THE PHYSICS OF HIGH FINANCE

It's no secret that mathematically inclined physicists can find an appreciative home as quantitative analysts in banking and other sectors of high finance. "There are a thousand guys like me out there" is how Albert Zisook of the Swiss Bank Corporation sums up the situation.

If not entirely uncommon, the jump from physics to finance nonetheless is a big one, and it took Zisook a while to find and settle into his career. After graduating from the University of Chicago in 1982 with a PhD in physics, he drifted through a postdoctoral appointment, worked in defense-related electronics and finally, six years later, found a home with O'Connor and Associates, an options trader in Chicago populated by ex-MIT engineers and scientists.

When Swiss Bank acquired O'Connor in 1992, Zisook was made an executive director with responsibility for developing the mathematical models that help determine value and risk for the company's worldwide business in interest-rate derivatives. Derivatives are financial agreements whose values are linked to or derived from changes in some underlying variables, such as interest rates, stock prices or currencies. For example, one can take an option to buy a certain number of shares of stock at a specified future date and price. One can buy and sell an option without ever possessing the underlying entity on which it is based—the stock in this example.

Zisook explains buying and selling a stock option: "Suppose I want an option to buy a stock that's presently priced at $50 a share for the same price a year from now. I want to know how much I should pay for that privilege—what the value of that option is. For example, if I think the price will soar to $75, the option is worth $25 a share; if I think the price will sink to $25, the option is worth nothing. What I *don't* do is try to predict through market research—which can range from intuition to sophisticated mathematical analysis—what the stock price will be in a year.

"I begin with an estimated range for the stock price—something substantially easier than predicting where the market will go. Let's say I think the stock price will be between $25 and $75 a share. I don't know whether the price will go up or down, but there is a probability distribution for the stock price that gives me the average value of the option. Suppose the average value turns out to be $8 a share. If a customer wants to buy the option, we'll offer to sell it for $9, or if a customer wants to sell an option, we'll offer to buy it for $7. We don't really care if the customer buys or sells; we just want to make $1 on the transaction."

But the story doesn't end there because there is considerable risk, as well as opportunity, that depends on the actual behavior of the stock price. "Suppose I have just bought an option," Zisook says. "If the stock price were to change, the probability distribution would readjust itself, and the value of my option would shift. If I calculate that the option value will move 50 cents for every $1 change in the stock price, I will sell half as many stock shares as the option was for. Then every time the stock price does go up, the loss incurred by selling stock before the shift exactly cancels the gain in the value of the option I bought. The gains and losses are reversed if the stock price decreases, but the result is the same: Everything comes out even. This is called statistical arbitrage."

Theoretical basis

The mathematical underpinnings of all this date back at least as far as a

Albert Zisook

1900 publication by the French mathematician Louis Bachelier. Independently of Einstein, Bachelier discovered the mathematical theory of Brownian motion—only Bachelier did it in the context of calculating the value of a stock option. In Bachelier's formulation the value of an option was ultimately governed by an equation that physicists would recognize as the diffusion equation, or Fick's second law. In 1973 the economists Fisher Black and Myron Scholes (then at MIT and the University of Chicago, respectively) established the modern context for analysis of option values with the so-called Black–Scholes equation and thereby indirectly provided an entrée for mathematical physicists into the field. "Black and Scholes bridged the gap between theory and practice in the options world; they got the field really moving," says Zisook.

Swiss Bank has three major financial-trading product areas: interest rates, foreign exchange and equities. Zisook's specialty is interest rates. Interest-rate derivatives—options to borrow a certain sum of money at a future date and interest rate—are considerably more complex than stock options, because there are more variables. "Stocks are one-dimensional—there is the price—whereas with interest rates, there is a quantity called the yield curve—interest rate versus time to maturity—that can jiggle like a rope," Zisook explains. "In principle, there are an infinite number of degrees of freedom."

"In practice, one addresses the value of interest-rate derivatives by restricting the problem to a few 'normal modes' or 'interest-rate drivers.' An example of a driver is the 'overnight' interest rate, the shortest term for a loan. In the years since the Black–Scholes equation, a rich academic literature has grown that discusses problems with one or two drivers, but everyone understands that the challenge is to make a workable multidriver model. When all the complications are thrown in, we have a multidimensional diffusion equation with tricky boundary conditions counterbalanced by potentially elegant, simplifying symmetry conditions. It is kind of like a unified field theory for finance. This is what makes the field so interesting to a physicist," enthuses Zisook.

At Swiss Bank's Chicago office, in the casual shirtsleeve environment inherited from O'Connor, Zisook works with about a dozen software engineers to develop the tools that will be used by the more than 100 traders who handle the bank's business in interest-rate derivatives. In addition to analytical abilities, interpersonal skills are important in Zisook's line of work. Once he proposes a solution, he must then convey it to the traders and salespeople in a compelling and straightforward manner in order for the solution to be adopted and implemented.

In certain ways Zisook's work resembles the basic science research done in industry. The success of a financial firm hinges on its ability to offer products and services to address ever more complex financial problems and to manage those products and services prudently. Competing firms work on many of the same problems, but each firm considers the solutions it derives to be proprietary, and often very little is published. For Zisook and those like him, there is a sense that the research they do is new and vital. "The game is to come up with a new kind of attractive deal that is priced competitively. Then the customer will trade with you rather than a competitor."

Zisook's group also develops tools to track every transaction, assessing the value and risk of each, as well as the aggregate value and risk of the bank's interest-rate derivatives portfolio.

Finding a home

Zisook's transition from mathematical physicist to mathematical financier is the happy outcome of a search to find a comfortable home. As a high school senior, he took physics and mathematics courses at Northwestern University. "It was really interesting stuff," he recalls—so interesting that as an undergraduate at MIT, he attempted a double major in math and physics. But when he was unable to pull off the experimental work required for his senior thesis, he settled for the math degree, along with a membership in Phi Beta Kappa, at his 1978 graduation. "I wasn't experimentally inclined. While I found subjects like relativity and quantum mechanics to be fascinating and wonderful, it was more of an intellectual thing—like I really didn't care about atoms that much."

Awarded a National Science Foundation fellowship, Zisook chose to attend grad school at the University of Chicago largely because he wanted to be near home, a desire that figured strongly in subsequent career choices. At Chicago, Zisook came under the tutelage of Leo Kadanoff. "Not only was Leo an intellectual giant, he really was a mentor and a guide for me. I was horribly immature and not sure where I was going," Zisook recalls. Kadanoff pointed him toward the newly exploding field of chaos, which at the time looked particularly promising as a workable model for investigating a wide range of nonlinear phenomena, such as fluid dynamics. Zisook's chaos work carried him into problems relevant to the plasma physics of tokamaks.

In 1982, full of confidence after receiving his PhD, Zisook was accepted to Harvard as a junior fellow, a prestigious position that allowed him considerable freedom to chart his own course. He spent the first year of his fellowship in France, at the Ecole Polytechnique in Paris, where he pursued plasma physics. While there, he was in the happy situation of being paid by both Harvard and the Ecole Polytechnique. "I spent two salaries on wine and food," he says. In other respects, however, the French adventure didn't work out so well. "I didn't prosper there, and when I went back to Harvard, I was feeling much less self-confident than before."

Back at Harvard, Zisook found he missed the strong guiding hand provided by Kadanoff, and he ended up writing only one paper during his fellowship tenure. During that time, however, he did settle down to married life with Nitza Ohana, whom he had met at Chicago.

With only that one publication to show for his efforts at Harvard, Zisook decided the prospects for an academic career were poor, and so he began to look for alternatives. He was fortunate to find in his own backyard, so to speak, an opening at MIT's Lincoln Laboratory, which combined some of the atmosphere of an academic research establishment with the security clearances and the other paraphernalia that go with working in a defense laboratory.

At Lincoln Lab, Zisook used classical electrodynamics to analyze the potential for radar systems to detect so-called low-observable vehicles, such as cruise missiles. This experience helped bring back his self-confidence. "I found that making small progress in solving problems of interest to my employers was appreciated. It wasn't necessary to do something unbelievably important." However, a touch of homesickness and the desire to start a family persuaded Zisook and his wife to pull up stakes at the end of 1986 and head back to Chicago, where an opportunity with Northrop Corporation awaited.

Zisook's work at Northrop involved the application of multiple-baseline interferometry to electronic countermeasures, another defense-electronics application. Slightly perturbed by what he viewed as "the unthinking negative reaction of everyone I knew to working in the defense industry," Zisook nonetheless continued to find working on such real-world problems a stimulus for growth and a source of satisfaction. But just as the opportunity to advance in the company seemed likely, a corporate headhunter approached him about a job at O'Connor. "It was only a few months after the 1987 stock market crash, and the financial industry didn't look so stable," Zisook recalls. "But the allure of finance and the possibility of a better career than at Northrop decided the matter."

In retrospect Zisook is happy he made the switch to finance. Now that the defense industry has fallen apart, he says, "it turned out to be the right decision."

—ARTHUR L. ROBINSON ■