American Scientist

**Biofilms:
Walled Cities
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Bettor Math

Elwyn Berlekamp

FORTUNE'S FORMULA: The Untold Story of the Scientific Betting System that Beat the Casinos and Wall Street. William Poundstone. x + 367 pp. Hill and Wang, 2005. $27.

Every investor must decide how to partition her portfolio among many possible investments. Plausible strategies range from "diversify" to "focus."

In a paper published in 1956, John L. Kelly of Bell Labs formulated the asset-allocation problem in terms of an idealized model for which he derived some quantitative results. He used colorful racetrack terminology reminiscent of the classic Damon Runyon movie *Guys and Dolls:* Suppose that one goes to the racetrack with an available bankroll, *B*. Suppose further that one knows for each horse the correct probability that it will win the next race. Suppose further that the betting odds are at least slightly inconsistent with this information. And finally, suppose that each race is merely one of a very long sequence of betting opportunities. Kelly found criteria for deciding how much one should then bet on each horse in each race.

Kelly observed that, under similar idealized assumptions, the same for-

mulation could also be applied to investments. In the idealized model, the portfolio manager has an accurate probability distribution on the future performance of each asset in the universe of potential investments. Kelly's methodology then provides a quantitative specification of how big a position to take in each of the candidate assets. Not surprisingly, the fraction of one's portfolio to be invested in any asset that has a negative expected rate of return will be zero. Most assets with positive expected rates of return will merit the investment of some positive fraction of the portfolio. Among assets with similar expected rates of return, those whose returns are relatively stable will be weighted more heavily than those whose future returns have significant risks of substantial losses, even when these risky investments also have some chance of large gains. All of these qualitative features of Kelly's performance criteria concur with conventional wisdom. What distinguishes Kelly's work from that of his predecessors is his quantitative specificity and the fact that he succeeded in proving that, under his assumptions, in the very long run the bankroll of an investor who followed his criteria would eventually surpass the bankroll of anyone following any other strategy.

Kelly also derived a formula for the rate at which this bankroll would grow. This formula is related to a fundamental information-theoretic notion that Claude Shannon (now widely considered to be the father of the information age) had introduced in 1948. Shannon had shown that noise on a communication channel need not impose any bound on the reliability with which information can be communicated across it, because the probability of transmitting a very long file inaccurately can be made arbitrarily small by using sufficiently sophisticated coding techniques, subject to a constraint that the ratio of the length of the source file to the length of the encoded file must be less than a number called the channel capacity.

Kelly showed that the asymptotically optimum asset allocation could be determined by solving a system of equations that maximized the *log* of one's capital. In his horse-track jargon, Kelly also showed that the resulting optimal compound growth rate could be viewed as the capacity of a hypothetical noisy channel over which the bettor was getting the information that distinguished his odds from those of the track. Kelly's betting system, expressed mathematically, is known as the Kelly criterion.

The title of Kelly's paper, "A New Interpretation of the Information Rate," highlighted his discovery of a situation in which Shannon's celebrated capacity theorem applied even though no coding was contemplated. The paper, which appeared in the *Bell System Technical Journal,* initially attracted a modest audience among information theorists but went unnoticed by economists and professors of finance courses in business schools. Perhaps it would have received more attention if it had had another title. "Information Theory and Gambling" was the title that Kelly himself used for an earlier draft of his paper, but that title was rejected by AT&T executives.

The phrase "Fortune's Formula," which could have served as the title of Kelly's paper, was coined by the mathematician Ed Thorp as the title for a paper he wrote in 1961 about a strategy for winning at blackjack. It is now also the title of William Poundstone's new book, which tells stories of gamblers and investors over the past 150 years and how some of them have been influenced by the Kelly criterion. The style is somewhat like that of the business pages of a good newspaper, with no formulas or equations but occasional graphs. There are many sources, most of which are reliable. Even though there are many footnotes, the tone sometimes changes from that of a science journalist to that of a gossip columnist. There are biographical sketches not only of Kelly (who died in 1965 of a heart attack at age 41) and such relevant intellectual titans as Claude Shannon and Paul Samuelson (the father of modern economics), but also of many other characters. The career of the legendary Thorp, who became a successful, innovative financial entrepreneur, is treated at considerable length.

Ed Thorp analyzed the game of blackjack far more deeply than anyone had ever done before, and he devised card-counting schemes to gain an edge, especially toward the end of a deck that

Mathematician and financial entrepreneur Ed Thorp wrote a bestseller, *Beat the Dealer,* about how to win at blackjack. His system, which involved a formula devised by John L. Kelly, was so successful that casinos had to ban him and change their rules for shuffling cards. Thorp is shown here at the Tropicana Hotel in Las Vegas in 1963. From *Fortune's Formula.*
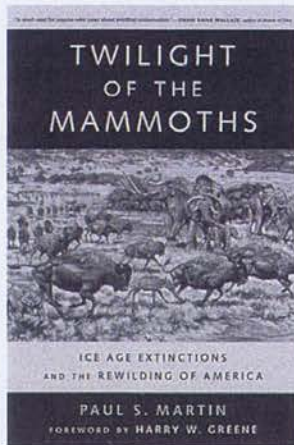
is not reshuffled after every deal. He wrote a bestseller, *Beat the Dealer*, on how to win at blackjack. Earlier in his career, when he was a mathematics instructor at MIT, he met Claude Shannon, and he brought Claude and Betty Shannon with him as partners on one of his early weekend forays to Las Vegas. Later, he discovered and exploited a number of pricing anomalies in the securities markets and made a significant fortune. Thorp's first hedge fund, Princeton-Newport, achieved an annualized net return of 15.1 percent over 19 years, and in May 1998, Thorp reported that his own investments had an annualized 20 percent return over 28.5 years.

Poundstone pursues a sequence of increasingly tenuous connections among moneymaking schemes and scams, some blatantly illegal and some with reputed mob connections, ranging all the way back in time to wire services that predated Alexander Graham Bell, and into the current political world of Rudy Giuliani. The reader can only wonder how much is fact, how much is literary license and how much is sensationalism. Marketing copy included on the book's dust jacket, characterizing Kelly as "gun-toting" and Shannon as "neurotic," falls squarely into the category of sensationalism.

In later sections of the book, the patient reader will find some interesting graphs and an overview of a now long-standing academic and philosophical debate about the relevance and appropriateness of the Kelly criterion. Most people with academic training in physics, mathematics, operations research, computer science or engineering view the Kelly criterion as a useful quantitative guideline for investing, to be used along with others. They also view most large institutional money managers and economists as too risk-averse; the latter folks view the former as too risk-prone. Some extremely risk-averse business-school professors espouse a doctrine called the efficient-market hypothesis. Whenever some money manager achieves significantly above-average returns, adherents of that hypothesis strive to explain away the accomplishment: Perhaps the manager is a lucky survivor of an unrepeatable strategy that took very big risks on a few very large bets; perhaps he or she depended heavily on inside knowledge or engaged in illegal activity.

No one who has made a legitimate fortune in the markets believes the efficient-market hypothesis. And conversely, no one who believes the efficient-market

hypothesis has ever made a large fortune investing in the financial markets, unless she began with a moderately large fortune. Of the stories presented in *Fortune's Formula,* the case of Ed Thorp presents the greatest challenge to the efficient-market hypothesis. Poundstone devotes only a single paragraph to the even stronger cases of Ken Griffin, D. E. Shaw and Jim Simons, presumably because financial wizards as successful as these have always been unwilling to discuss their formulas in public.

General readers seeking a broad overview of certain aspects of the field of financial mathematics and its practitioners will find the latter portions of Poundstone's book the most informative. Readers who enjoy a gossipy approach to business history will find the earlier portions more to their liking. Any experienced, quantitatively oriented investor will, without reading Poundstone's book, already know that she needs to estimate the likely distributions of returns of the various investments she is considering. This is quite difficult, because for some promising investments, historical data are very limited, and for others, there are good reasons to question whether the historical patterns are likely to persist into the future. So in practice, the allocation problem that Kelly's formula addresses is only one of the two main parts of the investor's puzzle. Poundstone recognizes this implicitly, but some readers would benefit from a more explicit statement of the dichotomy.

In my experience, abstract financial mathematics is the only truly significant commonality between the world of finance and the world of racetracks and casinos. Poundstone has been lured by Kelly's colorful terminology into seriously overemphasizing the relevance and importance of whatever other relationships might exist. Portrayal of the seamy side of business is a genre that runs at least as far back as the novels of Charles Dickens. Readers who are looking for something in that vein as well as a light introduction to financial mathematics will find things to relish in Poundstone's book.

Elwyn Berlekamp, a professor of mathematics at the University of California at Berkeley, is best known for his works on games and codes. In 1960 and 1962, he was John Kelly's research assistant. In 1967, he coauthored Claude Shannon's last paper on information theory. In 1990, he managed a 55% gain of Jim Simons's Medallion Fund.

Intel Insider

Alex Soojung-Kim Pang

THE MAN BEHIND THE MICROCHIP: Robert Noyce and the Invention of Silicon Valley. Leslie Berlin. xiv + 402 pp. Oxford University Press, 2005. $30.

The 1957 picture below shows eight young men, the cofounders of Fairchild Semiconductor Corporation, gathered around a table outdoors in northern California. At front and center is Robert Noyce: handsome, charismatic, yet easygoing, the epitome of the entrepreneurial spirit that would help shape postwar, high-tech America.

Noyce, the son of a minister, attended Grinnell College and then got a doctorate in physics from MIT. Two years later, in 1955, he moved to California to join a company in Palo Alto that had just been started by William Shockley, one of the coinventors of the transistor. Shockley's remarkable eye for talent was exceeded only by his gift for mismanagement. Less than two years later, the men in the photograph, who had all worked for Shockley—the "Traitorous Eight," he named them—were dissatisfied enough to strike off and found their own company: Fairchild Semiconductor. There Noyce invented the integrated circuit (at about the same time that Texas Instruments engineer Jack Kilby also produced one). And he quickly rose to the rank of general manager. A decade later, Noyce and Gordon Moore left Fairchild to start a second company, Intel, which became a leader in the semiconductor industry in the 1970s and 1980s.

The outlines of Noyce's life and work are fairly well known. Still, Leslie Berlin's excellent new study, *The Man Behind the Microchip,* is a welcome addition to the body of historical literature dealing with recent computer technology. The book is one of only a handful of scholarly biographies of members of the generation of inventors and entrepreneurs who were attracted to California in the 1950s and 1960s, built the semiconductor industry and helped create the economic and cultural phenomenon now known as Silicon Valley.

Berlin describes Noyce's technical accomplishments accurately and with appropriate detail, but she also makes clear that he was as much a social and economic innovator as a technical one. For example, the strategy he developed at Fairchild of regularly cutting the price of company products was seen as crazy at the time but has since been widely adopted in the high-tech

The eight founders of Fairchild Semiconductor pose shortly after starting their company in the fall of 1957. Robert Noyce is seated front and center. Around the table, clockwise from Noyce, are Jean Hoerni, Julius Blank, Victor Grinich, Eugene Kleiner, Gordon Moore, C. Sheldon Roberts and Jay Last. From *The Man Behind the Microchip.*