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Working Paper 2002-15
August 2002

# Working Paper Series

Federal Reserve Bank of Atlanta
Working Paper 2002-15
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# Are Stocks in New Industries Like Lottery Tickets?

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**Abstract:** We examine the distribution of returns in new industries to determine whether stocks in new industries are similar to lottery tickets. We focus on one characteristic of lottery tickets: negative expected returns. We examine data from the United States on sellers of own-brand personal computers, airlines and airplane manufacturers, automobile manufacturers, railroads, and telegraphs. A relatively small number of companies generate outstanding returns in some industries. We find no evidence of low expected returns. On the contrary, firms in new industries typically have high volatility of individual stocks' returns and high expected returns relative to indexes for the same periods. None of our evidence suggests that investors reasonably might expect to pay to play when investing in new industries.

JEL classification: G10, G12

Key words: stock prices, returns, lottery

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The authors gratefully acknowledge Mark Fisher and other members of a brown bag lunch at the Federal Reserve Bank of Atlanta for comments that substantially improved the paper. They also thank Scott Hein, Cesare Robotti, and Paula Tkac for helpful comments on earlier drafts. The authors have received helpful comments in presentations at the Bank of Finland, the City University Business School in London, EDHEC, the Universidad Carlos III de Madrid, and the Tor Vergata Financial Conference. Shalini Patel provided excellent research assistance, and Linda Mundy put everything together. The views expressed here are the authors' and not necessarily those of the Federal Reserve Bank of Atlanta or the Federal Reserve System. Any remaining errors are the authors' responsibility.

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# Are Stocks in New Industries Like Lottery Tickets?

## INTRODUCTION

The prices of Internet stocks seemed extraordinary before the crash in prices in 2001, and many still seem extraordinary relative to likely or even plausible outcomes. One explanation is craziness or euphoria, an explanation given more plausibility by the crash in prices. On the other hand, the predictability of the valuation of individual Internet firms may make this explanation less attractive than it would otherwise [Hand 2000].

An alternative explanation is that Internet stocks are similar to lottery tickets. This possibility has occurred to many observers, one prominent person being Alan Greenspan who was quoted as saying "When you are dealing with stock the possibilities of which are either it's going to be valued at zero or some huge number – you get a premium in that stock price which is exactly the same sort of price evaluation process that goes on in the lottery." [Blumberg Capital 1999]. Perhaps Internet stocks have a distribution of returns that includes the possibility of large gains and small losses? If so, then expected utility-maximizing investors can be locally risk-averse and simultaneously willing to pay for a probability of a large gain for the same reasons that people are willing to pay for lottery tickets. This explanation could be consistent with high valuations and even negative expected returns because investors are willing to pay on average to have a small probability of a large gain. This argument is

distinct from the point made by Schwartz and Moon [2000, 2001] that it is important to correctly allow for the dramatic importance of the volatility of returns, although their point is a crucial part of a correct analysis [Fisher 2002].

On one level, it is not possible to test the proposition that people perceive stocks in Internet firms to be similar to lottery tickets. If investors have an unfounded belief that Internet stocks are like lottery tickets, then even the subsequent evolution of the industry will not provide evidence on whether people thought the stocks were like lottery tickets. On the other hand, subsequent returns on average will be related to what people expect if people's expectations are rational in the sense of Muth. Ten or 20 years from now, Internet firms will provide one observation on whether Internet firms are like lottery tickets.

If investors' expectations are consistent with prior experience, the likely distribution of returns can be examined using the distribution of returns in earlier new industries. Many analogies have been drawn between Internet stocks and earlier industries as far back as railroads and telegraphs, e.g. in *Business Week* [Mandel 1999, Hof and Hamm 2002] and the *Economist* [Economist 2000].[1] If the distribution of returns in prior new industries does have a few large positive-return firms and many firms with smaller, negative returns, this would provide support for the proposition that investors are basing their decisions on such a distribution for Internet firms. If the expected return in these industries also is negative, then the lottery explanation acquires some plausibility. If the expected return in these earlier industries is a substantial positive number, then the lottery argument with rational expectations is not consistent with these earlier industries. Low or negative apparent expected returns is the observation to be explained.

It might seem that the distribution of returns to investors in Internet firms will be

[1] On a longer time scale, Jensen [1993] draws lessons for what he calls the Third Industrial Revolution since 1973 from earlier ones.

affected by winner-take-all effects, and this was not so for earlier industries. While natural, such a supposition is not correct because some of our industries are network industries if a network industry is defined as one in which a standard for the product or the availability of complementary inputs are high marginal value for the industry. For example, one of the industries included in our analysis is the telegraph industry, for which interconnection is as crucial as for the Internet. Nonetheless, we are not attempting to provide even preliminary evidence on whether winner-take-all effects change the distributions of returns because such a large undertaking is beyond the scope of this paper.

In this paper, we examine the plausibility of stocks in Internet firms being similar to lottery tickets by examining the distributions of returns in major, new industries in the United States. Our paper is related to recent papers by Cochrane [2001], Fama and French [2001] and Gompers and Lerner [2001]. Cochrane examines the distribution of returns to firms financed by venture capital and finds that their expected arithmetic returns are quite high, on the order of 50 percent per year. Fama and French [2001] examine the returns on newly listed firms in the CRSP dataset from 1926 to 2000 and find that these firms' returns are similar to their benchmark returns. Gompers and Lerner [2001] find that returns on initial public offerings (IPOs) before NASDAQ are similar to their benchmark returns. At first blush, this evidence is inconsistent with the well known underperformance of IPOs. Schultz [2002] presents cogent arguments and evidence that IPOs do not have low returns relative to benchmark returns when a selection bias in IPOs is recognized. Our paper is both narrower and broader than these papers. Our paper is narrower because we do not examine the returns to investors in all new firms; we examine the returns only for firms in new industries. Our paper is broader because we would have relatively few industries if we limited our analysis to the CRSP dataset. We extend the data back before 1926 in order to obtain evidence on more than just a couple of new, major industries.

In the first section, we briefly discuss what stock returns would look like if they were valued as lottery tickets and why investors who are compensated for bearing the risk embedded in most stocks simultaneously might buy stocks that resemble lottery tickets. This issue acquires interest, of course, only if we assume that pecuniary returns are all that matter, and we do that. In the second section, we examine the distribution of returns in the personal computer industry. The IBM PC was introduced in 1982 and detailed information on this industry is readily available.

In the rest of the paper, we examine the distributions of returns in major new industries in earlier time periods. The industries that we analyze besides personal computers are the aircraft industry, automobile production, railroads and the telegraph industry. These industries are associated with major changes in transportation and communications in the United States with widespread effects on the rest of the economy. It is not hard to think of other possible industries that could be studied. For example, the telephone industry had large effects on communication, but it would not be very informative because its early history is one of monopoly due to patents followed by a short window of competition and then overwhelming regulation [Wieman and Levin 1994].[2] The electric power industry is another obvious candidate, but its evolution also was heavily affected by regulation Other industries such as the frozen pizza industry might well be interesting, but our task is far simpler if many firms do business only in that industry.

We examine returns over the first 15 or 20 years or so after an industry begins to develop. This is long enough to be interesting but not so long as to require that investors at the beginning of an industry be prescient about developments a half century or more later. Our analyses generally end at the start of major, largely

[2]While no doubt of interest in some respects, this does not seem like an especially promising industry to include especially because many of the non-Bell firms traded on regional exchanges and consequently would have less readily available data.

unforeseen disruptions such as wars or the Great Depression.

There are more thorough price data available for the later industries. We have CRSP data on personal computer firms and the airline industry. Further back in time, we have less detailed underlying data. This mainly is reflected in a change from a monthly to annual frequency.

The most straightforward aspect of a lottery ticket is very simple: People pay to play lotteries. Do we find evidence that people predictably invest in stocks in which the expected return is negative? Our evidence is unambiguous: No. People receive returns on stocks in new industries that are quite positive and broadly in line with market returns. Our results are comparable in that respect to Cochrane [2001], Fama and French [2001] and Gompers and Lerner [2001] and show no evidence that investors in new industries receive negative expected returns. We think that the data presented in our paper show some evidence of the small probabilities of large gains and high probabilities of a small losses for which people might pay. If people are not paying to play, though, they are not playing a lottery. In sum, buying stock in a firm in some new industries has similarities to buying a lottery ticket in terms of there being outcomes with a low probability and a large payout, but there is no evidence that people pay to play in new industries.

The primary evidence concerning whether people pay to hold stocks in new industries is based on estimation of investors' expected returns. At first blush, this may seem trivial but it's not. The average arithmetic return computed over some period is not the expected return per period because the geometric average return is a non-linear function of the arithmetic return per period. We deal with this below in the concrete context of firms that sell own-brand personal computers. Because expected returns are positive, we do not do any detailed analysis of whether the industries have small probabilities of large gains and large probabilities of small losses: A positive expected return is sufficient to reject the general characterization of stocks in new

industries as lottery tickets. None of our evidence suggests that investors reasonably might expect to lose when investing in new industries.

## WHY WOULD PEOPLE BUY STOCKS THAT ARE LIKE LOTTERY TICKETS?

What is a lottery ticket and what is the distribution of returns on a lottery ticket? A lottery ticket is a payment of a sure amount today for an uncertain amount in the future. In this respect, lottery tickets are similar to many financial assets such as stocks. A common perception though is that a lottery ticket "has no place in the portfolio of a prudent investor." [Clotfelter and Cook 1990, p. 109] Why?

A negative expected return on lottery tickets is a major difference between lottery tickets and the typical stock or bond. Clotfelter and Cook [1990, p. 109] conclude that "the expected value of the prizes is typically only half the ticket price" for lottery tickets in the United States. It is interesting that Bernoulli in a study of an earlier lottery "concluded that the Genoese merchants defraud each lottery player by about 42% of every gold piece bet." [Bellhouse 1991, p. 144]. While we see no reason to require fifty or sixty percent as the expected payoff to say that stocks in new industries are like lottery tickets, it is fair to characterize lottery tickets as having nontrivial expected losses. In short, people pay to acquire the non-degenerate distribution of returns on a lottery ticket: they pay to play.

This negative expected return for some other forms of gambling can be explained by a nonpecuniary return, although this is an essentially untestable explanation. This explanation simply is an assertion that people buy lottery tickets because they like to buy them. Similarly, one could simply say that people buy stocks in new industries with a negative expected return because they like to buy them. A more powerful explanation would assume that buying a lottery ticket or a stock in a new industry is a transaction based on preferences about the distribution of returns, not on arbitrary

preferences for acquiring particular assets.

From this point of view, a key element of a lottery ticket is that people pay to acquire lottery tickets – the expected payoff is less than the purchase price – and lottery tickets are risky assets with a distribution of payoffs. Purchases of lottery tickets seem inconsistent with behavior that is generally risk averse, an apparent puzzle that has generated theoretical interest in lottery tickets.

There are various explanations of why people would buy lottery tickets, some based on expected utility and some not. Friedman and Savage [1948] consider why a locally risk-averse agent who maximizes expected utility might still buy lottery tickets. The distinguishing characteristics on which Friedman and Savage [1948] focus are the negative expected return which is to be explained and a particular asymmetric distribution of payoffs: a small probability of a large gain and a large probability of a small loss. Later arguments by Markowitz [1952] and Kwang [1965] suggest that indivisibilities in consumption are likely to be an important part of the explanation. Kwang argues that large increases in wealth can be more valuable to an investor because investors can change their consumption bundle in discrete ways, and only trivial changes in the consumption bundle result from small decreases in wealth. A completely satisfactory expected-utility explanation of why people buy lottery tickets remains to be worked out, but we think that indivisibilities in consumption are likely to be important. There also are alternatives to these expected utility explanations analyzed by Shefrin and Statman [2000] for example.[3]

The expected-utility analysis originally was designed to explain simultaneous purchases of insurance and lottery tickets, but a stock with a low probability of a large gain and a high probability of a small loss is like a lottery ticket and the known

[3]Our analysis merely is suggestive, so we do not compare or contrast these alternatives. The issue merely is whether it is even possible for some stocks to have a distribution of returns similar to lottery tickets.

existence of positive risk premia raises the same question if some stocks have negative expected returns. This informal review of the literature suggests the following: expected-utility maximizing investors may be willing to acquire stocks with a negative expected return if the distribution of payoffs is highly asymmetric with a small probability of a large gain and a large probability of a small loss.

In succeeding sections, we examine the data for new industries to determine whether stocks in these industries have negative expected returns. We also present data on whether the distribution is skewed with low probabilities of large gains and high probabilities of small losses. *Large* and *small* are hard to define precisely. We present the data for all of the firms in the industries that we examine, which makes it unnecessary for us to substitute our judgement for yours about whether the asymmetry in an industry is consistent with a lottery ticket.

## PERSONAL COMPUTERS

The market for personal computers is part of the phenomena raising the question and has been around for almost twenty years, so it is an obvious one to examine to see whether the distribution of stock returns resembles the returns from a lottery. High returns are easy to see at a glance. Three well known firms have very high returns: Dell, Compaq and Gateway. Suppose that one invested in these firms at the end of December 1983 or the first month in which it traded. One thousand dollars invested in Dell Computer Corp. in June 1988 became $178,560 by the end of December 2000. This is an annual average arithmetic return on the order of 51 percent per year for 12 years. One thousand dollars invested in Compaq in December 1983 became $36,493 by December 2000. While less spectacular, this investment has an annual average return on the order of 24 percent per year for 17 years. One thousand dollars invested in Gateway in December 1993 generated a noticeably smaller dollar value over the shorter period since it went public, $3,667 in December 2000, but the annual

average return still is an impressive 20 percent per year for seven years. Are these firms typical?

**The Distribution of Returns**

We use data from CRSP to estimate the distribution of returns to investors in publicly traded firms that make own-brand personal computers. We compute rates of return on all such firms. Table 1 provides a summary of the returns on those stocks. These data are for firms in the personal computer industry, even though some firms such as IBM do not receive their primary revenue from making PCs. The rates of return are average arithmetic returns with annual compounding. The returns for the whole period are from December 1983 through December 2000. If the whole period is not available, we compute the return for the period for which market prices are available. Table 1 indicates the period when data become available or are no longer available if those dates are different than December 1983 and December 2000. When a firm disappears from the CRSP files, we end the computations for the firm even if the firm merged into another firm, for example Zeos merging into Micron. Because we are attempting to measure returns, not duration of existence, this procedure seems better than our making a relatively arbitrary choice about subsequent returns. The numbers presented in the table make it relatively easy to see the effects of various choices other than our handling of firms disappearing. The choice of December 1983 as a starting date is somewhat arbitrary. The first personal computer generally is acknowledged to be the MITS Altair introduced in 1974 [Ceruzzi 1998, p. 226], but the introduction of the IBM PC in August 1981 and its subsequent commercialization seem to us to be more important for the values of firms traded on organized exchanges.

These data show dramatically different annual returns across the firms, and the returns for the whole period vary substantially. The highest average annual return is 51.4 percent per year for Dell and the lowest is -77.7 percent per year for Diversified

Technologies, which does not appear in the CRSP files after February 1985.[4] Dell, Compaq, Zeos and Gateway have positive returns that stand out. Not all firms in the PC industry have high positive returns though. The average return in Table 1 is an abysmal -5.7 percent per year, and this is for a period when the return for the CRSP value-weighted index for all firms is 15.3 percent per year and the return for the CRSP equally-weighted index is 11.7 percent per year. A cursory look at these numbers and the average returns suggests that these stocks may well be like lottery tickets.

The table, however, also provides final values from a dollar invested in each firm for the whole period and for subperiods. These cumulated values reflect reinvestment of any dividends. The table shows, for example, that one dollar invested in Dell in June 1988 has a cumulated value of $178.56 in December 2000. For Hewlett Packard, a dollar invested in December 1983 has a value of $8.57 in December 2000. The average cumulated values for subperiods show that a dollar invested in a portfolio of these firms provided superior payoffs to CRSP indexes in all periods except December 1987 to December 1991. Table 1 shows both the final values for both 1995 to 1999 and 1995 to 2000. We present both because the big decrease associated with the crash is pertinent and because the other periods are four-year periods, as is 1995 to 1999. We find it more informative to see the values for 1995 to 2000 than the values for 1999 to 2000 alone.[5]

These final values appear to tell a different story than the returns. The average of the final values for the whole period for all stocks in companies producing PCs is $10.77, which is greater than the initial investment of a dollar. This $10.77 can be interpreted as the amount received as a result of a strategy of investing 1/24 of a

[4]The averages are geometric means.

[5]The value of the payoff for 1999 to 2000 is easily estimated as the final value for 1995 to 2000 divided by the ratio for 1995 to 1999.

dollar in each of these PC firms when it enters our data set and selling at the price at the end of the last month for which we have data. The assumed return on the funds is zero when not invested in a PC company. The average annual arithmetic return is -5.7 percent per year and the average of the final values for the PC companies is substantially greater than a dollar, \$10.77. How can a negative average return be consistent with a final payoff greater than the initial investment?[6]

**Payoffs and Expected Returns**

The seeming contradiction between this higher payoff from investing in the PC producers and the negative average returns is largely due to the difference between averaging the annual average returns and averaging the final values across firms. The mean of the returns is

$$\mu_r = \frac{\sum_{i=1}^{N}(F_i^{(1/T_i)} - 1)}{N} \tag{1}$$

where $F_i$ is the final value for firm $i, i = 1, ..., N$, $T_i$ is the number of periods for which we have returns for firm $i$, $\mu_r$ is the mean return and we have used the fact that the initial value is one. The mean of the final values is

$$\mu_F = \frac{\sum_{i=1}^{N} F_i}{N} \tag{2}$$

These two averages need not produce similar rankings and equation (1) can have a negative solution while equation (2) has a solution greater than unity. The basic problem is the root taken to get the average annual return.

Agents' preferences are over final consumption in any standard economic model, so the final values are more pertinent than average returns for comparing payoffs relative to the market. Furthermore, by Jensen's inequality, equation (1) will be less than the

[6]Both averages are across firms.

expected return. In our case, this underestimation of the expected return is large.

There is another way in which there is a problem with the average annual return across firms. In that computation, each firm is weighted the same whether it exists for one year or for all 17 years. In effect, there is a reverse survivor bias, an *expiring bias*. The return per year for a few years that some firms exist has the same weight in (1) as the return per year for firms that exist for the whole period. If one is interested in the expected return in any given year, the average returns across firms conditional on their existence would weight each firm's average return for the years that it exists, $\mu_{ri} = F_i^{(1/T_i)} - 1$, by the number of years that the firm is in existence relative to other firms. This line of reasoning suggests an average return per firm conditional on their existence is provided by

$$\mu_{rw} = \frac{\sum_{i=1}^{N} w_i \mu_{ri}}{N} \tag{3}$$

where $w_i = T_i / \sum_{i=1}^{N} T_i$. This average return is higher for our data on PC firms, 5.7 percent per year, although still less than market returns. This average return still suffers from the fact that the average return is a nonlinear function of the annual returns experienced by the firms.

What is a better way of estimating the expected return from the stocks? We suppose that the expected return is constant across stocks since the interesting estimate is the distribution of those returns not conditional on any information about the individual firms. For simplicity, we also suppose that the expected value and volatility are constant over time with a log-normal distribution.[7] It is well known that normally distributed returns can cumulate into skewed distributions of final values such as these in Table 1. It might seem that the assumption of log-normality is grossly

[7] The daily data are available for PCs to support more detailed computations, but the purpose here is simple and data at higher frequencies are not available for all of the industries in this paper, so we stop with these simple computations.

inconsistent with the evidence for stock markets, but much of that evidence is for high-frequency time-series data conditional on prior returns. In contrast, we are estimating the expected return across firms for a typical period chosen at random, not a value for a specific period, say July 1992, conditional on prior returns. The issue for our estimates is whether the simple model is seriously at variance with the returns across firms, thereby suggesting that the estimated expected return is likely to be quite misleading. A Kolmogorov-Smirnov test and the Bera-Jarque test are reported in the tables with the estimates; these tests generally are consistent with the log-normal distribution being a reasonable characterization of the unconditional returns. This suggests a simple underlying price dynamic given by standard Brownian motion,

$$dF(t)/F(t) = \mu dt + \sigma dB(t), \tag{4}$$

where $F(t)$ is the final value at $t$, $\mu$ is the expected return, $\sigma$ is the underlying volatility of the return and $B(t)$ is a standard Weiner process. Applying Ito's lemma,

$$d \ln F(t) = (\mu - \frac{1}{2}\sigma^2)dt + \sigma dB(t) = \alpha dt + \sigma dB(t) \tag{5}$$

These equations indicate that

$$\mu = \alpha + (1/2)\sigma^2,$$

where $\alpha$ is the continuously compounded return. The maximum likelihood estimators of these parameters are well known [Tsay 2002; Gourieroux and Jasiak 2001; Campbell, Lo and MacKinlay 1996] and are given by

$$\widehat{\alpha} = \frac{1}{T}\sum_{t=1}^{T} r_t \tag{6}$$

$$\widehat{\sigma}^2 = \frac{1}{T}\sum_{t=1}^{T}[r_t - \widehat{\alpha}]^2 \tag{7}$$

$$\widehat{\mu} = \widehat{\alpha} + (1/2)\widehat{\sigma}^2, \tag{8}$$

where $r_t = \Delta \ln F_t$, $T = \sum_{i=1}^{N} T_i$ and $t = 1, ..., T$. The index $t$ runs over all time periods for all firms, so that an observation is a value of the log change for a period for a firm.

For personal computers, we have data on the returns monthly and the returns are most conveniently analyzed at annual rates. The diffusion equation is $dF(t)/F(t) = \mu h dt + \sigma\sqrt{h} dB(t)$ where $h$ is the time interval. Define $T = nh$, so the values of all variables are easy to determine. For example, if returns and variances are measured at an annual frequency, $T$ is 20 years and $n$ is 240 because the data are equally spaced monthly values over the twenty years, then $h = 20/240 = 1/12$. Data are available for different lengths of time for the firms. There are $n_i$ observations on firm $i$ over the time interval $T_i = T_i^e - T_i^f + 1$, which implies that $T_i = n_i h$. The symbol $T_i^f$ denotes the first time period for which a return is available and the symbol $T_i^e$ denotes the ending time period for which a return is available.

The maximum likelihood estimators of the parameters are

$$\widehat{\alpha} = \frac{\sum_{i=1}^{N} \sum_{t=T_i^r}^{T_i^e} r_t^i(h)}{h \sum_{i=1}^{N} n_i} = \frac{\sum_{i=1}^{N} \ln F_{T_i}^i}{h \sum_{i=1}^{N} n_i} = \sum_{i=1}^{N} w_i \ln F_{T_i}^i / T_i. \tag{9}$$

$$\widehat{\sigma}^2 = \frac{\sum_{i=1}^{N} \sum_{t=T_i^r}^{T_i^e} [r_t^i(h) - \widehat{\alpha} h]^2}{\sum_{i=1}^{N} n_i} \tag{10}$$

where $r_t^i(h)$ denotes the return for firm $i$ at frequency $h$. The variance-covariance matrix for $\widehat{\alpha}$ and $\widehat{\sigma}^2$ is

$$\mathrm{Var}\begin{bmatrix} \widehat{\alpha} & \widehat{\sigma}^2 \end{bmatrix}' = \begin{bmatrix} \frac{\sigma^2}{h \sum_{i=1}^{N} n_i} & 0 \\ 0 & \frac{2\sigma^4}{\sum_{i=1}^{N} n_i} \end{bmatrix}. \tag{11}$$

The estimator of $\widehat{\mu}$ is $\widehat{\mu} = \widehat{\alpha} + \widehat{\sigma}^2/2$ and the variance-covariance matrix for $\widehat{\mu}$ and $\widehat{\sigma}^2$ is

$$\mathrm{Var}\begin{bmatrix} \widehat{\mu} & \widehat{\sigma}^2 \end{bmatrix}' = \begin{bmatrix} \frac{\sigma^2}{h \sum_{i=1}^{N} n_i} + \frac{\sigma^4}{2 \sum_{i=1}^{N} n_i} & \frac{\sigma^4}{\sum_{i=1}^{N} n_i} \\ \frac{\sigma^4}{\sum_{i=1}^{N} n_i} & \frac{2\sigma^4}{\sum_{i=1}^{N} n_i} \end{bmatrix}. \tag{12}$$

Given this simple setup, the expected return is straightforward to compute. The mean of the log changes is -0.0291 per year and the maximum likelihood estimate of $\sigma^2$ is a quite high 0.3206 per year.[8] The implied estimate of $\mu$ is 0.1312, which is well above zero. These numbers are summarized in Table 1.

The last two columns of Table 1 also present Kolmogorov-Smirnov test and Bera-Jarque test statistics for examining the adequacy of the log-normal distribution for characterizing the distribution of returns. The p-values of these tests are 0.07 and 0.55, which suggests that the log-normal distribution is not extremely inconsistent with the data.

How does this expected return compare with the CRSP indexes for the same period? Using the values of the monthly equally-weighted CRSP index over the same period, we estimate a mean of the log changes $\alpha$ of 0.1115 per year and a volatility $\sigma^2$ of 0.0236. The implied estimate of $\mu$ is 0.1233 per year. Using the values of the monthly value-weighted CRSP index over the same period, we estimate an expected return $\mu$ of 0.1535 per year.

The estimate of the expected return on stocks in PC firms is on the order of 13 percent per year, well above zero by any standard. For the same period, the estimate of the market expected return is about 12 percent for the equally-weighted CRSP index and 15 percent per year for the value-weighted CRSP index. While it is possible that investors in PC firms received less than the risk-adjusted return on alternative investments, the expected return is well above zero. Many firms in the PC industry did badly and some firms disappeared; the distribution of final values

[8] Using all of the daily data on stock prices would have no effect on the estimate of the average return. Using all of the daily data on stock prices would increase the precision of the estimate of the variance. We doubt that it would affect the estimated variance in the first one or two decimal places and it would make these computations non-comparable to the computations that are feasible with earlier industries. As a result, we use monthly prices from the CRSP files.

across firms shows a high probability of loss and there is some probability of a large gain. Nonetheless, the expected return is far above zero. Our estimates indicate a high expected return for PC stocks, which is quite inconsistent with a lottery.

We now use this methodology to estimate the expected return for earlier industries.

## AIRLINES AND AIRPLANES

Table 2 shows the distribution of returns across the airline and airplane manufacturing industries. This table covers December 1925 to December 1940. December 1925 is the start of the CRSP data, which is our source for these data. These are all of the identifiable airlines and airplane manufacturers in the CRSP data in this period.[9] We use December 1940 as the last date to avoid effects of World War II, which are likely to be extraordinary relative to the distribution of returns that investors have in mind. These data span the Great Depression and some firms started at different points during the depression. As a result, making any comparisons with the overall market is important for assessing returns. Making comparisons with the market does not completely suppress the effect of the Depression, because the fall in stock prices might disproportionately affect a new industry, but comparisons with the market do ameliorate those effects. We have data on both airlines and airplane manufacturing. We analyze airlines and airplane manufacturers separately because these two sets of firms are quite different even if they both arose from the ability to fly in heavier-than-air machines.

There is substantial dispersion in the distribution of final values for the airline industry in Table 2. There are no very large payoffs, though, on the order of magnitude of the PC industry. Two firms – American Airlines and Eastern Airlines – have very

[9] Not all of the firms engaged exclusively in providing transportation services by plane. For example, Philadelphia Rapid Transit provided local transit service in Pennsylvania and provided airplane service between cities.

high annual average returns, but these firms exist only for brief periods toward the end of our data. Five of the eleven firms providing airplane transportation have final values less than the initial investment of a dollar. The average final payoff across all airlines when they existed is \$1.19 from an initial dollar invested, which is greater than the initial amount invested but less than the payoff of \$2.49 from the equally-weighted CRSP index for the whole period.

Over this period, the airplane manufacturing industry provides better returns for investors than the airline industry. None of these manufacturing firms has a payoff less than the initial investment, and Douglas Aircraft and Wright Aeronautical Aviation have average annual returns of 20 and 15 percent, respectively. At least relative to the PC industry, though, there is no evidence of exceptional payoffs in airplane manufacturing either, even though investors in Douglas Aircraft and Wright Aeronautical Aviation did well.

Returns in either industry provide support for there being substantial dispersion in outcomes. At one extreme, an investor of \$1 in Wright Aeronautical in December 1925 received \$8.41 in December 1940. At the other extreme, an investor of \$1 in Philadelphia Rapid Transit received \$.07 at the end of virtually the same period.

The expected return to an investor in airlines in this period is 0.1728 per year. The estimate of the mean of the log changes $\alpha$ is -0.0325 per year and the estimate of the volatility $\sigma^2$ is 0.4105 per year, figures similar in rough magnitude to PCs. The expected return to an investor in airplane manufacturing is quite a bit higher, 0.3315. This estimate is based on estimated mean of the log changes $\alpha$ of 0.0837 per year and a estimated volatility $\sigma^2$ of 0.4957 per year

For the CRSP index, the expected return is 0.1505 per year for the equally-weighted index and 0.0781 for the value-weighted index. The difference between these expected returns reflects both a higher average growth rate and a higher volatility of the CRSP equally-weighted index.

There is no evidence that the expected return to investors in the early airline and airplane manufacturing industries were negative. The point estimates provide no support for the expected return being negative. As for PCs, it is not possible to say whether the risk-adjusted return is about right without committing to a model of investor behavior. Short of doing that, though, we see no reason to think that investors sacrificed income to gamble on these stocks.

## AUTOMOBILES

Some investors in the automobile industry did enjoy extraordinary returns for part of the twentieth century. Table 3 shows that investors in three companies in particular did very well over some periods. One dollar invested in General Motors in 1912 was worth \$16.56 by 1928. Likewise, investing the same amount in Packard in 1922 or Hupp in 1920 was worth \$19.64 and \$10.21 by 1928.[10]

Table 3 presents the twenty companies for which we have dividend and stock price information. The data sources are available in a Data Appendix available on request.[11] The rates of return for the whole period are from December 1912 to December 1928. The data start in 1912 because there is little stock price data available before 1912. The computations end in 1928 to avoid the effects of the stock market crash and the Great Depression.

How well does this sample of twenty firms represent the automobile industry over this same period? From 1902 until the end of 1927, 181 different firms produced automobiles for some period.[12] There was substantial turnover, with at most 88 firms

[10] Ford also paid high dividends, but its stock price is not available because the stock was closely held.

[11] The Data Appendix also contains information on the data sources for the other industries.

[12] Seltzer [1928, p. 65, Table 5] shows the number of automobile producers and the number of firms entering and exiting for each year from the end of 1902 to 1926.

producing automobiles in any one year.[13] Only 44 firms were producing automobiles by the end of 1927. The companies most likely to be left out of our sample are those whose stock did not trade publicly, which means that the firms in our sample generally are among the most prominent. An obvious exception to this supposition is closely held Ford Motor Company.

While the cumulated values received by investors in GM, Packard, and Hupp are exceptional, they are not typical. Table 3 shows that the mean and median final values for all companies are 4.005 and 1.780. The final value for the Cowles index for the same period is 5.796, which is greater than either the mean or median. Only five of the 22 automobile manufacturers have final values as high as the Cowles Index. Simply put, $1 invested in over 75 percent of these companies earned a payoff of less than $5.7, the value of the same investment in the overall market over this period.

The returns in this table vary widely. The highest annual returns are 53.0 percent per year for Packard for the six years from 1922 to 1928, 33.6 percent per year for Stutz from 1916 to 1919 and 29.4 percent for Hupp Motor Car Corporation from 1920 to 1928. General Motors has an annual average return of 17.9 percent for 16 years. The lowest annual average return is -20.7 percent for Dodge Brothers.

The expected return to an investor in this sample of automobile companies in this period is a quite respectable 0.3481 per year. As for the other industries, a relatively high volatility is an important component of this estimate: the estimate of the volatility $\sigma^2$ is 0.5193 per year. This expected return is similar to the high expected return in firms that manufactured airplanes. The expected return to an investor in the Cowles index over the same period is 0.1161 per year, quite a bit lower than the return to automobile companies.

These results are not consistent with the notion that automobile stocks in this period are similar to lottery tickets. Investors do not appear to have paid to hold

[13] This maximum of 88 firms producing automobiles occurred in 1921.

stock in automobile companies.

## RAILROADS

The railroad industry expanded rapidly, fueled at least in part by stock offerings. Table 4 presents our data for railroads traded on the New York Stock Exchange (NYSE). The underlying data on stock prices are from contemporary periodicals. We compare railroad returns to returns based on the equally-weighted index with dividends reinvested from Goetzmann, Ibbotson and Peng [2001].

There is a wide dispersion in returns across firms, ranging from a high of 11.40 percent per year to a low of -19.59 percent per year. The average return across the firms is positive: 3.76 percent per year, although some firms did not survive long. The estimated expected return for an investor in these railroads is 0.0801 per year. This volatility of 0.0579 is an order of magnitude lower than the other industries' volatilities. In part, this lower volatility may reflect the absence of spectacular failures in the table.

Table 5 presents similar information on railroads traded on the Boston Stock Exchange (BSE). These data are from Martin [1871], who collected data on stock prices and dividends during his career as a stock broker. The estimated expected return for an investor in these railroads traded on the BSE is 0.0823.The estimate of volatility is 0.0440, the same order of magnitude as the estimate for railroads traded on the NYSE.

Goetzmann, Ibbotson and Peng [2001] construct an equally-weighted market index for the NYSE that can be used to estimate the expected return for the overall markets. For the period covered by the NYSE railroads, 1850 to 1870, the estimated expected return on this index is 0.1734. For the period covered by the Boston railroads, 1835 to 1870, the estimated expected return is 0.1546. For both comparisons, the estimates of the expected return for the market are greater than the corresponding estimates for

the railroads. The estimates of the volatilities also are larger for the market. Whether or not the railroads were less risky in terms of an asset pricing model, the estimated expected returns for the railroads are quite positive and inconsistent with the notion that the expected return is negative.

## THE TELEGRAPH INDUSTRY

The telegraph has been cited as the forerunner of the Internet, e.g. by Standage [1999]. The telegraph network is a network in which interconnections are paramount, interconnections that ultimately were associated with dramatic consolidation into the Western Union [Thompson 1947]. The telegraph had dramatic effects on the U.S. economy from the 1830s on [Garbade and Silber 1978], but an extensive search of New York periodicals and historical monographs did not turn up a price for a trade on an exchange before August 18, 1865. Virtually all of the consolidation in the telegraph industry into the Western Union monopoly had occurred by 1865, so this is too late for an analysis of the distribution of returns across firms. We do have sufficient information to calculate returns for Western Union. We also have evidence on dividends, which were more important in the middle 1800s than in the late 1900s [Baskin and Miranti 1997]. These dividends suggest that some investors in firms besides Western Union also did quite well.

Western Union stockholders clearly did well. A dollar invested in Western Union in April 1851 on incorporation was worth $1,816.75 at the end of 1865.[14] This is an annual average arithmetic return of 28 percent per year for almost 14 years. While not as spectacular as Dell's return of 51 percent for almost 14 years, 28 percent per year is quite high relative to market returns in this period. What did investors in

[14]Western Union did not pay cash dividends until the 1860s, so this simplifies the calculations. We assume that the reinvestment of cash dividends occurs at the par value. The par value is $50 and the price is $51 at the end of 1865.

other firms receive?

Available data indicate that some firms paid nontrivial dividends. One of the first telegraph firms established was the Magnetic Telegraph Company, which paid substantial dividends before being acquired shortly after October 1859. In early years, Magnetic Telegraph Company's dividend payments on the par value of stock were: 1848, 6 percent; 1849, 9 percent; 1850 and 1851, 2 percent; 1852, 9 percent; 1853 and 1854, 13 percent; and 12 percent was "paid quite regularly" thereafter. [Thompson 1947, p. 42, p. 331, p. 195].

The Atlantic & Ohio Telegraph Company was incorporated in March 1847 and later acquired. During its life, the Atlantic & Ohio paid dividends of 18 percent in 1848 and generally 3 percent per quarter thereafter [Thompson 1947, p. 99, p. 296, p. 137].

Dividends paid by the Pittsburgh, Cincinnati & Louisville Telegraph Company also are substantial. This line was established in February 1848 and consolidated into Western Union in 1856. During its existence, this line paid dividends of 11 percent in 1848 and generally 12 percent per year thereafter [Thompson 1947, p. 121, pp. 292-93, p. 137].

These dividend payments relative to par value are large relative to contemporaneous interest rates on government securities, which are on the order of 5 and 6 percent per year. [Dwyer, Hafer and Weber 1999]. These dividend returns also are high relative to the total returns on the market index in Goetzmann, Ibbotson and Peng [2001] for this period. Hence, it is fair to say that payouts were large. This, of course, does not imply that total rates of return to stockholders in these firms were high. Because these firms were bought by firms as part of the consolidation of the telegraph industry and our impression is that firms generally sold for less than par value, though, it is plausible that the overall rates of return were high.[15]

[15] Issuing sufficient stock that the price was noticeably less than the par value was called "watering"

Does this mean that rates of return were uniformly high? Clearly not. Thompson [1947] documents failed telegraph lines. In addition, there is no reason to think that Thompson mentions dividends for a random sample of telegraph firms. On the contrary, it is plausible that he mentions these firms' dividends because they were relatively high. Hence, we are comfortable concluding that some firms had high returns. It is less obvious whether an estimate of the typical expected return is positive, but none of the evidence points to a negative expected return for investors in telegraphs.

## SUMMARY AND CONCLUSION

While investors generally are averse to risk, many interpret prices of stocks associated with the Internet as being inconsistent with traditional asset pricing models. Some have suggested that the explanation may be that investors purchased these stocks as lottery tickets. Purchases of lottery tickets can be explained by investors being willing to accept a negative expected return if a high probability of a small loss is counterbalanced by some probability of a large gain.

Some new industries have distributions of payoffs across firms that are highly skewed. In this sense, new industries are similar to lotteries. As is well known though, this is quite consistent with even a log-normal distribution and our data across firms generally are consistent with a log-normal distribution.

The key question is: Do investors pay to play in new industries? Our evidence uniformly indicates that the expected return to owners of traded stock in new industries is positive. This is consistent with the proposition that investors receive expected returns that may well compensate them for the risk that they bear. There may, or may not, be a lottery component to these returns. If there is such a component to

the stock. While an automatic inference from railroads to telegraphs clearly is unwarranted, railroad stock generally traded at less than par value even with substantial dividends.

returns, it is not large enough to generate negative expected returns.

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**Table 1.**
**Personal Computer Companies and Stock Final Values**
**1983 through 2000**
**Individual Companies**

| Company | Date | | | Final Value ($) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First | Last | Annual Return | Entire Period | 1983-1987 | 1987-1991 | 1991-1995 | 1995-1999 | 1995-2000 |
| Dell Computer Corporation | Jun-88 | | 0.5141 | 178.5599 | | 2.7333 | 4.0537 | 47.1333 | 16.1153 |
| Compaq Computer Corporation | | | 0.2356 | 36.4926 | 4.4299 | 0.9525 | 5.4597 | 2.8356 | 1.5840 |
| Zeos International | Sep-89 | Mar-95 | 0.2075 | 2.8209 | | 4.2985 | 0.6563 | | |
| Gateway Incorporated | Dec-93 | | 0.2040 | 3.6670 | | | 1.2484 | 11.7655 | 2.9373 |
| NCR Corporation | | Aug-91 | 0.1997 | 4.0391 | 2.1672 | 1.8638 | | | |
| Hewlett Packard Company | | | 0.1347 | 8.5709 | 1.4040 | 1.0121 | 3.0823 | 2.8151 | 1.9569 |
| Canon Incorporated | | | 0.1233 | 7.2131 | 1.2977 | 1.7874 | 1.6477 | 2.2626 | 1.8873 |
| IBM | | | 0.0908 | 4.3789 | 1.0784 | 0.9141 | 1.1524 | 4.8690 | 3.8549 |
| NEC Corporation | | | 0.0775 | 3.5565 | 2.6366 | 0.6730 | 1.3167 | 2.0515 | 1.5223 |
| Apple Computers Incorporated | | | 0.0596 | 2.6759 | 3.4636 | 1.3962 | 0.5929 | 3.2255 | 0.9333 |
| Digital Equipment Corporation | | May-98 | 0.0300 | 1.5311 | 3.7499 | 0.4092 | 1.1606 | 0.8596 | 0.8596 |
| Advanced Logic Research | Apr-90 | Jun-97 | 0.0204 | 1.1556 | | 0.7170 | 0.6316 | 2.5521 | 2.5521 |
| Unisys Corporation | | | 0.0079 | 1.1425 | 2.3283 | 0.1384 | 1.3333 | 5.8069 | 2.6591 |
| Inmac Corporation | Oct-86 | Dec-95 | -0.0004 | 0.9962 | 1.4019 | 0.1921 | 3.7001 | | |
| ACT Networks Incorporated | May-95 | Jul-00 | -0.0647 | 0.7078 | | | 0.8247 | 0.5866 | 0.8582 |
| Intergraph Corporation | | | -0.0663 | 0.3117 | 1.2857 | 0.7172 | 0.8873 | 0.2976 | 0.3810 |
| Micron Electronics Incorporated | Apr-95 | | -0.2029 | 0.2765 | | | 0.7611 | 1.0349 | 0.3634 |
| Televideo Systems Incorporated | | Mar-99 | -0.2467 | 0.0133 | 0.0748 | 0.1316 | 4.4001 | 0.3068 | 0.3068 |
| Compudyne Corporation | | Feb-91 | -0.3174 | 0.0648 | 2.1296 | 0.0304 | | | |
| Tandon Corporation | | Feb-93 | -0.3800 | 0.0125 | 0.0844 | 0.8148 | 0.1818 | | |
| CPT Corporation | | Jul-90 | -0.4615 | 0.0169 | 0.1456 | 0.1167 | | | |
| Everex System Incorporated | Jul-87 | Dec-92 | -0.4746 | 0.0306 | 0.5306 | 0.5192 | 0.1111 | | |
| Wells American Corporation | | Nov-90 | -0.5248 | 0.0058 | 0.0641 | 0.0909 | | | |
| Diversified Technologies | | Feb-85 | -0.7767 | 0.1739 | 0.1739 | | | | |
| *Average* | | | *-0.0671* | *10.7673* | *1.5803* | *0.9754* | *1.7439* | *5.8935* | *2.5848* |
| *Median* | | | *0.0141* | *1.1491* | *1.3498* | *0.7171* | *1.1606* | *2.5521* | *1.5840* |
| *Standard Deviation* | | | *0.2994* | *36.5000* | *1.3529* | *1.0509* | *1.5725* | *11.7745* | *3.8868* |
| *CRSP Value-Weighted Index* | | | *0.1528* | *11.3459* | *1.6824* | *1.9072* | *1.6166* | *2.1141* | *2.1872* |
| *CRSP Equal-Weighted Index* | | | *0.1174* | *6.6569* | *1.4517* | *1.6328* | *1.6711* | *1.5258* | *1.6806* |

***Table 1 Continued on Next Page***

**Table 1 (Cont'd).**
**Personal Computer Companies and Stock Final Values**
**1983 through 2000**
**Expected Return**

| Expected Return for Personal Computer Firms | Mean Log Return | Variance of Log Return | Expected Return for CRSP Value-Weighted Index | Expected Return for CRSP Equally-weighted Index | Kolmogorov-Smirnov Test | Bera-Jarque Test |
|---|---|---|---|---|---|---|
| 0.1312 | -0.0291 | 0.3206 | 0.1535 | 0.1233 | 0.1715 | 1.1873 |
| 0.0352 | 0.0350 | 0.3054 0.3371 | 0.0354 | 0.0373 | (0.0676) | (0.5523) |

Notes:

The data for Individual Companies show the distribution of payoffs on personal computer (PC) companies from December 1983 to December 2000. The first and second columns after the name of the company indicate the years for which stock prices are available, with blanks indicating that the dates are the default ones of December 1983 or December 2000 or both. For example, Dell Computer first appears in the CRSP data in June 1988 and still exists in December 2000. The third column shows the annual average proportional return. The fourth column shows the terminal value an investor would have starting with a dollar invested in the firm with all dividends reinvested. The remaining columns show the terminal value for a dollar invested in the firm for each of the periods indicated. When data for a firm begins after the beginning of a period, the value in the table for the period starts when data become available. When data for a firm ends before the ending date of a period, the value in the table is the value for the last month that the stock price appears in the CRSP files. The subperiods shown are for four-year periods, with the exception of December 1995 through December 2000. The cumulated values are shown for December 1995 through December 1999 as well as for December 1995 through December 2000, which makes it easy to see the effects of the crash in prices in 2000.

The information on the Expected Return shows the estimated expected return for PC companies, $\mu = m + (1/2)\sigma^2$ , the average log return *m*, the variance of the log return $\sigma^2$ and two tests for log normality. The standard deviations of estimated parameters other than the variance of the log return are under the estimated parameters. The numbers under the variance of the log return are the 95 percent confidence limits because the variance has a chi-square distribution, which is not symmetric. The test statistics are the Kolmogorov-Smirnov test applied to a log-normal and the Bera-Jarque test. The associated p-values of the test statistics are in parentheses under the test statistics. The last two columns show the expected return for the CRSP value-weighted and equally-weighed indexes for December 1983 to December 2000.

**Table 2.**
**Airline and Airplane Companies and Stock Final Values**
**1925 through 1940**
**Individual Companies**

| Company | Date | | | Final Value ($) | | | | |
|---|---|---|---|---|---|---|---|---|
| | First | Last | Annual Return | Entire Period | 1925-1928 | 1928-1932 | 1932-1936 | 1936-1940 |
| **Airline Companies** | | | | | | | | |
| American Airlines Incorporated | Jun-39 | | 0.6878 | 2.1926 | | | | 2.1926 |
| Eastern Airlines Incorporated | Nov-38 | | 0.2947 | 1.7501 | | | | 1.7501 |
| Transcontinental and Western Air | Mar-35 | | 0.1536 | 2.2742 | | | 2.9786 | 1.7635 |
| Consolidated Aircraft Incorporated | Jul-37 | | 0.0883 | 1.3351 | | | | 1.3351 |
| National Aviation Corporation | Dec-33 | | 0.0286 | 1.2185 | | | 1.4852 | 0.8205 |
| Aviation Corporation | Jan-30 | | 0.0138 | 1.1613 | | 1.3171 | 1.1429 | 0.7715 |
| Pan American Airways Corporation | Dec-38 | | 0.0122 | 1.0245 | | | | 1.0245 |
| United Aircraft & Transportation | May-29 | | -0.0300 | 0.7027 | | 0.2291 | 1.7171 | 1.7864 |
| Bendix Aviation Corporation | May-29 | | -0.0381 | 0.6376 | | 0.1468 | 2.6954 | 1.6116 |
| Philadelphia Rapid Transit | | Oct-39 | -0.1717 | 0.0727 | 1.3045 | 0.0345 | 3.8460 | 0.4200 |
| National Air Transport | May-29 | Mar-32 | -0.4638 | 0.1711 | | 0.1711 | | |
| *Average* | | | *0.0523* | *1.1400* | *1.3045* | *0.3797* | *2.3109* | *1.2476* |
| *Median* | | | *0.0138* | *1.1613* | *1.3045* | *0.1711* | *2.2062* | *1.1798* |
| *Standard Deviation* | | | *0.2845* | *0.7312* | | *0.5287* | *1.0343* | *0.5729* |
| ***Airplane Manufacturers*** | | | | | | | | |
| *Douglas Aircraft Incorporated* | *Jun-31* | | *0.2015* | *5.7217* | | *0.6192* | *7.3578* | *1.2558* |
| *Wright Aeronautical Aviation* | | | *0.1517* | *8.4144* | *11.4176* | *0.0626* | *12.4405* | *0.9466* |
| *Boeing Airplane Corporation* | *Sep-34* | | *0.1281* | *2.1460* | | | *4.5081* | *0.4760* |
| *North American Aviation* | *Apr-30* | | *0.0838* | *2.3591* | | *0.4386* | *3.7760* | *1.4245* |
| *Curtiss Aeroplane & Manufacturing* | *Aug-29* | | *-0.0900* | *0.3432* | | *0.0736* | *3.2098* | *1.4529* |
| *Average* | | | *0.0950* | *3.7969* | *11.4176* | *0.2985* | *6.2584* | *1.1112* |
| *Median* | | | *0.1281* | *2.3591* | *11.4176* | *0.2561* | *4.5081* | *1.2558* |
| *Standard Deviation* | | | *0.1118* | *3.2306* | | *0.2761* | *3.8061* | *0.4082* |
| *CRSP Value-Weighted Index* | | | *0.0302* | *1.5620* | *2.0301* | *0.3087* | *3.1499* | *0.7914* |
| *CRSP Equal-Weighted Index (All Stocks)* | | | *0.0626* | *2.4853* | *1.8771* | *0.2615* | *13.1825* | *0.1885* |

***Table 2 Continued on Next Page***

***Table 2 (Cont'd).***
***Airline and Airplane Companies and Stock Final Values***
***1925 through 1940***
***Expected Return***

| *Industry* | *Expected Return* | *Mean Log Return* | *Variance of Log Return* | *Expected Return for CRSP Value-Weighted Index* | *Expected Return for CRSP Equally-weighted Index* | *Kolmogorov-Smirnov Test* | *Bera-Jarque Test* |
|---|---|---|---|---|---|---|---|
| *Airlines* | *0.1728* | *-0.0325* | *0.4105* | *0.1233* | *0.1505* | *0.1935* | *1.0549* |
| | *0.0758* | *0.0752* | *0.3745 0.4520* | *0.0805* | *0.1099* | *(>0.15)* | *(0.5901)* |
| *Airplane Manufacturers* | *0.3315* | *0.0837* | *0.4957* | *0.1233* | *0.1505* | *0.2600* | *0.8327* |
| | *0.0978* | *0.0968* | *0.4453 0.5551* | *0.0805* | *0.1099* | *(>0.15)* | *(0.6595)* |

*Note:*

*This table shows the distribution of payoffs on airlines and airplane manufacturers from December 1925 through December 1940. The notes to Table 1 explain the layout of the table.*

**Table 3.**
**Automobile Companies and Stock Final Values**
**1912 through 1928**
**Individual Companies**

| Company | Date | | | Final Value ($) | | | | |
|---|---|---|---|---|---|---|---|---|
| | First | Last | Annual Return | Entire Period | 1912-1916 | 1916-1920 | 1920-1924 | 1924-1928 |
| Packard Motor Car Company | 1922 | | 0.5301 | 19.6375 | | | 1.7903 | 10.9690 |
| Stutz Motor Car Company | 1916 | 1919 | 0.3364 | 3.1892 | | 3.1892 | | |
| Hupp Motor Car Company | 1920 | | 0.2945 | 10.2094 | | | 1.9644 | 5.1973 |
| Gardner Motor | 1923 | | 0.2099 | 3.1364 | | | 0.7509 | 4.1768 |
| Hudson Motor | 1922 | | 0.2078 | 3.7483 | | | 1.4533 | 2.5791 |
| Maxwell Class B | 1913 | 1924 | 0.2074 | 9.6000 | 12.6667 | 0.0474 | 16.0000 | |
| General Motors | | | 0.1796 | 16.5638 | 21.9748 | 0.0290 | 5.9067 | 4.3942 |
| Nash Motor | 1922 | | 0.1729 | 3.0527 | | | 3.1622 | 0.9654 |
| Maxwell Class A | 1921 | 1924 | 0.1551 | 1.7802 | | | 1.7802 | |
| Studebaker Corporation | 1912 | | 0.1391 | 9.1516 | 3.4711 | 0.7657 | 1.4649 | 2.3504 |
| Continental Motors | 1922 | | 0.1313 | 2.3709 | | | 0.8134 | 2.9147 |
| Reo Motor Car Company | 1926 | 1928 | 0.0739 | 1.2384 | | | | 1.2384 |
| White Motor Company Stock | 1916 | | 0.0594 | 2.1163 | | 1.0766 | 2.6446 | 0.7433 |
| Pierce-Arrow Motor Car Company | 1917 | | -0.0081 | 0.9073 | | 0.6390 | 0.7037 | 2.0175 |
| Willys-Overland Motor Car Co. | | | -0.0233 | 0.6697 | 0.5359 | 0.2046 | 1.9091 | 3.2000 |
| Kelly-Springfield Motor Truck Co. | 1917 | 1927 | -0.0251 | 0.7557 | | 1.1809 | 0.4246 | 1.5073 |
| Chandler Motor | 1916 | | -0.0457 | 0.5443 | | 1.0963 | 0.8411 | 0.5903 |
| Chrysler Motor | 1925 | | -0.0768 | 0.7265 | | | | 0.7265 |
| Paige-Detroit Motor Car Company | 1925 | 1927 | -0.1009 | 0.7269 | | | | 0.7269 |
| Peerless Truck and Motor Company | 1926 | | -0.1025 | 0.7229 | | | | 0.7229 |
| Moon Motors | 1923 | | -0.1425 | 0.3975 | | | 1.0446 | 0.3806 |
| Jordon Motor Company | 1924 | | -0.1789 | 0.3734 | | | | 0.3734 |
| Dodge Brothers | 1925 | 1927 | -0.2070 | 0.4987 | | | | 0.4987 |
| *Average* | | | *0.0777* | *4.0051* | *9.6621* | *0.9143* | *2.6659* | *2.3136* |
| *Median* | | | *0.0739* | *1.7802* | *8.0689* | *0.9645* | *1.6226* | *1.3728* |
| *Standard Deviation* | | | *0.1821* | *5.3667* | *9.7000* | *0.7657* | *3.7948* | *2.5106* |
| *Cowles Value-Weighted Index* | | | *0.1154* | *5.7958* | *1.3057* | *0.9218* | *1.8960* | *2.5398* |

***Table 3 Continued on Next Page***

**Table 3 (Cont'd).**
**Automobile Companies and Stock Final Values**
**1912 through 1928**
**Expected Return**

| Expected Return for Automobile Firms | Mean Log Return | Variance of Log Return | Expected Return for Cowles Index | Kolmogorov-Smirnov Test | Bera-Jarque Test |
|---|---|---|---|---|---|
| 0.3481 | 0.0885 | 0.5193 | 0.1161 | 0.1160 | 0.8139 |
| 0.0626 | 0.0558 | 0.4234 0.6519 | 0.0280 | (>0.15) | (0.6657) |

Note:

This table shows the distribution of payoffs on automobile companies from December 1912 to December 1928. The underlying data are year-end stock prices from the *New York Times* and dividends from Moody's. The notes to Table 1 explain the layout of the table.

**Table 4.**
**Railroads Traded on the New York Stock Exchange and Stock Final Values**
**1850 through 1870**
**Individual Companies**

| **Company** | **Date** | | | **Final Value ($)** | | | | |
|---|---|---|---|---|---|---|---|---|
| | First | Last | Annual Return | Entire Period | 1850-1855 | 1855-1860 | 1860-1865 | 1865-1870 |
| Panama | Dec-51 | Dec-61 | 0.1140 | 3.2798 | 1.9939 | 1.6230 | 1.0135 | |
| Delaware and Western | Dec-56 | Dec-62 | 0.1115 | 2.0960 | | 1.2766 | 1.6419 | |
| Delaware and Hudson | Dec-51 | | 0.0932 | 5.9422 | 1.6669 | 1.0638 | 2.5362 | 1.3213 |
| Chicago, Burlington, and Quincy | Dec-57 | Dec-66 | 0.0832 | 2.2246 | | 1.0848 | 1.8671 | 1.0984 |
| Baltimore and Ohio | Dec-56 | Dec-63 | 0.0736 | 1.7651 | | 0.8054 | 2.1915 | |
| Chicago, Rock Island, and Pacific | Dec-54 | | 0.0673 | 3.0267 | 1.1724 | 0.6853 | 3.1657 | 1.1900 |
| Illinois Central | Dec-54 | Dec-68 | 0.0573 | 2.3062 | 0.8929 | 0.9231 | 2.1279 | 1.3150 |
| New York Central | Dec-53 | | 0.0563 | 2.6818 | 0.9677 | 1.3142 | 1.7656 | 1.1944 |
| Michigan Central | Dec-52 | Dec-69 | 0.0401 | 2.0276 | 0.8667 | 0.5077 | 3.2653 | 1.4113 |
| Hudson River | | Dec-68 | 0.0286 | 1.7090 | 0.3808 | 1.4553 | 2.4246 | 1.2719 |
| Pennsylvania | Dec-57 | Dec-59 | 0.0267 | 1.1410 | | 1.1410 | | |
| NY, New Haven&Hartford | | Dec-53 | -0.0100 | 0.9605 | 0.9605 | | | |
| Utica and Schenectady | | Dec-51 | -0.0191 | 0.9621 | 0.9621 | | | |
| Catawissa | Dec-56 | Dec-58 | -0.1959 | 0.5200 | | 0.5200 | | |
| *Average* | | | *0.0376* | *2.1888* | *1.0960* | *1.0333* | *2.1999* | *1.2575* |
| *Median* | | | *0.0568* | *2.0618* | *0.9621* | *1.0743* | *2.1597* | *1.2719* |
| *Standard Deviation* | | | *0.0783* | *1.3468* | *0.4738* | *0.3573* | *0.6876* | *0.1042* |
| Goetzmann *et al*. Price-Weighted Index | | | *0.0234* | *1.6260* | *0.9463* | *0.8185* | *2.2074* | *0.9511* |
| Goetzmann *et al*. Equal-Weighted Index | | | *0.1355* | *14.4127* | *1.2315* | *3.3813* | *3.3169* | *1.0435* |

***Table 4 Continued on Next Page***

**Table 4 (Cont'd).**
**Railroads Traded on the New York Stock Exchange and Stock Final Values**
**1850 through 1870**
**Expected Return**

| Expected Return for NYSE Railroads | Mean Log Return | Variance of Log Return | Expected Return for Goetzmann et al. Equally-weighted Index | Kolmogorov-Smirnov Test | Bera-Jarque Test |
|---|---|---|---|---|---|
| 0.0801 | 0.0512 | 0.0579 | 0.1734 | 0.1484 | 1.6207 |
| 0.0188 | 0.0185 | 0.0473 0.0726 | 0.0634 | (>0.15) | (0.4447) |

Notes:

The date for Individual Companies show the distribution of payoffs on railroads that traded on the New York Stock Exchange from December 1851 to December 1870. The notes to Table 1 explain the layout of the table.

The information on the Expected Return shows the estimated expected return for PC companies, $\mu = m + (1/2)\sigma^2$ , the average log return *m*, the variance of the log return $\sigma^2$ and two tests for log normality. The test statistics are the Kolmogorov-Smirnov test applied to a log-normal and the Bera-Jarque test. The associated p-values of the test statistics are in parentheses under the test statistics. The last two columns show the expected return for the CRSP value-weighted and equally-weighed indexes for December 1983 to December 2000.

**Table 5.**
**Railroads Traded on the Boston Stock Exchange and Stock Final Values**
**1835 through 1870**
**Individual Companies**

| Company | Date | | | Final Value ($) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | Last | Annual Return | Entire Period | 1835-40 | 1840-45 | 1845-50 | 1850-55 | 1855-60 | 1860-65 | 1865-70 |
| Cincinnati, Sandusky and Cleveland | 1863 | | 0.6324 | 50.4148 | | | | | | 3.4137 | 14.7684 |
| Ogdensburg and Lake Champlain | 1866 | | 0.2162 | 3.9368 | | | | | | 1.2412 | 3.1718 |
| Hartford and New Haven | 1845 | 1869 | 0.1250 | 18.9899 | | | 1.7878 | 1.6169 | 1.8671 | 1.9058 | 1.8463 |
| Hannibal and St. Joseph | 1863 | | 0.1253 | 2.5706 | | | | | | 0.7647 | 3.3615 |
| Wilmington | 1855 | | 0.1193 | 6.0686 | | | | | 2.1876 | 2.4193 | 1.1467 |
| Worchester and Nashua | 1849 | | 0.1131 | 10.5613 | | | 0.9158 | 1.5550 | 1.7634 | 2.1441 | 1.9614 |
| Granite Railway | 1865 | 1869 | 0.1079 | 1.6689 | | | | | | | 1.6689 |
| Providence and Worcester | 1855 | 1869 | 0.1061 | 4.5382 | | | | | 1.8617 | 1.7368 | 1.4035 |
| Boston and Maine | 1840 | | 0.1027 | 20.7173 | | 3.0784 | 1.2561 | 1.2403 | 1.6794 | 1.4389 | 1.7876 |
| Philadelphia, Wilmington, and Baltimore | 1845 | 1854 | 0.1012 | 2.6226 | | | 1.6843 | 1.5571 | | | |
| Michigan Central | 1847 | | 0.1000 | 9.8557 | | | 1.2404 | 1.6488 | 0.8009 | 3.1738 | 1.8959 |
| Manchester and Lawrence | 1849 | 1870 | 0.0994 | 8.0494 | | | 1.0328 | 1.0678 | 2.5544 | 6.6058 | 1.7794 |
| Chicago, Burlington and Quincy | 1857 | | 0.0966 | 3.6344 | | | | | 0.8677 | 2.3399 | 1.7902 |
| Summit Branch | 1864 | | 0.0954 | 1.8925 | | | | | | 0.7196 | 2.6300 |
| Eastern in New Hampshire | 1855 | 1869 | 0.0912 | 3.7013 | | | | | 1.4118 | 1.6646 | 1.5750 |
| Concord | 1842 | | 0.0875 | 11.4007 | | 1.6732 | 1.1815 | 1.2112 | 1.7353 | 1.4778 | 1.8567 |
| Nashua and Lowell | 1839 | | 0.0855 | 13.8110 | 1.1380 | 1.7228 | 1.2928 | 1.2164 | 1.8203 | 1.5225 | 1.6164 |
| Reading | 1845 | 1869 | 0.0830 | 7.3455 | | | 1.0500 | 2.4789 | 0.5935 | 3.3487 | 1.4199 |
| Connecticut River | 1846 | | 0.0785 | 6.6083 | | | 1.1735 | 0.8871 | 1.9451 | 1.7668 | 1.8471 |
| Boston and Worcester | 1835 | 1867 | 0.0771 | 11.6117 | 1.4220 | 1.4976 | 1.1599 | 1.2932 | 1.6928 | 1.6662 | 1.2889 |
| Old Colony and Newport | 1855 | | 0.0715 | 3.0189 | | | | | 1.7726 | 1.4141 | 1.2043 |
| New York Central | 1855 | | 0.0708 | 2.9874 | | | | | 0.8723 | 1.7240 | 1.9865 |
| Western | 1836 | 1867 | 0.0707 | 8.9098 | 0.9726 | 1.2938 | 1.4821 | 1.2784 | 1.7636 | 1.6515 | 1.2830 |
| Portland and Saco | 1855 | | 0.0697 | 2.9390 | | | | | 1.4907 | 1.3763 | 1.4326 |
| Boston and Providence | 1835 | | 0.0696 | 11.2712 | 1.1552 | 1.5302 | 1.0703 | 1.0624 | 2.1759 | 1.6952 | 1.5202 |
| Taunton Branch | 1836 | | 0.0685 | 10.1547 | 1.2414 | 1.6301 | 1.3079 | 1.3827 | 1.4973 | 1.4131 | 1.3116 |
| Fitchburg | 1843 | | 0.0682 | 6.3448 | | 1.2826 | 1.3219 | 0.9314 | 1.6675 | 1.4840 | 1.6238 |
| Concord and Montreal | 1848 | 1855 | 0.0668 | 1.6779 | | | 0.7707 | 2.1770 | | | |
| Boston and Lowell[b] | 1835 | | 0.0662 | 10.0511 | 1.2343 | 1.4864 | 1.3287 | 0.8377 | 2.2059 | 1.2211 | 1.8274 |
| Boston and Albany | 1867 | | 0.0656 | 1.2894 | | | | | | | 1.2894 |
| Northern (New Hampshire) | 1845 | | 0.0645 | 5.0762 | | | 0.7573 | 0.7353 | 1.9491 | 2.4078 | 1.9426 |
| New Bedford and Taunton | 1845 | 1869 | 0.0636 | 4.6731 | | | 1.4076 | 1.1937 | 1.1642 | 1.7172 | 1.3912 |

| **Company** | **Date** | | | **Final Value ($)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | First | Last | Annual Return | Entire Period | 1835-40 | 1840-45 | 1845-50 | 1850-55 | 1855-60 | 1860-65 | 1865-70 |
| Rutland Common | 1867 | | 0.0635 | 1.2791 | | | | | | | 1.2791 |
| Eastern | 1837 | | 0.0612 | 7.5284 | 1.2853 | 1.5020 | 1.3172 | 0.7180 | 1.3750 | 1.6930 | 1.7714 |
| Vermont and Canada | 1849 | | 0.0606 | 3.6461 | | | 1.0125 | 0.8211 | 1.0476 | 2.7297 | 1.5338 |
| New York and New Haven[a] | 1855 | | 0.0571 | 6.8098 | | | | | 2.8284 | 1.4166 | 1.5373 |
| Boston Concord and Montreal | 1855 | | 0.0489 | 2.1452 | | | | | 0.3684 | 3.7143 | 1.5677 |
| Portland, Saco, and Portsmouth | 1841 | 1855 | 0.0487 | 2.0392 | | 1.2584 | 1.4163 | 1.1442 | | | |
| Norwich and Worcester | 1839 | | 0.0420 | 3.7293 | 0.9584 | 1.2084 | 0.6603 | 0.7404 | 1.1577 | 3.3524 | 1.6972 |
| Stonington (New York, Providence and Boston) | 1837 | 1869 | 0.0417 | 3.8461 | 0.6675 | 1.0824 | 1.2649 | 1.1518 | 1.8180 | 2.4238 | 08292 |
| Fall River | 1846 | 1854 | 0.0417 | 1.4439 | | | 0.9355 | 1.5434 | | | |
| Erie New York | 1845 | 1855 | 0.0403 | 1.5447 | | | 2.3821 | 0.6485 | | | |
| Burlington and Missouri | 1869 | | 0.0384 | 1.0782 | | | | | | | 1.0782 |
| Cape Cod | 1848 | | 0.0268 | 1.8375 | | | 0.6027 | 0.9236 | 0.700 | 3.3625 | 1.4025 |
| Old Colony | 1845 | 1855 | 0.0044 | 1.0495 | | | 0.6938 | 1.5128 | | | |
| Vermont and Massachusetts[c] | 1845 | | -0.0114 | 0.7431 | | | 0.2936 | 0.5328 | 1.0164 | 2.6452 | 1.7672 |
| South Shore | 1849 | 1869 | -0.0351 | | | | 0.4273 | 06383 | 0.9083 | 0.9725 | 1.9623 |
| Indianapolis and Cincinnati | 1855 | | -0.0538 | 0.4130 | | | | | 0.6278 | 2.2139 | 0.3097 |
| Chesire | 1855 | | -0.0909 | 0.3504 | | | 0.0698 | 0.5747 | | | |
| Long Island | 1842 | 1854 | -0.0947 | 0.2743 | | 0.6165 | 0.2087 | 2.1321 | | | |
| Grand Junction | 1849 | 1855 | -0.1033 | 0.4661 | | | 1.0636 | 0.4383 | | | |
| Passumpsic | 1848 | 1854 | -0.1499 | 0.2727 | | | 0.9249 | 0.2949 | | | |
| Boston, Hartford, and Erie | 1864 | | -0.2192 | 0.1770 | | | | | | 0.6049 | 0.2925 |
| Ogdensburg Northern NY | 1847 | 1855 | -0.2312 | 0.0938 | | | 0.6324 | 0.1484 | | | |
| Sullivan | 1847 | 1854 | -0.2518 | 0.0983 | | | | 0.5809 | | | |
| Rutland & Burlington - old | 1847 | 1854 | -0.2699 | 0.0808 | | | 0.6100 | 0.1324 | | | |
| Vermont Central | 1845 | 1855 | -0.2763 | 0.0285 | | | 0.3927 | 0.0727 | | | |
| *Average* | | | *0.0394* | *5.4358* | *1.1194* | *1.4902* | *1.0221* | *1.0558* | *1.5055* | *1.9357* | *1.9222* |
| *Median* | | | 0.0662 | *3.0189* | *1.1552* | *1.4920* | *1.0568* | *1.0651* | *1.6735* | *1.6952* | *1.6164* |
| *Standard Deviation* | | | 0.1332 | *7.6651* | *0.2238* | *0.5389* | *0.4588* | *0.5585* | *0.5869* | *0.7964* | *2.0810* |
| Goetzmann *et al*. Equally-Weighted Index | | | *0.1228* | *64.6153* | *0.8861* | *1.4777* | *3.4241* | *1.2315* | *3.3813* | *3.3169* | *1.0435* |

**Table 5 Continued on Next Page**

**Table 5 (Cont'd).**
**Railroads Traded on the Boston Stock Exchange and Stock Final Values**
**1835 through 1870**
**Expected Return**

| Expected Return for BSE Railroads | Mean Log Return | Variance of Log Return | Expected Return for Goetzmann et al. Equally-weighted Index | Kolmogorov-Smirnov Test | Bera-Jarque Test |
|---|---|---|---|---|---|
| 0.0823 | 0.0603 | 0.0440 | 0.1546 | 0.2182 | 9.203 |
| 0.0047 | 0.0046 | 0.0401 0.0486 | 0.0451 | (<0.01) | (0.0100) |

Note:

This table shows the distribution of payoffs on railroads that traded on the Boston Stock Exchange from 1835 to 1870. See the notes to Table 1 concerning the layout of the table.