# PHYSICS IN IRANIAN FINANCIA

ECONOPHYSICS AND COMPLEXITY ECONOMICS CONFERENCE

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**Tehran – March 3, 2022**

# FINANCIAL PHYSICS

Financial physics is the application of conventional physics methods to the study of financial markets as complex systems.

**How ideas and thoughts from physics have been used to understand financial markets**

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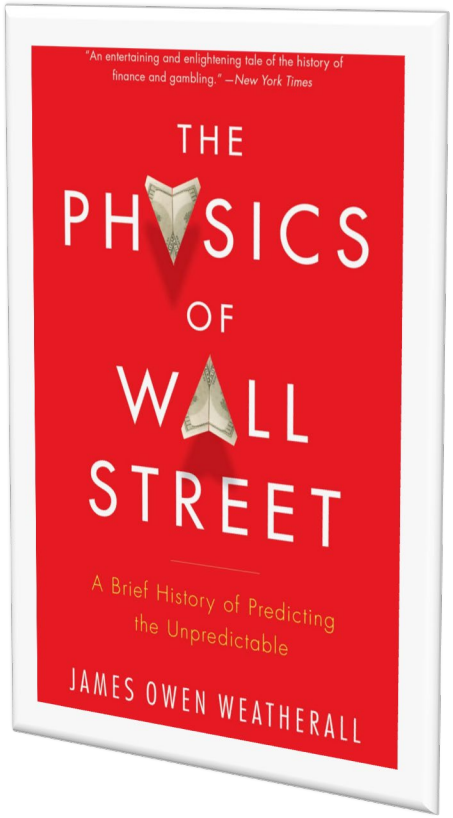
# فیزیک مالی

پیش‌بینی پیش‌بینی‌ناپذیرها
چگونگی تسلط علم بر وال‌استریت


نوشتهٔ
جیمز اوئن ودرال

با ترجمهٔ
دکتر حسین عبده تبریزی




About the bookThis

- book studies the enigmatic relationship between physics and finance.
- Examines the role of physicists in the evolution of modern financial theory.
- It explores how financial theories are formed in the minds of these physicists with a compelling narrative.

# HISTORY

- **Financial physics applies conventional physics methods to studying financial markets as complex systems. How ideas and thoughts from physics have been used to understand financial markets?**
- **Brown (1827): Introducing the concept of Brownian motion.**
- **Bachelier (1900): Using the concept of Brownian motion in the Paris Stock Exchange; Introduction random walk in explaining market behavior.**
- **Mandelbrot (1963): The fat tail distribution better explains the observed data than the Gaussian distribution.**
- **1967: Ed Thorp - Market failure: The scientific stock market system.**
- **The 1980s: Increasing exponential access to electronic information due to new technologies.**
- **1997: The financial industry attracts 48% of new Ph.D. and physics graduates in the United States.**
- **1997: Scholes and Merton Prize for the Derivatives Pricing Model.**

# HISTORY

- 1990 to present: Articles in financial and economic physics are published in prestigious journals such as Nature, Physica Review Letters, Physica, European Physics Journal, etc.
- 1990: Black-Derman-Toy model of short-term interest rates.
- 1990: The beginning of university courses, conferences and seminars, and textbooks.
- 1999: The European Physicists Association declares economic physics as its field of research.
- 2007: Physics and its models are not responsible for the economic ills of the 2007 crisis.
- 2013: Reflexivity demands a new scientific method that is not physics-based (Soros).
- 2014: Scientific understanding of financial markets should not exclusively have physics-based foundations → intersection of finance and the biological, cognitive, and behavioral sciences (Sornette).

# هری مارکویتز، برندهٔ جایزهٔ نوبل اقتصاد (۱۹۹۰)

## Mean-Variance Model (1952)

$$\hat{r}_P = \begin{bmatrix} w_1 & w_2 & \cdots & w_n \end{bmatrix} \begin{bmatrix} \hat{r}_1 \\ \hat{r}_2 \\ \vdots \\ \hat{r}_3 \end{bmatrix}$$

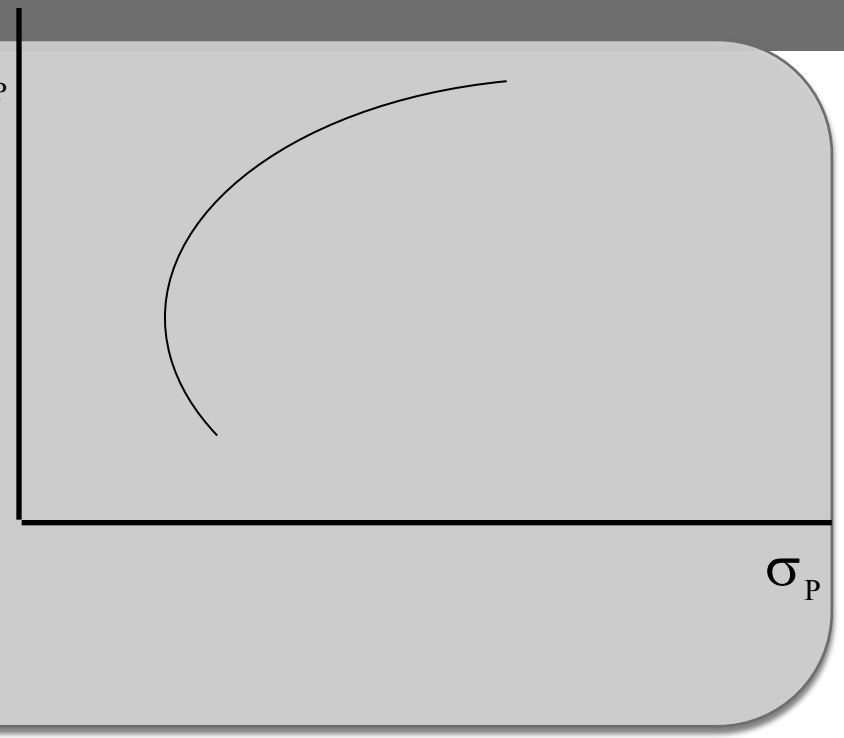
$$\sigma_P = \begin{bmatrix} w_1 & w_2 & \cdots & w_n \end{bmatrix} \begin{bmatrix} \sigma_{11} & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_{nn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

# مرز کارا EFFICIENT FRONTIER

$$\text{Min } z = \sigma_p^2$$

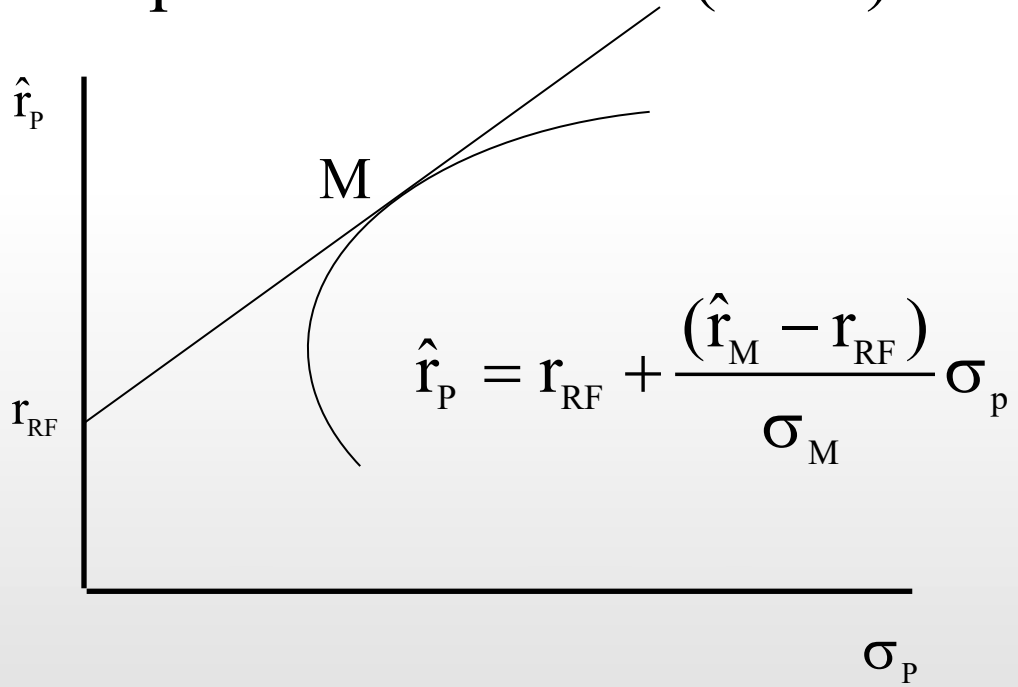
$$\text{S.T}: \quad \hat{r}_P = \sum_{i=1}^{n} w_i \hat{r}_i$$

$$\sum_{i=1}^{n} w_i = 1$$



# جیمز توبین، برندهٔ جایزهٔ نوبل اقتصاد (۱۹۸۱)

Capital Market Line (1958)



# ویلیام شارپ، برندهٔ جایزهٔ نوبل اقتصاد (۱۹۹۰)

$$r_{it} = \alpha_i + b_i r_{Mt} + \varepsilon_{it}$$

Single Factor Model (1963)

Capital Asset Pricing Model (1964)

$$r_i = r_{RF} + b_i (\hat{r}_M - r_{RF})$$

# فیشر بلک و رابرت مرتون (۱۹۹۷)

Option Pricing Model (1997)

$$d_1 = \frac{Ln(S/X) + (r_f + \sigma^2/2)t}{\sigma\sqrt{t}}$$

$$c = SN(d_1) - Xe^{-rt}N(d_1 - \sigma\sqrt{t})$$

# CALL OPTION VALUATION EQUATION

1st Stage

$$S_T = S_0 * \exp\left[\left((r - \frac{\sigma^2}{2})dt + \sigma\sqrt{dt} * z\right]\right.$$

2nd Stage

$$z \sim N(0,1)$$

3rd Stage

$$\{z_1, z_2, \cdots, z_{5000}\} \quad \{s_{T,1}, s_{T,2}, \cdots, s_{T,5000}\}$$

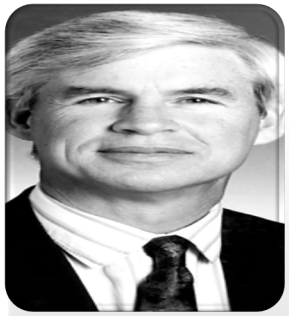
4th Stage

$$\text{payoffvec} = \max(S_T - X, 0) \qquad \text{callprice} = \text{mean(payoffvec)} * \exp(\text{-rT})$$

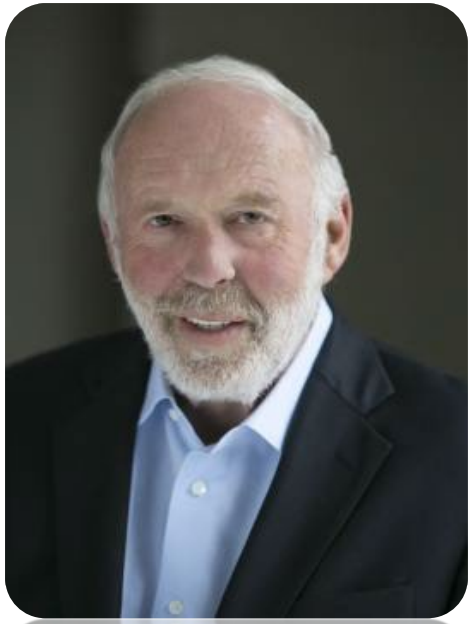
# EUGENE FAMA (2013) EFFICIENT MARKET THEORY

**analyzing economic time series with time-varying volatility (ARCH)**

ROBERT F. ENGLE (2003)



$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \, \varepsilon_{t-i}^2$$



Jim Simons (1938)

The Medallion Fund was founded in 1988 by Jim Simmons, a mathematician and theoretical physicist, the Chern–Simons Triangular Theory creator, and one of the leading figures in string theory in physics.

The fund under his management was able to achieve a return of 2478% in the first decade of its activity. Quantum Fund, managed by George Soros, had a return of 1,710 percent during the same period.

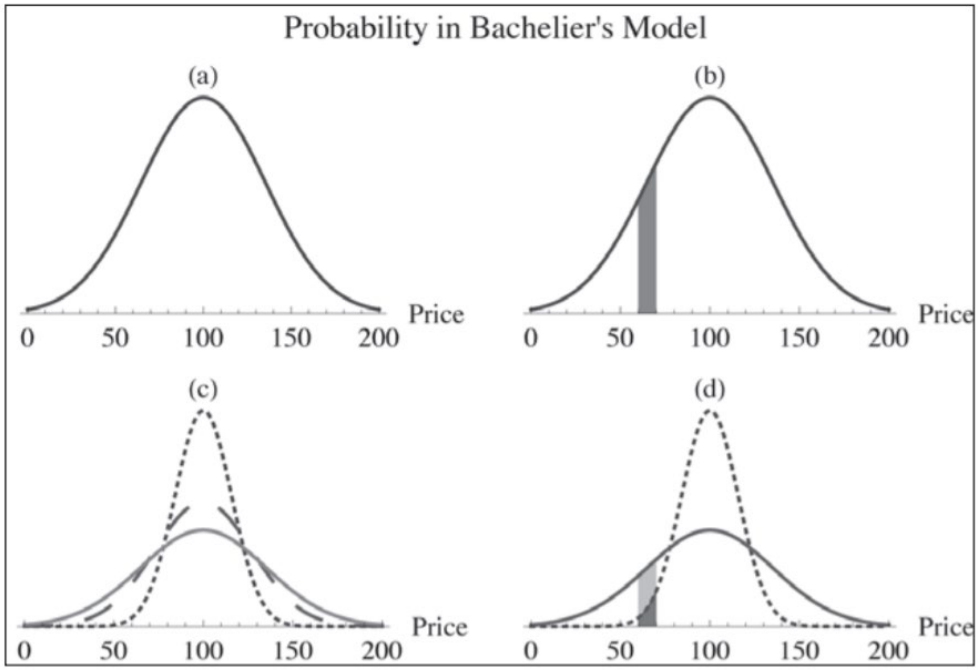
In 2007, despite the onset of the financial crisis, the Medal Fund achieved a return of 73.7%, while the median return of value conservation funds this year was 10%.

**Louis Bachelier (1870 – 1946)**

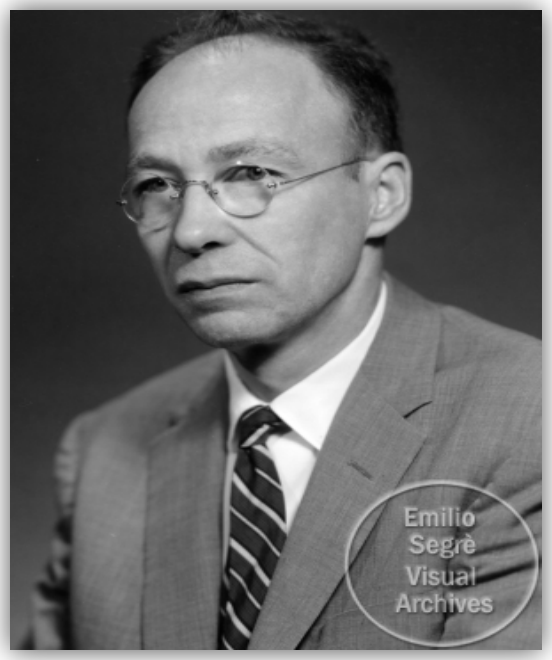
A French mathematician and physicist who, while studying physics at the University of Paris, was able to find a job on the Paris Stock Exchange, despite his ulterior motives, due to his financial need and his high ability in mental calculations; This was the beginning of his entry into the financial world.

In his doctoral dissertation, The Theory of Speculation, which he defended in 1900, Bachelier formulated financial mathematics half a century before Paul Samuelson, and five years earlier than Albert Einstein came up with the concept of random walk. He formulated it not in physics but in financial mathematics.

He actually answered that if stocks start at a certain price and follow a random walk, what is the probability that the price will reach a certain value after a certain time?

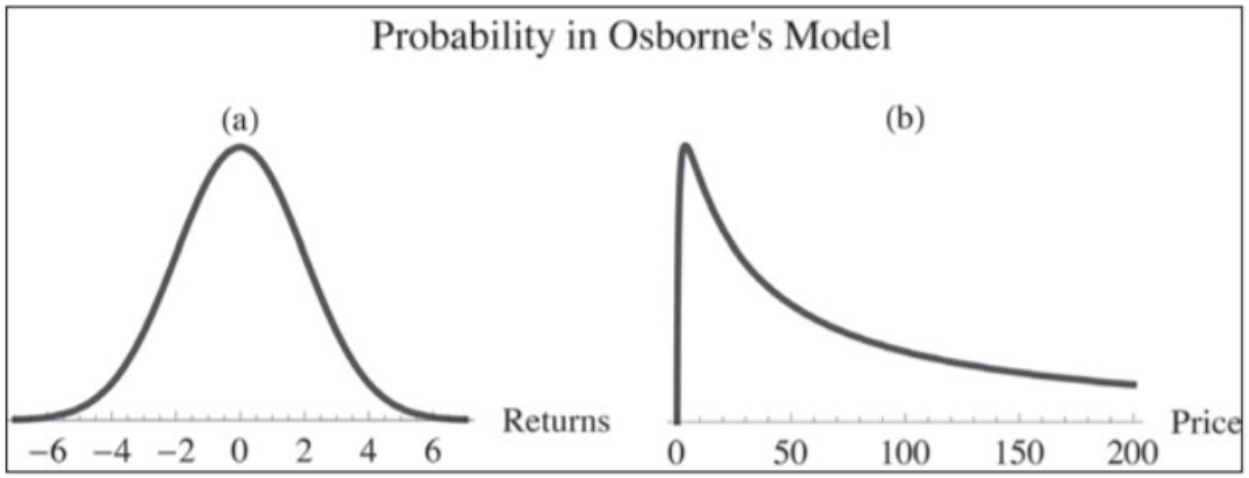



**Probability in the Bachelier' Model for a $ 100 Stock**

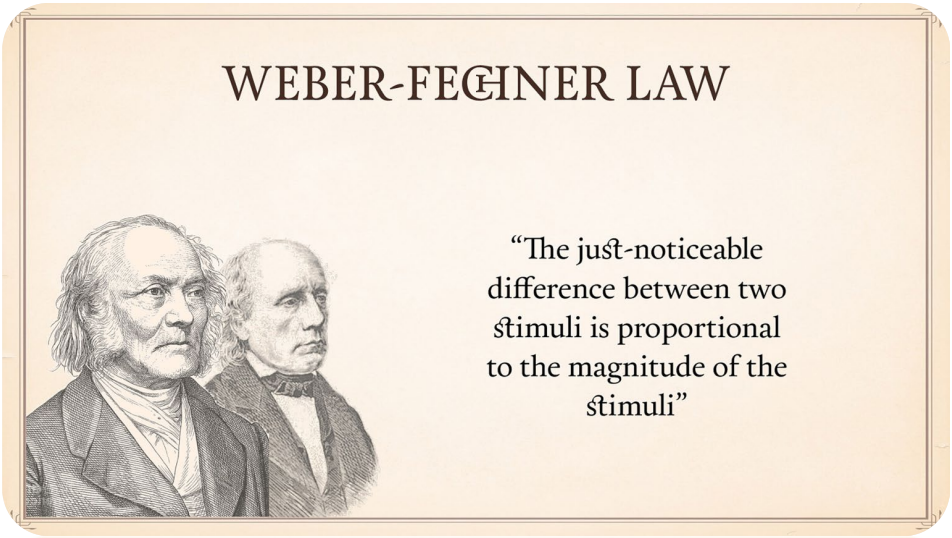



Maury Osborne (1916 - 2003)

Maury Osborne is a physicist who has never done research on a particular subject in his scientific life. His studies ranged from astronomy to aerodynamics of insect fluttering to finance. The 1959 paper entitled The Brownian Motion in the Stock Market was a revolution in finance.
In the first step of his study, Osborne rejected **Bachelier'** view that stock prices followed a normal distribution. It was enough to select a set of stocks and plot their prices to test this hypothesis. If Bachelier's assumption was correct, it would have been expected that the stock price would have been a normal bell-shaped curve, which it did not.




- The curve obtained by Osborne had a hump with a long tail on one side and did not resemble a normal curve.
- Osborne found in his research that it is not the price itself that has a normal distribution, but the stock returns follow the normal distribution.
- Therefore, if stock returns have a normal distribution, stock price distributions will have a logarithmic normal or lognormal distribution.

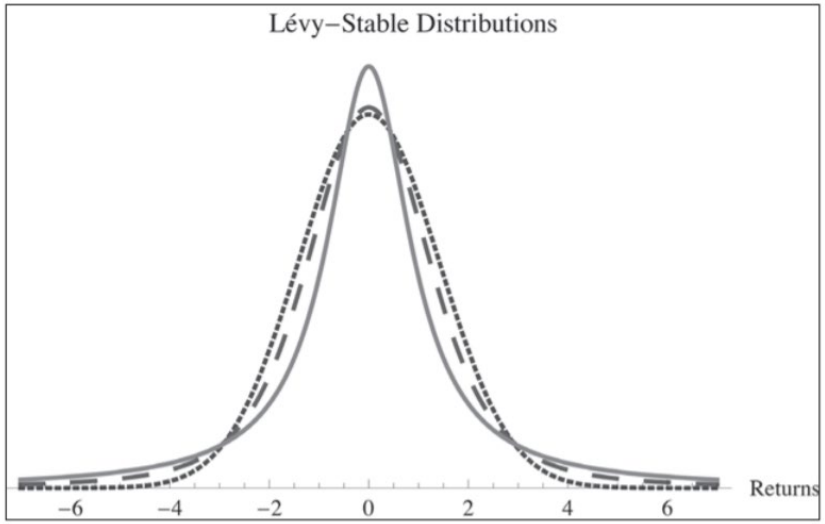



Osborne argues in his article Brownian Motion in the Stock Market that stock price changes do not matter in themselves, but that the logarithm of prices matters because it better reflects the investor's sense of profit and loss.

Osborne's main motivation for choosing the logarithm of prices as the main variable seems to be to pay attention to a psychological principle called Weber-Fechner law, which tries to explain how people react to external stimuli.

Benoit Mandelbrot (1924 – 2010)

- He was a mathematician and the father of fractal geometry who became interested in finance.
- Mandelbrot criticized Osborne's theories about the randomness of stock prices.
- Mandelbrot's research did not rule out the possibility that stock prices were random, but he believed that they were different from what Osborne thought.

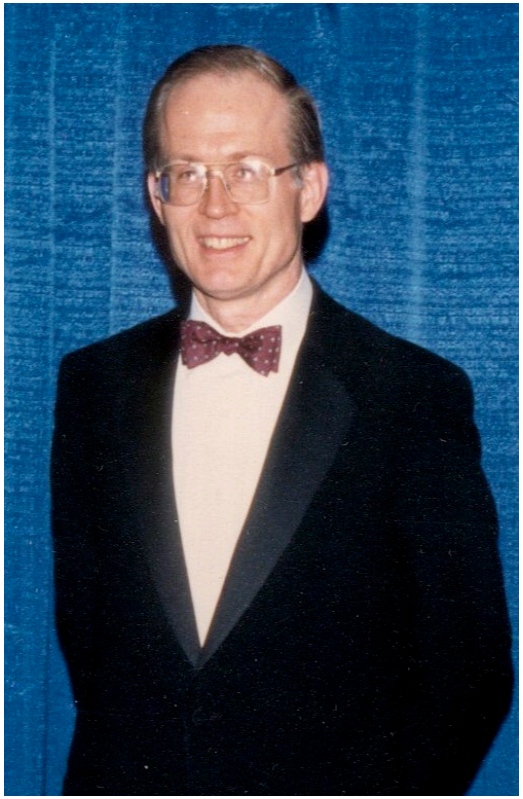



- In his 1963 writings, Mandelbrot argued that markets are subject to Paul Levy's stable distribution and that, with the exception of normal distribution, Levy's stable distribution volatility is infinite; That is, most standard statistical tools are not useful for analysing these distributions.
- After more than half a century of research, the consensus today is that distribution of the rates of return has a fat tail, but their distribution is not Levy stable. Therefore, available statistical tools can be helpful.

Edward O. Thorp (1932)

Edward Thorpe was a mathematician and professor at MIT University who tried to use mathematics to make money in casinos in the 1960s.Together with Claude Shannon, a mathematician and father of information science, he built a device that enabled them to defeat roulette in 1961 at Las Vegas casinos.He also developed game-winning strategies with the help of probability theory.

## فصل پنجم: فیشر بلک و مایرون شولز



Fischer Black (1938 – 1995)

- فیشر بلک فیریکدانی بود که به گفتهٔ خودش به دلیل مفهوم تعادل، جذب مالی و اقتصاد شد.
- او پس از مطالعهٔ مالی و آشنایی با مدل CAPM و با جدیت روی رابطهٔ ریسک و بازده در بازارهای مالی کار کرد.
- هدف بلک دستیابی به سبدی مرکب از سهام و اختیار سهام بود که عاری از ریسک باشد. این استراتژی که توسط بلک ارائه شد امروزه به پوشش پویای ریسک (Dynamic Hedging) شهرت دارد.
- بلک تلاش کرد تا نحوهٔ تغییر قیمت دارایی‌های مبنا در طول زمان را مدل‌سازی کند. براساس رابطه‌ای که بین قیمت سهام و قیمت‌های اختیار کشف کرده بود، دریافت که قیمت‌های اختیار معامله در طول زمان چگونه باید تغییر کنند. تنها چند گام جبری مانده بود تا ارزش اختیار معامله را بر اساس رابطهٔ میان قیمت سهم و اختیار آن و نرخ‌بهرهٔ بدون ریسک کشف کند که به علت پیچیدگی معادلهٔ دیفرانسیل به دست آمده در حل آن ناتوان ماند.

Myron Scholes (1941)

Robert C. Merton (1944)

- اما پس از چندی آن را با مایرون شولز در میان گذاشت و آن دو توانستند با همکاری یکدیگر آن معادله را حل کنند.
- همزمان با آن‌ها رابرت مرتون نیز با شروعی کاملا متفاوت به همان معادلهٔ دیفرانسیل رسیده بود.
- معادلهٔ حاصل امروزه به مدل فیشر–شولز (یا بعضاً معادلهٔ فیشر–شولز–مرتن) مشهور است که در سال ۱۹۹۵ جایزهٔ نوبل را مشترکاً برای این سه نفر به همراه داشت. اگرچه بلک در هنگام دریافت جایزه از دنیا رفته بود.