr>
<td>55</td>
<td>Value for month t-10</td>
<td>units</td>
</tr>
</tbody>
</table>
### Market Aggregates

The list below identifies the elements of array \( E(K), K=1,30 \):

<table>
<thead>
<tr>
<th>Value of ( K )</th>
<th>Identity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Current value, Dow Jones Industrial Averages</td>
<td>dollars</td>
</tr>
<tr>
<td>2</td>
<td>Mean daily change parameter, Dow Jones Industrial Averages</td>
<td>percent</td>
</tr>
<tr>
<td>3</td>
<td>Standard deviation parameter, Dow Jones Industrial Averages</td>
<td>percent</td>
</tr>
<tr>
<td>4</td>
<td>Current value, Dow Jones Transportation Average</td>
<td>dollars</td>
</tr>
<tr>
<td>5</td>
<td>Current value, Standard &amp; Poor's 500 Stock Composite</td>
<td>dollars</td>
</tr>
<tr>
<td>Value of K</td>
<td>Identity</td>
<td>Units</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>6</td>
<td>Mean daily change parameter, Standard &amp; Poor's 500 Stock Composite</td>
<td>percent</td>
</tr>
<tr>
<td>7</td>
<td>Standard deviation parameter, Standard &amp; Poor's 500 Stock Composite</td>
<td>percent</td>
</tr>
<tr>
<td>8</td>
<td>Number of issues listed, New York Stock Exchange</td>
<td>units</td>
</tr>
<tr>
<td>9</td>
<td>Latest number of issues advancing</td>
<td>units</td>
</tr>
<tr>
<td>10</td>
<td>Latest number of issues declining</td>
<td>units</td>
</tr>
<tr>
<td>11</td>
<td>Volume factor, New York Stock Exchange</td>
<td>units</td>
</tr>
<tr>
<td>12</td>
<td>Latest value, advance/decline ratio</td>
<td>actual</td>
</tr>
<tr>
<td>13</td>
<td>Moody's Aa Composite (Yields)</td>
<td>**percent</td>
</tr>
<tr>
<td>14</td>
<td>Barrons' 10 Hi-Grade Bonds (Yields)</td>
<td>percent</td>
</tr>
<tr>
<td>15</td>
<td>Dow Jones 40-Bond Index (Yields)</td>
<td>percent</td>
</tr>
<tr>
<td>16</td>
<td>Latest value, short interest ratio</td>
<td>actual</td>
</tr>
<tr>
<td>17</td>
<td>Percentage change, Dow Jones Industrial Average, current year</td>
<td>percent</td>
</tr>
<tr>
<td>18</td>
<td>Percentage change, Standard &amp; Poor's 500 Stock Composite, current year</td>
<td>percent</td>
</tr>
<tr>
<td>Value of ( K )</td>
<td>Identity</td>
<td>Units</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>19</td>
<td>Time since last Dow Jones Industrial Average parameter change</td>
<td>months</td>
</tr>
<tr>
<td>20</td>
<td>Time since last Standard &amp; Poor's 500 Stock Composite parameter change</td>
<td>months</td>
</tr>
<tr>
<td>21</td>
<td>Initial margin requirement</td>
<td>percent</td>
</tr>
<tr>
<td>22</td>
<td>Maintenance margin requirement</td>
<td>percent</td>
</tr>
<tr>
<td>23</td>
<td>Latest value, Barron's Confidence Index</td>
<td>actual</td>
</tr>
<tr>
<td>24</td>
<td>Current yield, 5-year Treasury Bonds</td>
<td>percent</td>
</tr>
<tr>
<td>25</td>
<td>Current yield, 6-month Treasury bills</td>
<td>percent</td>
</tr>
<tr>
<td>26</td>
<td>Calling bit for parameter change routine: 0 for no change, + for Dow Jones Industrial Average Index, - for Standard &amp; Poor's 500 Stock Composite Index</td>
<td>+1</td>
</tr>
<tr>
<td>27</td>
<td>Margin requirement, U.S. Government securities</td>
<td>percent</td>
</tr>
<tr>
<td>28</td>
<td>Monthly summation, Barron's 10 Hi-Grade Bonds</td>
<td>actual</td>
</tr>
<tr>
<td>29</td>
<td>Monthly summation, Dow Jones 40-Bonds</td>
<td>actual</td>
</tr>
</tbody>
</table>
Value of K | Identity | Units
---|---|---
30 | Monthly summation, New York Stock Exchange volume | (millions)


** $7\frac{1}{2}$ percent = 7.5

*** Magnitude indicates amount, sign indicates direction
(+ = restraint; - = expansion)

The list below defines some of the other variable names used in SIMSTOCK:

1. AD(5) - daily advance/decline ratio (cumulative)
2. BOND$s$ (I,J) - array of bond information for I bonds
   for J=1,2-10 character alphanumeric name
   =3-current price as percent of face value
   =4-annual coupon as percent of face value
   =5-face value factor and identifier (type of bond)
   =6-maturity date
   =7-numeric rating
   =8-letter rating
3. CPN(J) - coupon payments per bond J, current cycle
4. DIV(I) - dividends payable for stock I, current cycle
   (deductible for short positions)
5. DJ(K) - closing daily prices, Dow Jones Industrial Average
   or daily number of issues declining
6. \texttt{IDATE(K)} - Pass Two clock
   for \(K=1\), number of current week (1,2,3, or 4)
   =2, number of current month (1 to 12)
   =3, number of current year (14)

7. \texttt{KDATE(K)} - Pass Three simulator clock, same as \texttt{IDATE}

8. \texttt{LOOP} - number of weeks per cycle (changed in Pass One)

9. \texttt{NBONDS} - number of bonds in game

10. \texttt{NOPTNS} - number of options in game

11. \texttt{NPLYRS} - number of players in game

12. \texttt{NRPT(13)} - reporting codes for up to 12 weeks
    (by definition, \(NRPT(\text{LOOP+1})=0\))

13. \texttt{NSTOCK} - number of stocks in game

14. \texttt{NWRNTS} - number of warrants in game

15. \texttt{OPTION (I,J)} - array of I options
    for \(J=1\), contract price
    =2, option code
    =3, object common stock
    =4, expiration date

16. \texttt{RANDOM} - current random seed for next cycle

17. \texttt{RR(5)} - daily closing prices, Dow Jones Transportation
    or daily number of New York Stock Exchange
    issues traded
18. SP(5) - daily closing prices, Standard & Poor's 500 Stock Composite or daily number of issues advancing, New York Stock Exchange

19. STOCKS (I,J) - array of I stocks for J=1,2, 10 character alphanumeric name =3, market identifier and split factor =4, current price =5, current mean change parameter =6, current standard deviation parameter =7, current earnings per share =8, latest dividend =9, months to next dividend payment, and number of months for current parameters =10, unadjusted initial price

Price Movement Factors =11, credit rates =12, market, general performance of aggregates =13, firm =14, industry =15, Consumer Price Index (cost of living)

20. VJ(5) - daily volume, New York Stock Exchange, in millions of shares

21. WARNTS (I,J) - array of I warrants for J=1, current price =2, cash conversion =3, effective date (0.0 if passed) =4, terminal date (0.0 if perpetual) =5, number of warrants per share =6, common stock identifier
22. **WKLY (I,J)** - is array of weekly market data in Pass Three for day J
   
   when I=1, Dow Jones Industrial Average
   =2, Dow Jones Transportation
   =3, Standard & Poor's 500 Stock Composite
   =4, issues traded, New York Stock Exchange
   =5, volume, New York Stock Exchange
   =6, number advancing
   =7, number declining
   =8, number unchanged (computed in Pass Three)
   =9, advance decline ratio

* This array is also used in Pass Three for processing player cards.
  One card per order follows a player card with general information:
  (1) a fifteen alphanumeric player name;
  (2) cash balance;
  (3) portfolio market value;
  (4) debits;
  (5) total brokerage charges, all cycles;
  (6) margin status;
  (7) number of issues owned;
  (8) number of option contracts still in effect.
APPENDIX III

NOTES ON RANDOM GENERATION

Fundamental parts of SIMSTOCK are the random generators required for the econometric and pricing subroutines. All computer-generated "random" numbers are the result of arithmetic processes, and it can therefore be argued that such sequences are really "deterministic." Nevertheless, simple arithmetic processes exist which are capable of generating a series of numbers statistically equivalent to a sequence of random numbers. These processes are referred to as pseudo-random generators. D. H. Lehmer's definition of a random sequence is a useful one: "...a vague notion embodying the idea of a sequence in which each term is unpredictable to the uninitiated and whose digits pass a certain number of tests traditional with statisticians."¹ Both uniformly-distributed and normally-distributed generation were required in the model, and two generative processes were considered for each requirement.

The simplest and most widely used generators are "residual," or "congruence," methods of the form:

\[ R_{i+1} = (AR_i + B) \mod C. \]

The KINGSTRAN FORTRAN II compiler includes two library functions of this form. The first is a power residue, or simple multiplicative function, called RANL (Subroutine Number 20) whose output is uniform over the range 0.0 to 1.0, excluding the end points; it employs values of A=23.0, B=0.0, and C=1.00000001.\(^1\) The second function, RAND (Subroutine Number 74), employs a "mixed" multiplicative method (B≠0.0). Both generators appeared satisfactory for the requirements of the model. The RAND generator was chosen based upon testing performed by students in a seminar conducted during the Winter 1970-1971 term at Malmstrom.\(^2\)

The RAND library function is also designed to generate normally-distributed numbers of mean=0.0 and standard deviation=1.0, by summing twelve consecutive numbers uniformly distributed between 0.0 and 1.0 and then subtracting 6.0 from the sum. The individual numbers summed are calculated by the uniform process RAND where A=1010101., B=.00096327, and C=1.0.\(^3\) A second normal generator considered also uses inputs from a uniform generator, but uses


\(^2\)Course BA 691B. Testing included Chi-square on subintervals, mean value of sample, ten-dimensional random walk, poker test, and gap test.

\(^3\)KINGSTRAN Manual, p. 67.
only two such values per computation. The formula employed is

\[ R_n = \left( \sqrt{-2r_1} \right) \cosine(2\pi r_2), \]

where \( r_1 \) and \( r_2 \) are the two uniformly-distributed values. The process is a close relative of the Monte Carlo technique used to evaluate integrals.

Output of these generators, as mentioned previously, consists of random normal deviates, or "Z"-values. These values may be transformed to \( KZ + U \) where \( K \) is the desired standard deviation and \( U \) is the desired mean. Both process generators were tested for sample mean and standard deviation, kurtosis, and goodness-of-fit. Testing was conducted on five runs for each generator, each run being one thousand consecutive normal deviates. Each run was begun with a different starting "seed" for the underlying uniform processes used as inputs; these seeds were chosen from a random number table. The test program calculated the following sample means and standard deviations for each run, and for the over-all sample of 5000:

---

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Mean (RAND)</th>
<th>Mean (Formula)</th>
<th>Standard Deviation (RAND)</th>
<th>Standard Deviation (Formula)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.02379</td>
<td>.04191</td>
<td>.96965</td>
<td>1.03534</td>
</tr>
<tr>
<td>2</td>
<td>-.03358</td>
<td>-.05662</td>
<td>1.00233</td>
<td>.98698</td>
</tr>
<tr>
<td>3</td>
<td>-.01492</td>
<td>.01205</td>
<td>.99019</td>
<td>.98663</td>
</tr>
<tr>
<td>4</td>
<td>-.00174</td>
<td>-.03660</td>
<td>.98602</td>
<td>.98573</td>
</tr>
<tr>
<td>5</td>
<td>-.00674</td>
<td>.02591</td>
<td>1.02096</td>
<td>1.03236</td>
</tr>
<tr>
<td>Total</td>
<td>-.00664</td>
<td>-.00267</td>
<td>.99375</td>
<td>1.00598</td>
</tr>
</tbody>
</table>

The results of each run have been listed to show how misleading the total sample statistics are; the RAND process generator was superior in every run except number three for mean error, and had a more consistent standard deviation in each of the five test sequences.

All 5000 values generated by each method were tabulated on an expected frequency basis with the following results:

<table>
<thead>
<tr>
<th>Cumulative Standard Deviations</th>
<th>Theoretical Density</th>
<th>Actual Density</th>
<th>Actual Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>±.5</td>
<td>.3829</td>
<td>.3786</td>
<td>-.0043</td>
</tr>
<tr>
<td>±1.0</td>
<td>.6827</td>
<td>.6798</td>
<td>-.0029</td>
</tr>
<tr>
<td>±1.5</td>
<td>.8664</td>
<td>.8716</td>
<td>+.0052</td>
</tr>
<tr>
<td>±2.0</td>
<td>.9545</td>
<td>.9596</td>
<td>+.0051</td>
</tr>
<tr>
<td>±2.5</td>
<td>.9876</td>
<td>.9868</td>
<td>-.0008</td>
</tr>
<tr>
<td>±3.0</td>
<td>.9973</td>
<td>.9986</td>
<td>+.0016</td>
</tr>
</tbody>
</table>

Both methods performed satisfactorily while again the formula generator appeared somewhat better. The tabulation for goodness-of-fit was more detailed than above, however; values
were grouped into non-cumulative intervals of .025 standard deviations. RAND had better Chi-square test results. Also, the formula generator had a higher, or less acceptable, Kolgomirov-Smirnoff statistic. A higher concentration of values outside the ±2.75 standard deviations range was the primary cause, although an asymmetric tendency was discernible throughout the formula-generated sample.

The RAND generator was chosen for inclusion in the model primarily due to its predictability and symmetry. A "side" benefit was also realized in speed: RAND is about four times faster computationally than the other process.
## APPENDIX IV

### SAMPLE TEST RESULT

<table>
<thead>
<tr>
<th>Year</th>
<th>Quarter</th>
<th>GNP*</th>
<th>FRB Index*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>7.28</td>
<td>3.41</td>
</tr>
<tr>
<td>2</td>
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* Percentage gain for year ending in quarter shown.  
** Current monthly value of the diffusion index of leading barometric indicators for month coinciding with end of quarter shown.  
*** Extremities of values of Dow Jones Industrials for month shown.
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APPENDIX IV--Continued
SOURCES CONSULTED

BOOKS


**MANUALS**


**NEWSPAPERS**


**PAMPHLETS**


PERIODICALS


