Stephen A. Ross

Stephen Ross speaking at the 2017 IAQF/Northfield Financial Engineer Year Award Dinner

In Memoriam: Stephen A. Ross

Stephen J. Brown

Professor Stephen A. Ross died on 3 March 2017 at his home in Old Lyme, Connecticut. His death is a great loss to his family, to his colleagues at MIT, to the academic community more generally, and to the world of investment management. A preeminent academic, Ross published many papers across a wide range of subjects in both economics and finance. Moreover, his work—particularly as it relates to investment management—had an intensely practical focus. As he wrote in an article he published with John Cox in 1976, he had no patience for arguments that required the cunning of a currency speculator to understand.[1] Many of the innovations in the financial markets and the way we think about those markets in recent decades can be traced to his thought and his writings, although he was not especially interested in the ephemera of the markets. Rather, his view was that financial transactions are central to the human experience. A gifted communicator, Ross delighted in making the most complicated ideas transparently simple, even common-sense. In this context, he was particularly proud of *Fundamentals of Corporate Finance*,[2] an introductory text that he published with Randolph Westerfield and Bradford Jordan.

Many of Ross's financial market insights were drawn from the understanding that two financial securities or packages of securities that provide the same financial outcomes in the future ought to be offered at the same price today. If this were not so, simple and profitable arbitrage opportunities would arise. It is not that such arbitrage opportunities do not exist but rather that they are necessarily small and fleeting in a well-organized securities market. This intensely practical insight lies at the heart of his contributions to factor pricing, option valuation, and fixed-income analysis. He was not the first to think about these issues. Previous research had assumed that all investors behave rationally in a world in which there is no particular role for the trading of securities. Unrealistic equilibrium assumptions of this nature had led many to view asset pricing theories as having few practical applications. Ross argued that the absence of arbitrage is a more fundamental concept than equilibrium because only a few rational agents are needed to bid away profit opportunities that arise, even in a sea of agents driven by "animal spirits."[3]

In the investment management community, Ross is best known for his arbitrage pricing theory, which provides the intellectual basis for factor investing and factor pricing approaches.[4] His point of reference is a well-diversified investor. For such an investor, many investment risks can be diversified away, and those risks that remain must be relatively small in number. Ross provides a very simple and elegant demonstration showing that if the returns investors expect on securities, over and above the return on risk-free alternative investments, are disproportionate to the security exposures to those risks, a simple arbitrage is possible. This work did not immediately suggest what these risks might be, and as he observed in a recently published article,[5] the importance of finding the right factors explains why this search so absorbs the attention of the equity investment management profession. His work with Richard Roll and Nai-Fu Chen[6] proposed several plausible candidates, but the search continues; many factors have been proposed even though we know that the number of pervasive factors that influence the markets as a whole is necessarily limited.[7]

The arbitrage pricing theory provides an important conceptual foundation for the way many people view the financial markets. In addition, it has profound implications for portfolio management, spelled out in an article that Richard Roll and Stephen Ross published in the *Financial Analysts Journal* in 1984.[8] The practical significance of Ross's work may be gauged by the fact that this article is among the 10 most downloaded

articles in the history of the *Financial Analysts Journal*. It forms the basis for most of the risk factor and smart beta approaches prevalent today, and the arbitrage pricing theory is mentioned in 202 articles subsequently published in the *Financial Analysts Journal*.

Developed at the same time and using a similar intuition, Ross's work with John Cox[9] reduced the complicated nature and tortuous intuition of the option pricing mathematics developed by Fischer Black and Myron Scholes to a matter of simple arithmetic. If security values can only go up or down, then there must be an intimate relationship between the value of options and the value of securities and cash that leads to the same financial outcome. In their work with Mark Rubinstein,[10] Cox and Ross showed that, considering the many ways that security values can rise or fall in the course of time, this binomial option pricing approach can value a wide range of derivative securities and strategies. Each step of the calculation involves simple arithmetic, but it is arithmetic repeated many times.

By the time options started trading on the Chicago Board Options Exchange, the Black–Scholes model had come into general use, and in 1975, Texas Instruments introduced its new programmable pocket calculator that came equipped with a card allowing the calculation of call values and hedge ratios using this model. The derivative securities markets have developed since that time. Options and options trading strategies have developed beyond the assumptions of Black and Scholes. It would be a number of years before computer technology developed to the point where it would be a trivial matter to perform the number of calculations necessary to implement the simple, common-sense approach that Ross and his coauthors proposed. Now this approach has become the workhorse of most, if not all, options trading concerns and options strategy implementations. As some indication of the relevance for practice, Ross's work with Cox and Rubinstein has been cited in 67 articles we have published in the *Financial Analysts Journal*.

The binomial option pricing analysis led to a more fundamental insight. If it is possible to replicate the payoffs of any derivative security—indeed, any asset—by combining a position in another security with cash holdings, then it is possible to define position weights at each point in time that lead to an investment that has no risk and deserves a riskless rate of return. These weights are referred to as "risk-neutral probabilities." The idea of valuing financial securities using the derived "risk-neutral" measure has become such a standard approach in asset pricing applications that few people remember that this terminology ultimately derives from Ross's work. It is particularly important in the area of fixed-income analysis. Indeed, with John Cox and Jonathan Ingersoll,[11] Ross developed the first equilibrium model of the term structure of interest rates. At a theoretical level, it links the pricing of fixed-income securities to the process responsible for interest rate movements; at the practical level, it provides a basis for valuing fixed-income derivative securities. In a recent work,[12] Ross studied the extent to which one can use risk-neutral probabilities to tease out from market prices the views that the market has about future security returns.

Although these contributions are most directly relevant to the practice of investment management, many of Ross's other contributions to economic thought also have a bearing on important issues in this field. An example is his development of the economic theory of agency and how to compensate agents appropriately.[13] This analysis has particular relevance in the context of delegated fund management. In addition, his thinking has found practical application in the series of asset management companies he founded, including Roll & Ross Asset Management. More recently, he was a co-founder of Ross, Jeffrey & Antle LLC, a Connecticut-based institutional investment firm.

Stephen Ross was always a teacher, always a friend. He was a very warm person, and he and his wife Carol had a particularly wide circle of friends. He was very proud of his two children, Jonathan and Kate, and his two granddaughters. On a personal note, he was a very important mentor of mine. I remember those wonderful days in the mid-1980s when Stephen would take a few of us to lunch in his new red sports car, driving along the streets of New Haven with the Beach Boys' music playing. He will be missed by many.

Notes

1. John C. Cox and Stephen A. Ross, "A Survey of Some New Results in Financial Option Pricing Theory," *Journal of Finance*, vol. 31, no. 2 (May 1976): 383–402.
2. Stephen A. Ross, Randolph W. Westerfield, and Bradford D. Jordan, *Fundamentals of Corporate Finance* (New York: McGraw-Hill/Irwin, 1991).

3. Philip H. Dybvig and Stephen A. Ross, "Arbitrage," in *Finance*, edited by John Eatwell, Murray Milgate, and Peter Newman (London: Palgrave Macmillan, 1989): 57–71.

4. Stephen A. Ross, "The Arbitrage Theory of Capital Asset Pricing," *Journal of Economic Theory*, vol. 13, no. 3 (December 1976): 341–360.

5. Stephen A. Ross, "Factors—Theory, Statistics, and Practice," *Journal of Portfolio Management*, vol. 43, no. 5 (Special Issue 2017): 1–5.

6. Nai-Fu Chen, Richard Roll, and Stephen A. Ross, "Economic Forces and the Stock Market," *Journal of Business*, vol. 59, no. 3 (July 1986): 383–403.

7. A skeptical view of the search for statistically based factors can be found in Campbell R. Harvey, Yan Liu, and Heqing Zhu, ". . . And the Cross-Section of Expected Returns," *Review of Financial Studies*, vol. 29, no. 1 (2016): 5–68.

8. Richard Roll and Stephen A. Ross, "The Arbitrage Pricing Theory Approach to Strategic Portfolio Planning," *Financial Analysts Journal*, vol. 40, no. 3 (May/June 1984): 14–26.

9. John C. Cox and Stephen A. Ross, "The Valuation of Options for Alternative Stochastic Processes," *Journal of Financial Economics*, vol. 3, no. 1–2 (January–March 1976): 145–166.

10. John C. Cox, Stephen A. Ross, and Mark Rubinstein, "Option Pricing: A Simplified Approach," *Journal of Financial Economics*, vol. 7, no. 3 (September 1979): 229–263.

11. John C. Cox, Jonathan E. Ingersoll, Jr., and Stephen A. Ross, "A Theory of the Term Structure of Interest Rates," *Econometrica*, vol. 53, no. 2 (March 1985): 385–407.

12. Steve Ross, "The Recovery Theorem," *Journal of Finance*, vol. 70, no. 2 (April 2015): 615–648.

13. Stephen A. Ross, "The Economic Theory of Agency: The Principal's Problem," *American Economic Review*, vol. 62, no. 2 (May 1973): 134–139.

ROUNDTABLE

Q Group Panel Discussion: Looking to the Future

Martin Leibowitz, Andrew W. Lo, Robert C. Merton, Stephen A. Ross, and Jeremy Siegel

Moderator Martin Leibowitz asked a panel of industry experts—Andrew W. Lo, Robert C. Merton, Stephen A. Ross, and Jeremy Siegel—what they saw as the most important issues in finance, especially as those issues relate to practitioners. Drawing on their vast knowledge, these panelists addressed topics such as regulation, technology, and financing society's challenges; opacity and trust; the social value of finance; and future expected returns.

Andrew W. Lo: Regulation, Technology, and Financing Society's Challenges

Over the course of the next decade or two, I see three tremendous challenges and opportunities in finance. The first challenge is the regulatory environment in which we operate, as pointed out by Rodgin Cohen, a highly respected securities lawyer, at a recent conference. He said that after having been in the business for almost half a century, he has never seen the kind of animosity and frictions between industry and regulators as he sees today in the financial industry. This tension is a problem because finance is a means to all sorts of important ends.

We seem to be cutting off our noses to spite our faces over the past several years. Financial economists bear some responsibility in that we need to be more involved with regulatory processes to make sure the very best financial thinking is reflected in regulations. We could all contribute to this challenge in one form or another.

The second challenge and opportunity is to think about how technological advances in other fields, particularly computer science, can be used in finance. We tend to be a somewhat closed group, which perhaps is true for all fields. We have our favorite perspectives

(Photo courtesy of the Q Group.)

Martin Leibowitz is a managing director at Morgan Stanley, New York City. Andrew W. Lo is the Charles E. and Susan T. Harris Professor of Finance at the MIT Sloan School of Management. Robert C. Merton is the School of Management Distinguished Professor of Finance at the MIT Sloan School of Management. Stephen A. Ross is the Franco Modigliani Professor of Financial Economics and a professor of finance at MIT and a managing member of Ross, Jeffrey, Antle, LLC. Jeremy Siegel is the Russell E. Palmer Professor of Finance at the Wharton School of the University of Pennsylvania.

Editor's note: We wish to thank the Q Group for allowing us to publish an edited version of this panel discussion, held 19 April 2016, and thus making the panelists' comments available to a wide audience.

and paradigms, but one of the things that is changing rapidly, as many of you know, is data science.

A genuine revolution is taking place in the use of computational techniques for analyzing things that we traditionally think of as being outside the domain of computer science, and we now have many interesting synergies, with robo-advising being a case in point.

A tremendous amount of data, and therefore wisdom, is buried in these datasets, and we have to think about how to mine them, which may mean putting aside our paradigms and focusing instead on the underlying structures in the data that only these computational methods can give us.

The last challenge relates to how far we have progressed as a species. In 1900, about a billion and a half people were living on the planet. Now, the world has approximately 7 billion people. From an evolutionary timescale, in the blink of an eye, we have more than quadrupled the number of *Homo sapiens* running around. Most of these people are born without wealth, savings, or income, and they need some kind of financing to live out their lives.

This rapid change suggests that financial structures will be much more complex, which means that we will have to think about more sophisticated ways of dealing with some of society's biggest challenges. Examples of these challenges might include cancer and other diseases, climate change, and the energy problem. All of these issues require some kind of financing, and it is both a challenge and an opportunity to develop the kind of finance of the future to deal with these issues.

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— Lo

Robert C. Merton: Opacity and Trust

The following comments are likely to be quite significant, either in practice or in academic research. The first issue has to do with the notion of inherent opacity and trust. What do I mean by inherent opacity? It is something we cannot make transparent. And if something is inherently opaque, then the only mechanism that works is trust.

Usually, we think of trust as in trustworthy. But trust actually has two components. The first component is trustworthy, in which we want the individual to do the right thing and we deal with the agency problem the best we can. The second component is competence; we want the individual to be competent. A well-meaning fool can do as much damage as an evil-meaning trustee.

Financial services, like financial advice, are inherently opaque. If you agree with this premise, then trust is, therefore, the only mechanism that provides an answer. And with this line of thinking, you obtain insights into what we can and cannot do and who can do what.

We see many references these days to robo-services. The news from Silicon Valley says robo-services are going to come and "eat all the banks' lunches." Certainly, in some areas, that will prove to be true, especially processing activities, such as clearing and settling. Having a phone that can get data to you anywhere, in order to think quicker in analyzing the data—that works. But replacing advice may not be as successful—or at least not without coupling it with something that is not from Silicon Valley.

Think of medicine. Suppose you need surgery. The process can be made more transparent by showing you all of the scientific studies, a list of all the tools to be used, and the step-by-step surgical procedure. Is that transparency? No. You cannot judge how the surgery will come out. Surgery is inherently opaque, and so is financial advice. Those engaged in providing advice who are really good at it will find themselves leveraged as opposed to facing stiffer competition.

The next issue is that goal-based investing will be very important in the next decade. For example, if you have a goal of funding retirement or a benefit plan, you set the goal and manage it through a process called LDI (liability-driven investing). If you follow a liability-driven goal, then regardless of whether your Sharpe ratio exceeds those of your competitors, you can outperform competitors who lose their focus on the goal.

It is not that managers are not good at getting high Sharpe ratios. Rather, they are too good at it because there is so much money and so much competition. It may be easy for a manager to show that competitors do not have as good a Sharpe ratio, but in the future, we are likely to have a more important focus. We will be driven to the idea of greater service by knowing the client better, understanding what the client really needs, getting the client to identify what the actual goal is, and then designing dynamic strategies that achieve that goal.

The third issue is globalization. Think of the applied area of designing retirement solutions. These solutions should not be designed, for

example, for Western or Asian cultures but, rather, designed to work across geopolitical borders. This approach is possible if that design is based on solid finance principles because those principles are as reliable as gravity. Finance principles apply everywhere, independently of the culture. This does not mean that culture does not matter. But if you design to principles, the cultural aspects will fall into place.

The fourth issue is the idea of replacing dynamic strategies with new securities. We know the replicating principle for derivatives: We can replicate a derivative with active trading. But we can also run the principle in reverse: We can replicate a dynamic strategy with a security. We are likely to see more and more of this type of replication.

Stephen A. Ross: Social Value of Finance

We need to make a social case for the value of finance. We must realize the bad state we are in because politicians, regulators, and the academic community do not see the need for a case to be made.

Before 2008, a faculty member at MIT might have said, "What are you people doing over there in finance? You are taking these really wonderful kids we have in physics and engineering, and they all want to leave and go into finance." They were saying that somehow finance is, if not socially irresponsible, at least nowhere near as valuable as what they were teaching them in other departments.

After 2008, it became impossible to make the case that finance is as important as other disciplines. People looked at those of us in finance as if we were the evil folks who caused all of the problems. Most people never learned the lesson of 2008, which was not how bad a situation various institutions found themselves in but, surprisingly, how few institutions really found themselves in that situation, and how much was really solved with finance.

Securitization did what it was supposed to do. It spread the risk. When you spread the risk, it does not go away and some people ended up bearing it. Some areas had too much risk because people made foolish decisions. An efficient market may protect the sheep from the wolves, but nothing protects the sheep from themselves.

We have to make the social defense for finance, and in doing so, we have to separate it from the general argument for the value of economics. To some extent, we are tainted by macroeconomics. Macroeconomic theory is now a place people turn to when they want to figure out what to do about monetary policy, and it is questionable whether we really know what to do about monetary policy.

We should be pushing the variety of ways in which the structures, theories, and empirics of finance are and can be used to better this world. Perhaps then we might see governments turn away from the current animosity they have for the financial world. We have not made the case strongly enough, and if we do not, we and the world will suffer.

We need to make a social case for the value of finance.

— Ross

Jeremy Siegel: Future Expected Returns

What kind of returns are we going to get in the next 10 years? Are we in a new world of returns going forward? One of the stylized facts that we all think about is the price/earnings ratio (P/E) of the market. For the long run, people throw out the number 15, which is not really a bad estimate.

Robert Shiller, of course, started this research. For stocks, 6.7% is the annualized long-run, real return, dating from 1926 to the present. It is not a coincidence that 1/15 is 6.7%. Stocks are real assets, so the earnings yield, which is the reciprocal of the P/E, should be 6.7%. It is comforting that there is some economics related to what we have seen in the equity market.

Where do we stand right now? One would think it would be simple to talk about what P/Es are today, but it is not, mainly because we have several different types of earnings definitions. As an example, these differing definitions tended to diverge by an extremely large amount last year, primarily because of significant write-downs in the energy industry.

The S&P 500 Index just crossed 2,000. S&P 500 operating earnings, which are very conservative but not as conservative as GAAP earnings, came in last year at $100. That is a P/E of 20, which is quite a bit higher than the long-run average.

Standard & Poor's thinks operating earnings will go to $110 this year. I/B/E/S already said operating earnings were $110 last year. Taking an earnings yield from a P/E of 18–20 gives a 5.0% to 5.5% real return going forward, which is about a point and a half under the long-run average.

It is critical to compare stocks with bonds. Ten-year maturity US Treasury inflation-protected securities (TIPS) were first floated at 3.7% in 1997. They went to almost 4.5% in 2000. They yield about zero now. Very few economists would have ever expected this development. The world's largest asset class, fixed income, has actually experienced a far more serious drop in yields than equities have.

Going back to 1802, the long-run real return on bonds is 3.5%. It has been lower over the more recent period, around 2.0% to 2.5%, which gives a historical equity premium of between 3.0% and 3.5%. It is interesting that 3.0% to 3.5% is the same number that Dimson, Marsh, and Staunton determined in their book, where they originally reviewed 16 countries and the world since 1900.[1]

The equity premium is above that now. A conservative P/E of 20 translates into a 5.0% real return. We are at zero on 10-year TIPS. The 30-year TIPS are a little bit higher, but there is some indexing risk that the government could shift over the next 30 years. Depending on how much inflation there actually is, we are at about a 5.0% equity premium now. So, either stocks are undervalued relative to bonds, or you can say that stocks are slightly overvalued but bonds are very much overvalued according to historical means.

Two possible reasons may explain why the real return is going to stay low. One is increased risk aversion. Older investors, who tend to have a high risk aversion, push down the safe rates. Bonds have also become good negative-beta assets for short-term investors. When the stock market drops 700 points, T-bonds usually go up 2.0% or 3.0%, which is comforting when diversifying a portfolio. By the way, the bond market did not have these negative betas in the late 1960s through the 1980s when inflation was a problem. If inflation gets bad once again, one could conjecture whether those negative betas on bonds will actually turn the other way.

The second reason why returns may stay low relates to slow growth. According to the US Congressional Budget Office (CBO), we have experienced 3.5% real GDP growth in the post-war period. The CBO says that growth will be 2.0% over the next 10 years. Apparently, labor market growth in the United States is at the slowest point in its 240-year history. We also have had a productivity collapse over the past five years. All of this combines to tremendously slow down real growth, and real interest rates are related to real growth.

Finally, we should probably expect future returns to be lower on stocks and bonds and probably much lower on bonds than on stocks. Stocks do not appear to be at risk for any deep decline, looking at the yield structure going forward.

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— Siegel

Question and Answer Session

Moderator/Leibowitz: How do demographic trends, lower birthrates, and higher life expectancies throughout the developed world change finance as we know it?

Merton: We have two significant changes around the world. The first one is that the population is older than it used to be. It is much older in the United States but is growing even older and faster in China and in South Korea.

The second change is that people are living longer, which is a good thing and not a problem. But like many good things, it has a dysfunctional aspect, which is, how are we going to fund it?

Retirement has three main sources of funding. Is government the answer? Unlikely. Not too many people are thinking social security will be expanded to higher benefits.

Employer plans? We know that the benefits have gotten smaller. And there has been an exodus, at least in the corporate sector, and eventually probably in the public sector, out of defined benefit (DB) plans because they were too expensive or too risky—that is the same statement—for what they were providing. Employers did not get out of DB to have more expensive defined contribution (DC) plans. So, the amount that people will get from employer plans is going to be less.

The only source left is personal saving. For working, middle-class people, personal saving is, for the most part, their house—if we exclude their retirement accounts.

So, if you are going to live longer and if you want to work the same number of years as your parents did, you have to save more to pay for that longer life and thus you have to cut your standard of living. If you want to enjoy the same standard of living as your parents did, you have to work longer. Everything in between is feasible. What is not feasible is to live longer and at the quality level of your parents and work for the same number of years.

That trade-off is at the core of what we need to address. Getting higher returns is not in the cards. You cannot manufacture another 200 bps unless you take more risk. If you take more risk, then you have to have a policy if the risk is realized.

What you can do is improve the benefits you get from the assets you have. For working and middle-class people, two things can do that. One is the annuity, because you give up your money when you no longer need it. In return, you are getting money when you do need it, which is when you are still here—a pretty good trade in my view.

The second thing that people can tap to extract more retirement benefits from the assets they have is the reverse mortgage. The Korean name, home pension, is much more descriptive. Basically, it does

the same thing as an annuity. It transfers value back to retirees when they need it.

Remember that we cannot rely on the government or on the expansion of DB plans, so the only way to fund a longer retirement is through higher personal saving. We are not going to transform personal saving sufficiently without legislation, such as has been done in Australia and Chile. The beauty of the reverse mortgage is that it uses the asset that people already have in order to save and then transforms it into more benefits. It is not magic, but it is very, very important.

Moderator/Leibowitz: Of course, there is the risk of people monetizing the value of their home as they need it. We cannot assume the valuation of the house will continue to rise. It was a problem in recent times.

Merton: That is part of why the name "reverse mortgage" is so unfortunate. It is not a loan in the usual sense. You never pay it back. The way to think about it is to imagine you have no beneficiary. The deal is you do not pay anything back—either interest or principal—until you leave the house. Usually the expression of "leaving the house" is to go somewhere where you do not need either money or the house.

That scenario is very different from the one in which people take a home equity loan, where if the bank decides it does not like that business, it calls the loan. The retiree would then have to repay both the principal amount and any cumulative interest, with full recourse. Part of the misconception about this product is because of its name.

Moderator/Leibowitz: You raise a very valuable point: The personal portfolio of most people is dominated by things such as homes, the present value of their social security, their health care benefits, and their human capital. All of these things are difficult to analyze. Are we missing something by not trying to put these items into the pot and seeing what the implications are for the areas where we do have choices?

Lo: Absolutely. We are missing out on the $64 trillion question, which is how to integrate financial decision making across all of the different decisions that are relevant for individuals. Obviously, from an academic perspective, we tend to focus on models and securities and figuring out optimal portfolio policies under various circumstances, but this question really goes to the difference between products and solutions when you think about providing value for individuals.

Perhaps the best way to think about this situation is the comparison of the iPhone with the telephone before we realized we needed an iPhone. The reason an iPhone is so useful is not because it is incredibly sophisticated—it is useful because it is incredibly simple. Investors are not looking for products; they are looking for solutions. Few people in finance think in those terms, at least not yet, and it will be a sign of maturity when we start developing solutions.

A case in point is medicine. We are now at the threshold of developing breakthrough therapies that can actually cure various human diseases, and these therapies are very expensive. One example is a gene therapy that literally manipulates the genes in your body to change your genetic structure. It costs $1 million per patient.

How are we going to pay for such treatments? That is the challenge of integrating all of these expenditures and, ultimately, designing the proper financing for them. This is the kind of solution that investors really want.

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— Lo

Moderator/Leibowitz: We are often viewed as being aligned with Wall Street and the banking industry and thus the source of the problems rather than the solution. In terms of the social dialogue, this has generated a lot of ire against our field. In some ways, our financial evolution has enabled us to facilitate all kinds of things that would not have otherwise happened. So, how can we turn this around? How can we get the expression "financial engineering" to not have a bad ring to it?

Ross: We cannot do anything in the short run about that perception. It is going to be a long-run process. The question is, why do we want to turn it around? The answer is, or should be, we want to turn it around because if we have a credible voice in policy circles, then we will be able to apply finance and do some useful things with it. Without that, we will not be listened to or taken seriously. More importantly, others will think that everything we say has an ulterior motive behind it and that we are not talking for the social good.

This perception will be very hard to change. People want solutions, not products. In addition to offering solutions to people, we also must be careful to not oversell ourselves.

The truth of the matter is that it is easier to manage a $100 billion portfolio than it is to manage an individual person's portfolio. We are very comfortable saying, "I want to be on a mean–variance frontier" or "I want to be on some efficient frontier." But we are not comfortable with the decisions of an individual investor.

A friend of mine is an expert in these sorts of things, and he stood up at a symposium and said, "With all these economists in the room, I will bet that not one of you knows what the right time is to apply for social security." He was right on target. No one really knew because the rules are so complex. The environment in which an individual operates is very complicated, and we have only begun to scratch the surface.

If you are talking about issues such as behavioral finance, you talk about factors that affect individuals, and you do have to bring some of those ideas in when you are talking about doing what is good for a person. But in order to not oversell what we are able to do, we have to do some more basic research on what are the best solutions for some of these people.

Moderator/Leibowitz: Let us talk about the issue of robo-advising. Is this really a reasonable way to help people with lower assets who cannot afford the benefits of a financial adviser?

Lo: A lot of progress, particularly in the area of artificial intelligence, has been made that can be very useful for developing better robo-advising algorithms, but the problem is not artificial intelligence—it is "artificial stupidity." We need algorithms for capturing the mistakes and other human predilections that cause the most mischief for people's portfolios, and then we need to design products around them.

We are getting there, but it will probably be another 10 to 20 years before we have robo-advisers that can actually perform the functions that we do, and the functions that people are looking for.

Merton: We have to be careful to distinguish between a good idea, product, or solution and its execution. Robo-advisers can be terrible just as ordinary advisers can be terrible. We have to distinguish between a terrible or costly version of something that is good and something that inherently is not a good idea.

If I may go back to the topic of trust, recall that creating trust entails the aspects of trustworthiness and competence. It is not a question of the mechanics as to how much is done by a computer and how much is done by a human.

We use human beings in structured situations in an odd manner. A model is an approximation. Therefore, there are conditions under which the model does not work, which is when something, usually a human being, has to intervene and make a decision in a nonstructured situation—turn the model off or keep with the model. But you cannot anticipate what the decision will be because otherwise it would be part of the model. We all know that finance models have their limitations and that a well-trained person who understands the limitations of a particular model is incredibly valuable.

We are starting to see change. For example, there is a huge trend into index funds because of their lower cost. Why? Because an index fund is absolutely mechanical. It is transparent, and if you have transparency, you do not need trust. Since the 2008–09 crisis, $500 billion went out of equity funds. Why? Because in that crisis, trust was lost. People had to do something, and something mechanical and fixed did not require having trust.

The problem is that even with the best of conceivable robo- or financial-advisory systems, you will still have blowups. It is not going to be sufficient to have the best system run by the best pilot. The system is still going to be vulnerable, and it is not going to be easily understood or accepted comfortably by those who are in the passenger seats.

Finance models have their limitations and a well-trained person who understands the limitations of a particular model is incredibly valuable.

— Merton

Lo: The fact is that investors have a hard time thinking about investing when they are losing extreme amounts of money over short periods of time.

The technical term is that they are "freaking out." When people freak out, it is hard for them to remember that they should think about stocks for the long run. Between the fourth quarter of 2008 and the first quarter of 2009, the maximum drawdown in the S&P 500 was 51%. We expect retail investors to sit back and say, "Yeah, no problem; that is just fine." Of course, there will be a fraction of them who will say, "I cannot take this anymore—after a 20% or 30% or 40% loss, I am out."

If we want to prevent that kind of behavior from happening, we have to change our products so that people do not experience those kinds of rollercoaster rides.

Moderator/Leibowitz: There is the issue of dealing with volatility, but there is also the issue of dealing with the prospect that a rebound may not happen or may be long delayed.

Lo: If you simulate strategies in which you pull out your money after a 20% or 30% loss, it turns out that pulling out your money is not the most damaging part of that reaction. The real damage comes from waiting too long to get back in. Following a simple rule such as reducing my equity exposure by half any time the S&P drops by a cumulative amount of 30% or more over a six-week period then waiting a fixed period of

time, say, 7 or even 18 months, and getting back into equities 100% actually does better than many other rules of thumb.

Moderator/Leibowitz: Suppose we have two types of investors, one who is going into a retirement home in five years, so basically has to consider many risks, and another one who has a very long-term horizon and can tolerate short-term volatility. What should these investors do?

Siegel: With a five-year horizon, there is a lot of variance in the market. That risk can be measured somewhat by the P/E. The risk is much higher if you start the five-year period with a high P/E than if you start out at or below average. Even with today's terribly low interest rates, if you must have safety over the next five years, it would be risky to put the money in stocks. But as stated earlier, when you look long term, the premium of stocks over bonds is very, very high. At this time, however, we have to expect lower returns on both asset classes going forward.

Moderator/Leibowitz: Should long-term investors hold any bonds?

Siegel: Only junk bonds, which are kind of quasi-stocks. Whether or not the investor holds junk bonds lets you know something about his or her risk tolerance. If you feel good by having your T-bonds cushion the loss on equities when the stock market drops 700 points, then you are paying for an expensive insurance policy, but that may be your risk preference.

At today's rates, if one is limited to stocks or bonds, preferences would point overwhelmingly to stocks.

Moderator/Leibowitz: It is interesting to recall that before 1974, it was not uncommon for endowment funds to be 80% in stocks. Their rationale was because they were long-term investments, the greatest fear was inflation and they felt that stocks would be a long-term inflation hedge.

Siegel: You can use TIPS. But with current TIPS returns, you have a slightly different perspective.

Ross: I recall a debate at TIAA-CREF about whether it was the money of a participant or the money of the fund that owns the asset. We are now in a world where individuals are making all of their own investment decisions, so we have a large percentage of people who aspire to be day traders. It is difficult to imagine anything that is worse for your financial health than being a day trader.

We can present this advice as reflecting the best solutions in the world, but the reality is that people are not going to take it. One of the great questions that arose at TIAA-CREF when a money market fund was added to the mix was whether people would allocate properly among equities, TIAA, and a money market fund. People did exactly what we thought they would do: A large percentage decided, "I'm going to put a third in each."

We have to bridge the gap between our good advice, on one end, and whether we might have some disputes about what our advice would be on the other end. Once we get to good advice, we need to get a good solution.

Moderator/Leibowitz: On that TIAA-CREF story, we did learn something. We found that a large percentage of the younger professors were investing in cash. When we talked to them, we learned that they knew this was tax-deferred money for their retirement. They also knew they had few other resources and that, in a pinch, they could use the cash for emergencies. Their allocation was not nearly as irrational as it seemed.

Siegel: That TIAA-CREF example reinforces the need for goal- or liability-driven investing. Forget about strategies. What is the risk-free rate for investors? You cannot know what risk is until you know the time frame of the investors.

Regarding the TIAA-CREF example, it is important to decide whether the pot is a savings account or a retirement account. It is hard to have two different goals because they conflict. One calls for having principal stability, which is a Treasury bill. The other calls for standard-of-living and income stability, which is a long-term bond. You cannot have both.

If you get clients to focus on rates of return and asset mixes, it is likely to be the wrong approach. You should get people to determine their goals instead of asking them how much they want to put in real estate.

Everyone in this room knows what people want for retirement. It is an income. Social security gives an income. DB plans give an income. In DC plans, for some reason, we do not show people the funded ratio. We are showing them the wrong thing, and then we are saying they are making the wrong decisions. We are telling people that risk is the value of their fund, when risk is really how much income they can sustain for retirement. We must get that straight, and by "we" I am including the US Department of Labor and the SEC so that they do not force us to give people the wrong numbers.

We are telling people that risk is the value of their fund, when risk is really how much income they can sustain for retirement.

— Siegel

Lo: One proposal is that we help individual investors by offering them some kind of variance-stabilized investment in equities. Equities in the long run make sense. But you have to make sure that the short run does not kill you first. Investors are willing to take risk, but they want to know that the risk that they signed up for is the risk that they are getting.

A simple strategy would be to use futures overlays on investment in an S&P 500 index fund. As the volatility investment piece spikes up, start putting more money into cash. As the volatility comes back down, put that money back into equities. Do this in an automatic fashion to stabilize the volatility throughout these kinds of rollercoaster rides. This simple change can make these products a lot more palatable to a broad set of investors.

Moderator/Leibowitz: Some people say that such a strategy sounds a bit like portfolio insurance.

Lo: Actually, it is related to portfolio insurance except that it works a lot better. You are not insuring anything but rather managing risk. Daily risk management is a reality now. We can actually do that because we have liquid futures markets, such as the S&P 500 futures. If we are trading that dynamically, we can smooth out a lot of volatility.

Siegel: If you have options, yes.

Moderator/Leibowitz: One way or another, if that becomes too much of a common strategy, it can be destabilizing.

Merton: And who is on the other side of that trade? If there is nobody on the other side of the trade, that is a problem. But I would argue that on the other side of the trade are the folks who actually can and want to take the risk, and who are willing to provide that kind of dynamic hedging.

Moderator/Leibowitz: Of course, people who take that kind of risk are also trying to lay it off.

Merton: Right, but that is why we have the options market. The options market now is much larger than it was before. We have the capacity to be able to do that.

Ross: The options market is really surprisingly small. In fixed income, it is enormous. But in equities, it is actually quite small. You have about $20 trillion in options now against the equity. That is not that big.

Lo: It is a little misleading because you have to look at it based on volatility. The equity markets are a lot more volatile, so $20 trillion in options in equities is a lot more than $400 trillion in fixed income given the low volatility of interest rates. You cannot just look at the notional—you have to look at risk-bearing capacity. From the kind of stabilizing strategies being proposed, the options and futures market will be more than large enough to handle the overlays you would need.

Ross: It can be read in the opposite way because the higher volatility in the equity markets is an argument for why you need more depth in that market to really cover it.

Moderator/Leibowitz: Let us change the subject and talk about target date funds.

Siegel: If a target date fund is a fund that is designed to hit a particular objective, or to get as close as you can to a particular objective, it would save investors the trouble of trying to figure how to do it. I am a big fan of that, but the current incarnations of target date funds do not do that at all. They are based on a variety of different myths about how much you should have in equity and fixed income as you get closer to some projected horizon for the individual.

One other point is that target date funds are completely divorced from life expectancy risk. How can you possibly run funds that supposedly benefit the individual without providing a complete solution that covers both insurance risk and inflation issues? What kind of annuity are you going to have at the end?

Moderator/Leibowitz: We are talking about trying to get an integrated product that can take people, with the risk that they can bear over time, toward a situation where they get a proper, real annuity.

Ross: There is a place for a properly designed product. But the industry has yet to design that product.

Merton: One of the needs recognized during the financial crisis was to give people what they think they are getting and let them know the risk they are taking and not taking. Ask people who are fairly knowledgeable, "What does a 2045 fund mean?" Most people think that it has some kind of glide path that adjusts over time and will glide you to a good place when you retire in 2045. That is not the way target date funds are designed. If you read the prospectuses, they do not even say they do that. They simply say, "We have a process. For five years, you have one base; for the next five years, you have another base." They do not even dissolve in 2045. They just stop changing the mix in 2045, and that is it.

If you look at the history of target date funds, it revolved around what could be devised that would not make us fiduciaries. These products look like clients are being advised because the portfolio changes over time. How would you like to hear this directly? "I have something to get you to 2045. By the way, it has been legally determined that this is not advice, or not a fiduciary, but I am going to make it sound like it is advice."

The second thing is, we all should be very happy that they do not work well, because if they did, we could solve the complex problem of inter-temporal

optimization for people where they would put money in every month for 10, 20, 30, 40 years and out the other end would come a good retirement. If such a product existed, there would be many fewer opportunities for those in our industry.

Target date funds suggest we can solve the problem with a simple rule that is based only on age and not even on gender or on how much people make. The worst thing we can do is promise something that we really cannot deliver or make people think it is simple and we have an answer when we do not. What is worse than being uninsured when you thought that you were insured?

In 2016, it is feasible to deliver customized products targeted to goals that take account of individual characteristics, delivering it at low prices consistently on a scalable basis to millions of people. For those who think that "on average" is good enough, I will bet there are people in this room with a size 6 shoe and others with a size 12 shoe. How about you turn all your shoes in, and when you leave, you all get a size 9?

In some ways, financial techniques have enabled people to do more things that they wanted to do, faster and earlier. That sounds like a good thing, and it has many good qualities, but it can also lead to misuse, to overshoots, to bubbles, and to crisis events because we made things too easy to happen too quickly.

It is feasible to deliver customized products targeted to goals that take account of individual characteristics, delivering it at low prices.

— Merton

Lo: Any kind of technology can be abused as well as used. What we saw in the financial crisis was not that securitization did not work—it actually worked way too well. It pumped tremendous amounts of money over a short period of time into US residential real estate; much too much money.

The same is true with all powerful technologies. But isn't that the nature of progress though—two steps forward, one step back? We have to recognize there will be frailties, fragilities, and unintended consequences of these technologies, and the answer is not to forswear them but to actually go back to the drawing board when necessary and develop better technologies.

Moderator/Leibowitz: How can we try to get finance appreciated for the good it does and put its overall role into the proper context?

Lo: Recently, I compared our field with some others—psychology, biology, and so on. Take a look at the website of the American Psychological Association. It is the largest organization of psychologists, both academic as well as practitioners. Read the mission statement. It is a relatively short paragraph that emphasizes the application of psychological knowledge to benefit society and improve people's lives. It is a very heartwarming and broadly encompassing mission statement.

If you read the mission statements for the American Economic Association and the American Finance Association, you will see a huge contrast. Nothing is mentioned about making society better or using economics or finance for the greater good. It is incredibly narrow and, as you might expect, focused just on what we do, which is to try to understand the allocation for scarce resources. I think that part of the issue is that we have been so focused on our field as a science that we sometimes forget about practice and the kind of impact—good and bad—that we can have. Ultimately, we have to spend more time thinking about the consequences of what we do.

Moderator/Leibowitz: Let me end on the following note. In some ways, what we are saying is that finance may not be a zero sum game. To the extent we can make finance more of a positive sum game, facilitating things on a net–net basis even though there are issues that we have to try to deal with and resolve, we will be doing as much societal good as we can, morally and ethically. Hopefully, it will also lead to a better place for our field in the future.

To the extent we can make finance more of a positive sum game, we will be doing as much societal good as we can, morally and ethically.

— Leibowitz

Notes

1. Elroy Dimson, Paul Marsh, and Mike Staunton, *Triumph of the Optimists: 101 Years of Global Investment Returns* (Princeton, NJ: Princeton University Press, 2002).

by Richard Roll and Stephen A. Ross

The Arbitrage Pricing Theory Approach to Strategic Portfolio Planning

The well known Capital Asset Pricing Model asserts that only a single number—an asset's "beta" against the market index—is required to measure risk. Arbitrage Pricing Theory asserts that an asset's riskiness, hence its average long-term return, is directly related to its sensitivities to unanticipated changes in four economic variables—(1) inflation, (2) industrial production, (3) risk premiums and (4) the slope of the term structure of interest rates. Assets, even if they have the same CAPM beta, will have different patterns of sensitivities to these systematic factors.

The central focus of portfolio strategy is the choice of an appropriate pattern of sensitivities. This choice will depend upon the economic characteristics of the beneficiary of the portfolio's income—in particular, upon whether it is more or less concerned with the economic factor risks than the broad average of investors. An organization, for example, may expect to spend less on food than the average investor. To the extent that food prices coincide with general inflation and are somewhat independent of productivity risk, the organization's optimal portfolio could have a lower inflation beta and a higher productivity beta than the broad-based average has.

Such concerns have tactical implications. The organization unconcerned about inflation in agricultural prices would also wish to skew its portfolio holdings out of this sector. Conversely, a sensitivity to energy costs might lead it to skew its holdings in the direction of the energy sector. Implementation of the chosen strategy might be carried out directly by the fund itself, or it may be delegated to select investment managers who follow established investment policy guidelines.

THE ARBITRAGE PRICING THEORY (APT) has now survived several years of fairly intense scrutiny.[1] Most of the explanations and examinations have taken place on an advanced mathematic and econometric level, which means that few persons outside academia have had the time to read them.[2] Nevertheless, APT has gained the notice of the investment community, and their curiosity will no doubt grow considerably during the next few years as the logical appeal and, more importantly, practical implications of APT become apparent. This article aims to accelerate the process by providing an intuitive description of APT and discussing its merits for portfolio management.

1. Footnotes appear at end of article.

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This article was originally presented at the Fall Seminar of the Institute for Quantitative Research in Finance at Colorado Springs, Colorado, on October 11, 1983.

The Intuitive Theory

At the core of APT is the recognition that only a few systematic factors affect the long-term average returns of financial assets. APT does not deny the myriad factors that influence the daily price variability of individual stocks and bonds, but it focuses on the major forces that move aggregates of assets in large portfolios. By identifying these forces, we can gain an intuitive appreciation of their influence on portfolio returns. The ultimate goal is to acquire a better understanding of portfolio structuring and evaluation and thereby to improve overall portfolio design and performance.

The Influence of Systematic Factors

The returns on an individual stock in, say, the coming year, will depend on a variety of anticipated and unanticipated events. Anticipated events will be incorporated by investors into their expectations of returns on individual stocks and thus will be incorporated into market prices. Generally, however, most of the return ultimately realized will be the result of unanticipated events. Of course, change itself is anticipated, and investors know that the most unlikely occurrence of all would be the exact realization of the most probable future scenario. But even though we realize that some unforeseen events will occur, we do not know their direction or their magnitude. What we *can* know is the sensitivity of asset returns to these events.

Asset returns are also affected by influences that are not systematic to the economy as a whole, influences that impinge upon individual firms or particular industries but are not directly related to overall economic conditions. Such forces are called "idiosyncratic" to distinguish them from the systematic factors that describe the major movements in market returns. Because, through the process of diversification, idiosyncratic returns on individual assets cancel out, returns on large portfolios are influenced mainly by the systematic factors alone.

Systematic factors are the major sources of risk in portfolio returns. Actual portfolio returns depend upon the same set of common factors, but this does not mean that all large portfolios perform identically. Different portfolios have different sensitivities to these factors. A portfolio that is so hedged as to be insensitive to these factors, and that is sufficiently large and well-proportioned that idiosyncratic risk is diversified away, is essentially riskless.

Because the systematic factors are the primary sources of risk, it follows that they are the principal determinants of the expected, as well as the actual, returns on portfolios. The logic behind this view is not simply the usual economic argument that more return can be obtained only by bearing more risk. While this line of reasoning certainly contains a great truth, its appeal comes more from Calvin than from Adam Smith. There is a far simpler reason why the expected return on a portfolio is related to its sensitivity to factor movements.

The logic is the same as that which leads to the conclusion that two three-month Treasury bills or two shares of GM must sell for the same price. Two assets that are very close substitutes must sell for about the same price, and nowhere in the entire economy are there any closer substitutes than two financial assets that offer the same return. Two portfolios with the same sensitivity to each systematic factor are very close substitutes. In effect, they differ only in the limited amount of idiosyncratic, or residual, risk they might still bear. Consequently, they must offer the investor the same expected return, just as the two Treasury bills or the two shares of the same stock offer the same expected return.

At this point, a bit of mathematics is probably desirable, if not inevitable. Given what we have said so far, it is possible to see that the actual return, R, on any asset—be it a stock, bond or portfolio—may be broken down into three constituent parts, as follows:

$$R = E + b\,f + e, \qquad (1)$$

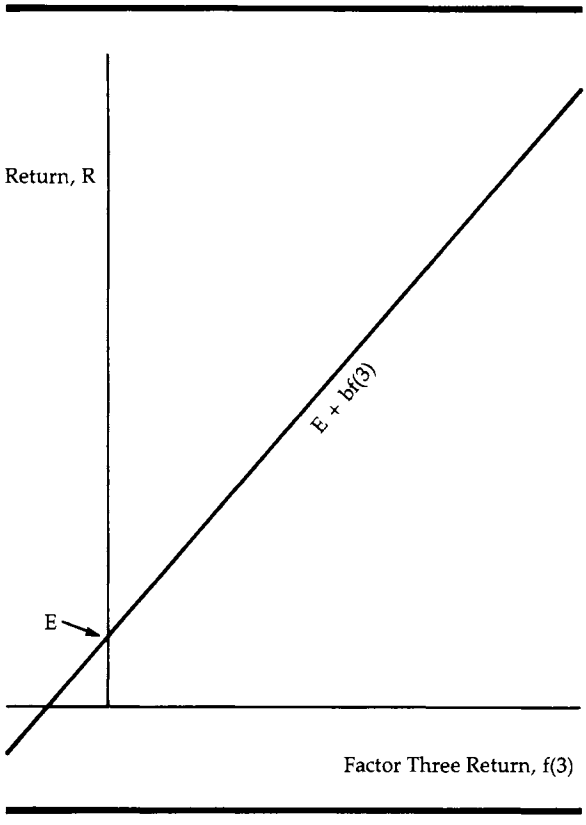
where

- E = the expected return on the asset,
- b = the asset's sensitivity to a change in the systematic factor,
- f = the actual return on the systematic factor, and
- e = the return on the unsystematic, idiosyncratic factors.

Equation (1) merely says that the actual return equals the expected return plus factor sensitivity times factor movement plus residual risk.

As we have noted, however, there is more than one systematic factor. There are several important ones, and if all of them are not represented, then our understanding of how the capital market works is inadequate. Our basic equation, then, must be expanded to in-

Figure A Returns and Factor Three



corporate multiple systematic factors.

Empirical work suggests that a three or four-factor model adequately captures the influence of systematic factors on stock market returns. Equation (1) may thus be expanded to:

$$R = E + (b1)(f1) + (b2)(f2) + (b3)(f3) + (b4)(f4) + e. \quad (2)$$

Each of the four middle terms in Equation (2) is the product of the returns on a particular economic factor and the given asset's sensitivity to that factor.

What are these factors? They are the underlying economic forces that are the primary influences on the stock market. Our research has suggested that the most important factors are (1) unanticipated inflation; (2) changes in the expected level of industrial production; (3) unanticipated shifts in risk premiums and (4) unanticipated movements in the shape of the term structure of interest rates. We will elaborate on this result later. Right now, our task is to show that there is a simple relation between the factor sensitivities of an asset—b1, b2, b3 and b4—and the asset's expected return, E.

Factor Sensitivity and Asset Returns

Figure A shows a hypothetical plot of Equation (2) using the third factor as an example and holding factors one, two and four at zero. The figure shows the straight-line relation between actual realized returns and movements in factor three for a particular asset. A more sensitive asset—i.e., one with a larger value for b—would have a steeper line, indicating that factor three has a greater influence on its return. Conversely, the plot for an asset with a lower b would be closer to the horizontal; its return would be less affected by movements of the third factor. There is, in fact, nothing to prevent a sensitivity from being negative. If this were the case, then a rise in the factor would cause this asset's price to fall.

Note that a factor return of zero (f = 0) does not mean the actual return will be zero. The actual return will in this case equal the expected return, E. The factor movements represented by f are unanticipated. Any anticipated changes have already been incorporated into the expected return on the portfolio, E. Thus f stands for the deviation of the actual factor return from its expected return. When it is zero, actual factor movements have been just as was expected, and actual portfolio returns will be just what investors had expected. Put simply, if there are no surprises in factor movements, then there can be no surprises in portfolio returns.

Figure B illustrates the relation that must hold between expected return, E, and sensitivity, b. Here point A represents a riskless asset, perhaps a short-maturity bond, with an expected return, r, of 15 per cent. Points B and C represent two stocks with, respectively, expected returns of 20 and 35 per cent and sensitivities of one and two.

A portfolio that is evenly divided between the bond A and stock C will have a return that is a simple average of the returns of the two constituent assets:

$$E = 1/2 \times 15\% + 1/2 \times 35\% = 25\%.$$

The sensitivity of this portfolio will also be halfway between the sensitivities of bond A and stock C:

$$b(3) = 1/2 \times 0 + 1/2 \times 2 = 1.$$

This portfolio is plotted as point P in Figure B.

Figure B Expected Return and Exposure

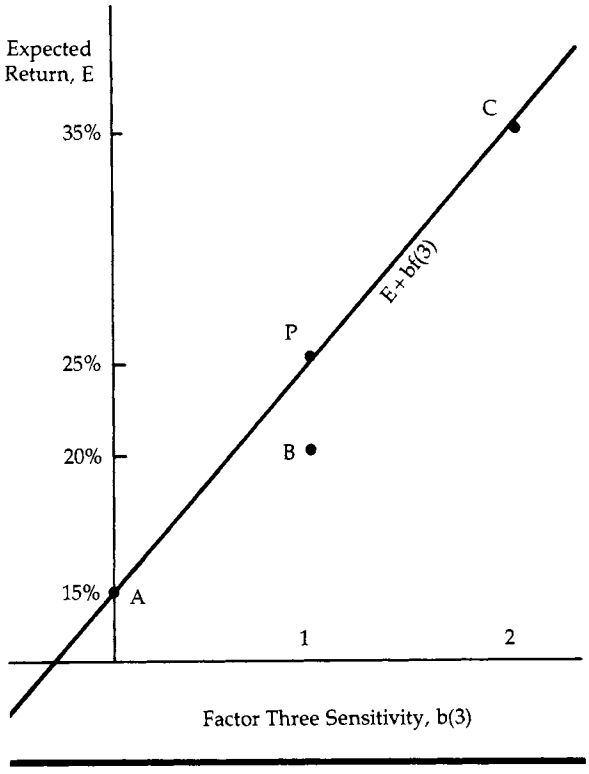
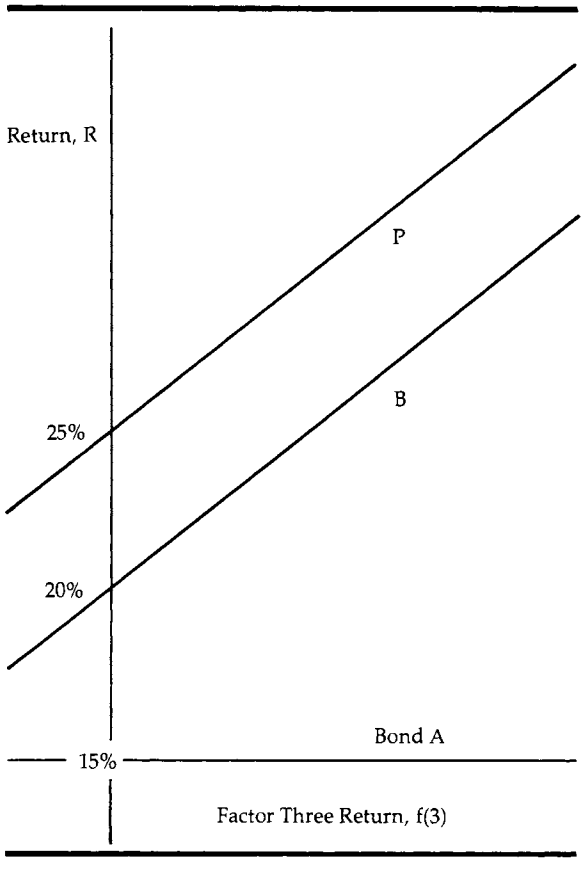


Figure C Actual Returns: Stock B vs. Portfolio P



Note that P lies directly above stock B. Consider what this means. A portfolio of bond A and the higher risk stock C has the same sensitivity to systematic factor risk as stock B. But, although the portfolio has the same sensitivity as stock B, it has a higher expected return—25 per cent, versus an expected return of only 20 per cent for stock B.

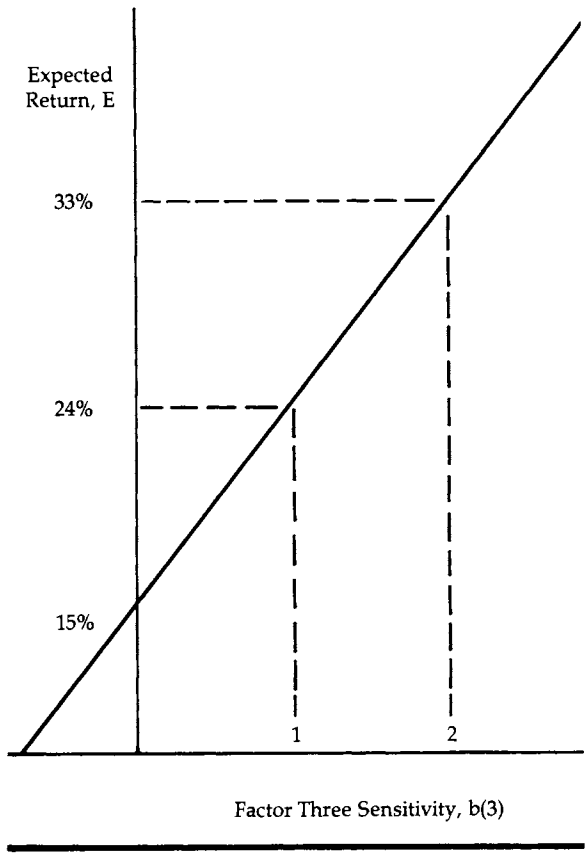
More importantly, no matter what value factor three happens to take, the portfolio's return will dominate that of stock B. Figure C displays the actual returns on the portfolio and on stock B in relation to the factor three return. Regardless of the outcome (and remember that the actual outcomes cannot be known in advance), portfolio P does 5 per cent better than stock B. The situation presented is the very same sort of arbitrage opportunity that would occur in the bond market if two Treasury bills with the same maturity sold at different yields. It is the same sort of situation that foreign exchange traders exploit when the dollar/mark price differs from what a dollar could buy if it were first exchanged for marks. In well-functioning capital markets, such opportunities exist only momentarily, until they are closed by traders whose reward comes from eliminating such gaps.

When this arbitrage takes place, with investors reducing their holdings of stock B and covering themselves by purchasing the portfolio, the price of stock B falls and that of stock C rises. At the lower price, stock B becomes more attractive relative to stock C. This process terminates only when the portfolio and stock B offer the same expected return. In fact, as in the foreign exchange market or in the bond market, the process works sufficiently rapidly that a gap would probably be too fleeting for an outside investor even to notice. Arbitrage opportunities will no longer exist only when all three assets in Figure B lie on the same line; in any other case, there will always be another portfolio that beats (or is beaten by) one of the assets, no matter what unanticipated developments come to pass.

Figure D plots the line on which all three assets must fall. As we have drawn it, there is a direct positive relation between the expected return, E, on any portfolio or individual asset and its risk sensitivity, b(3). The slope of this line measures the market price of this type of risk.

In Figure D, the price of risk for factor three is displayed as the difference between the expect-

Figure D Equilibrium Expected Returns



ed return at a sensitivity of one and the riskless return. As the riskless rate is 15 per cent and assets with a factor three sensitivity of one have a 24 per cent return, the market price of risk is 9 per cent (24% − 15%). This means that any asset with a b(3) of one—i.e., any asset whose return rises or falls by 1 per cent whenever the third factor rises or falls by 1 per cent—will have an expected return 9 per cent above the riskless return of 15 per cent. An asset that is more sensitive will have a higher expected return; for example, the return for an asset with a b of two is 33 per cent (15% + 2 × 9%). In other words, the price of risk for factor three of 9 per cent is the rate at which the investor is rewarded for assuming a unit of sensitivity to movements in this factor.

In summary, the expected return on any asset is directly related to that asset's sensitivity to unanticipated movements in major economic factors. If we let E3 stand for the return on a portfolio with a sensitivity of one to factor three (E3 equals 24 per cent in the example of Figure D), then the total expected return (E) on the portfolio may be computed as:

$$E = r + (E1\text{-}r)\,(b1) + (E2\text{-}r)\,(b2) + (E3\text{-}r)\,(b3) + (E4\text{-}r)\,(b4). \quad (3)$$

This equation simply states the relationship we have proved: The expected return on any asset, E, exceeds the riskless return, r, by an amount equal to the sum of the products of the market prices of risk, Ef-r, and the sensitivities of the asset to each of the respective factors.

Examining the Factors

We have defined sensitivities as the responses of asset return to unanticipated movements in economic factors. But what are these factors? If we knew them, we could measure directly the sensitivities of individual stocks to each. We could, for example, attribute a particular fraction of the observed price movements in a given stock to movements in the economic factor.

Unfortunately, this is much more difficult than it sounds. To begin with, any one stock is so influenced by idiosyncratic forces that it is very difficult to determine the precise relation between its return and a given factor. At a more practical level, we have so much more data available on individual stock returns than we have on broad economic factors that this approach would be very inefficient. It would be a bit like attempting to see what happens to the yield on a Phoenix Power and Light bond when the money supply changes. A much better approach would be first to determine the impact of an index of municipal bond yields on the Phoenix bond; this can be done with considerable accuracy. We can then see how sensitive bond yields as a whole are to money supply changes. The sensitivity of the Phoenix bond to the money supply can then be determined as the product of these two sensitivities, each of which can be measured with some precision.

The biggest problem in the measurement of sensitivities, however, is separating unanticipated from anticipated factor movements. The bs measure the sensitivity of returns to *unanticipated* movements in the factors. By just looking at how a given asset relates to movements in the money supply, we would be including the influence of both anticipated and unanticipated changes, when only the latter are relevant. Anticipated changes are expected and have already been incorporated into expected returns. The unanticipated returns are what determine the bs, and their measurement is one of the more important components of the APT ap-

proach.

What economic factors relate to unanticipated returns on large portfolios? As noted above, empirical research indicates that the following four economic factors are relevant:[3]

(1) unanticipated changes in inflation,
(2) unanticipated changes in industrial production,
(3) unanticipated changes in risk premiums (as measured by the spread between low grade and high grade bonds), and
(4) unanticipated changes in the slope of the term structure of interest rates.

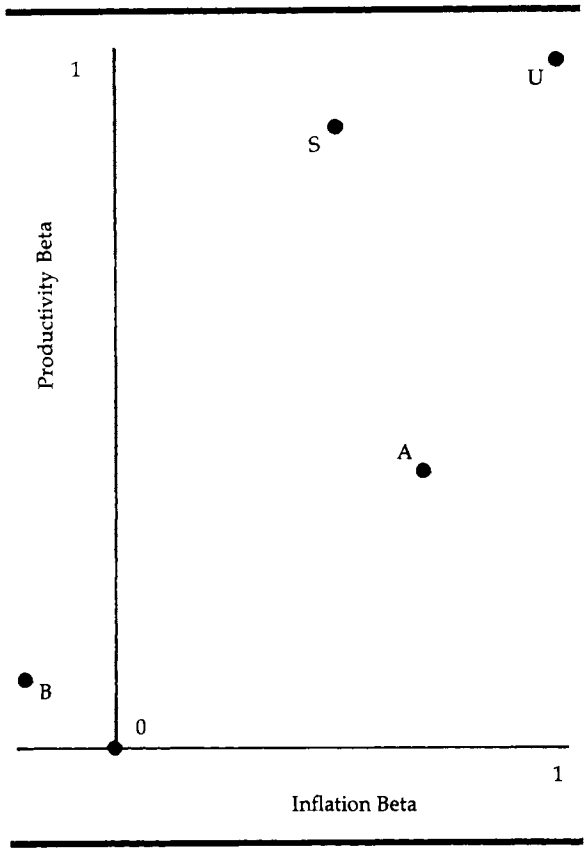
It is possible, of course, to think of many other potential systematic factors, but our research has found that many of them influence returns only through their impact on the above four factors. The money supply, for example, is an important variable, but it is not as good a yardstick against which to measure sensitivities, because most of the influence of unpredicted money supply changes is captured by the other variables. For instance, the change in interest rates on a Friday (from before the money supply announcement to after) is an adequate measure of the surprise in the announcement.

It's hardly surprising that the variables listed above were found to be important determinants of market returns. They appear in the traditional discounted cash flow (DCF) valuation formula. Two of them—changes in industrial production and unanticipated inflation—are related to the numerator in the DCF formula, i.e., to the expected cash flows themselves. Expected industrial production is a proxy for the real value of future cash flows. Inflation enters because assets are not neutral; their nominal cash flow growth rates do not always match expected inflation rates.

The other two variables would seem intuitively to be more related to the denominator in the DCF formula—i.e., to the risk-adjusted discount rate. The risk premium measure is an amalgam of investor attitudes toward risk-bearing and perceptions about the general level of uncertainty. The term structure of interest rates enters because most assets have multiple year cash flows and, for reasons relating to risk and time preferences, the discount rate that applies to distant flows is not the same as the rate that applies to flows in the near future.

These variables make intuitive sense, and it also makes sense that they are indeed "systematic." *Every* asset's value changes when one of these variables changes in an unanticipated way. Thus investors who hold portfolios that are more exposed to such changes—i.e., that contain assets whose bs are higher on average—will find that their portfolios' market values fluctuate with greater amplitude over time. They will be compensated by a higher total return in the long run, but they will have to bear up under more severe reactions to bear markets.

Figure E Sensitivities to Productivity and Inflation Risks



Strategic Portfolio Planning

No "off-the-shelf" approach to strategic planning is appropriate for all investment funds any more than one size of suit fits all customers. Below, we outline some general considerations that figure into the determination of investment goals.

The Structuring Decision

Traditionally, portfolio strategy is perceived as the choice of the proper mix of stocks and bonds (with real estate and other assets occasionally included). Every portfolio has its own pattern of sensitivities to the systematic economic factors. Stocks as a group and bonds as

another group have different sensitivities to systematic risks, hence the traditional approach may offer a rough solution to the choice of the optimal pattern of risk exposure. But the results can be improved significantly by examining the sensitivity of *each asset* to systematic risks.[4]

The first problem facing the architect of the fund's investment strategy is that of determining the most desirable exposure to systematic economic risks. Altering the mix of stocks and bonds in the portfolio will certainly affect the amount and type of risk exposure, but so will nearly every other purchase and sale decision. The strategist must first choose the desired level of exposure, then appropriate transactions can move the fund toward that desired position.

For example, assume that two of the empirically relevant exposures—to the general level of risk tolerance and to the term structure of interest rates—are held constant and that we are interested in the choice of exposure to inflation risk and to industrial production risk. In Figure E, the horizontal axis depicts the sensitivity, or "exposure," of a portfolio to inflation risk. The vertical axis plots the same portfolio's exposure to production risk. We will refer to these sensitivities as the inflation and productivity "betas," respectively.

The betas measure the average response of a portfolio or an asset to unanticipated changes in the respective economic factors. For example, a portfolio with an inflation beta of one will tend to move up and down by 1 per cent in response to a 1 per cent unanticipated rate of inflation. A beta greater than one, say an inflation beta of 1.5, means that the portfolio's returns are magnified by inflation, with a 1 per cent unanticipated inflation leading to a 1.5 per cent additional return on the portfolio. Similarly, if beta is less than one, unanticipated inflation has a less than proportional impact on the portfolio's returns. A portfolio with a beta of 0.5 will show a 0.5 per cent increase in return for every 1 per cent unexpected inflation. And a portfolio with a beta of zero will, on average, be unaffected by unanticipated inflation. Of course, many assets actually have negative betas and tend to do worse than expected when inflation is greater than expected. A utility stock with an inflation beta of -0.3 loses 0.3 per cent of return for each 1 per cent unanticipated inflation.

In Figure E, point A depicts a large investment fund with an inflation sensitivity of about 0.7 and a production sensitivity of 0.4. Is this a usual or an unusual pattern of sensitivities? There is no way to answer this question without referring to some landmarks.

One obvious landmark is the origin, O—the point at which both betas are zero. A portfolio at this point would be affected by neither unanticipated inflation nor by changes in expected industrial production. This may seem to be desirable, but it is not necessarily so. For one thing, such a portfolio offers no insurance against unexpected inflation risk; when inflation is greater than anticipated, this portfolio will, on average, not respond. Perhaps more importantly, there is a tradeoff between return and risk exposure. Moving a portfolio to O, where it will not respond to changes in inflation or to productivity, will have an impact on average return.

Point U represents unit sensitivity to both economic factors. A portfolio located at U will increase in value by 1 per cent with either a 1 per cent unexpected inflation or a 1 per cent increase in expected industrial production. The expenditures of an investment portfolio such as a pension fund are probably exposed to the risk of inflation in an adverse way; unanticipated increases in inflation will, on average, increase expenditures. The inflation sensitivity of a portfolio at U will help to offset this. Industrial production, however, could tell a different story. Declines in industrial production will generally be associated with increases in unemployment, which in turn will place greater economic burdens on individuals and corporations. In addition, productivity changes will be associated with changes in the relative prices of the goods and services purchased by the plan sponsor and its beneficiaries, and these may also be adverse. But, rather than helping the fund to insure against these risks, a portfolio with a productivity beta of one actually magnifies them. When industrial production turns down, so too does the return on the portfolio. Whether or not point U is attractive depends upon the particular situation of the fund.

Point B represents the typical pattern of sensitivities for a portfolio of long-term government bonds. Notice that it has a negative beta with inflation and a slightly positive beta with productivity. Investments in bonds are subject to significant adverse inflation effects and are also somewhat sensitive to productivity (although to a far lesser extent than equities). Productivity sensitivity is larger for corporate bonds than for

governments, for obvious reasons.

Point S is the location of a broad-based market index of large, listed stocks. Although this is a useful reference point, it would be wrong to ascribe too much importance to it. The right choice of a pattern of sensitivities for a given fund depends upon a variety of considerations unique to that fund and to the markets in which its beneficiary is a buyer, and these will not generally result in choosing the market index of stocks. The market index should not be ignored, but neither should it be worshipped. It is simply a useful landmark on the horizon, a signpost that is a guide in unfamiliar territory.

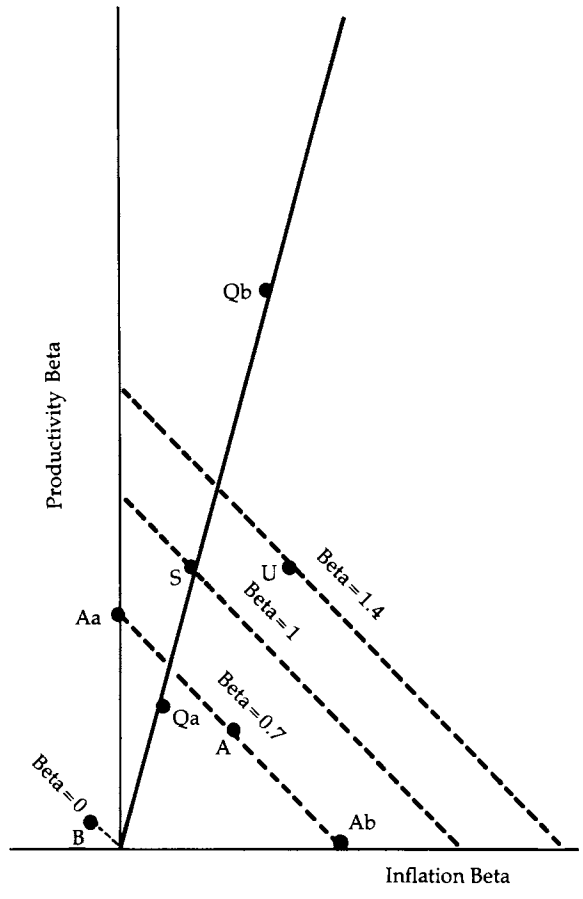
APT and the CAPM

We now have the necessary apparatus to relate the well known Capital Asset Pricing Model (CAPM) to APT. The CAPM asserts that only a single number—the CAPM "beta" against a market index—is required to measure risk. As Figure F illustrates, the CAPM beta measures the distance along a ray from the origin through S, where a broad-based market index is located. We assume that portfolio S is the market index used in computing CAPM betas; it could be any of the commonly used indexes, such as the S & P 500.

Portfolio S has a CAPM beta of 1.0 (by construction). Another portfolio, such as Qa, which is located halfway along the ray between O and S, has a CAPM beta of one-half. Similarly, Qb has a CAPM beta of two, because it is twice as far from the origin as S itself. Note that the CAPM beta of any portfolio can be measured by its distance along the ray *relative* to the market index S. The CAPM beta is a relative risk measure.

But there are many portfolios that are not on the ray OS. For instance, portfolios such as B, A and U, all of which have certain desirable properties, are located in the productivity-inflation space *off* the CAPM ray. What are their CAPM betas? It turns out that there are entire families of portfolios with a particular value of the CAPM beta whose members are not on the ray. The dashed lines in Figure F show some of these families. For example, portfolio A is in the family whose CAPM beta is 0.7; but so are all the portfolios along the dashed line that passes through A. There are portfolios in this family, that have no inflation risk (such as Aa) and there are portfolios with no productivity risk (such as Ab). All of them have CAPM betas of 0.7. We doubt very much, however, that most investment managers and clients would regard them as equally desirable.

Figure F CAPM and APT Betas



If S happens to be a mean-variance efficient portfolio, a so-called "optimized" portfolio, then all portfolios whose CAPM betas are the same will have equal returns on average over time. In this sense, the CAPM beta measures the overall desirability of an asset as perceived by the average investor in the marketplace. Even in this case, however, it is not necessarily true that a particular individual or client will consider all portfolios with the same expected return equally desirable. For example, portfolios Aa and Ab in Figure F might have the same long-term expected return, but they are exposed to far different types of risk and neither is preferable for all funds.

Finally, there is usually no reason to think that a particular portfolio such as S, even though it is a broad index such as the S & P 500, is itself optimized. If it is not optimized, then

portfolios A, Aa and Ab will not have equal expected returns, even though they do have equal CAPM betas. Recent empirical evidence has shown unequivocally that most of the commonly used market indexes are not optimized portfolios. Under this condition, the CAPM beta is not even a reliable indicator of expected return and, as we have already seen, it is virtually worthless as a measure of the type of risk to which the portfolio is exposed.

Now consider fund A, located on the exposure terrain with an inflation sensitivity of 0.7 and a productivity sensitivity of 0.4. What should be the strategy for fund A? How should it go about making its strategic investment decision? To put the question another way, where should the fund go to in Figure E? Should it move closer to S, the stock market index? Should it be somewhere between B and S, divided between bonds and stocks? Just "choosing between bonds and stocks" limits the fund to a position along a line between B and S. The strategic decision is clearly much broader than this.

The appropriate choice of risk exposure depends upon the uses to which the income generated by the fund is to be put. Just as different individuals choose to live in different places, different investment funds will choose different patterns of risk exposure.

Analyzing Portfolio Strategy

To choose the optimal pattern of risk sensitivities and move to the best position in Figure E, we must examine the economic situation of the sponsors and the beneficiaries of the fund. To argue that there is one best strategy for everyone—such as "buying the market"—is simply wrong. In the case of pension systems, we might assume that the principal goal is to serve the interests of the beneficiaries by meeting the promised pension benefits with a minimum of additional taxes (if the plan is public) or of corporate contributions (if it is private), but this goal structure may not be appropriate in all cases (for example, for a nonprofit institution, such as a university).

The economic situations confronting the sponsor and the beneficiaries are determined by the markets within which they operate and by the uses to which they put funds. The sensitivity of prices in these markets to overall inflation, for example, is an important determinant of the proper investment policy. The location of the organization is important as well. A company that employs blue-collar workers in the Los Angeles area has a different pattern of expenditures than a white-collar service firm located in New York.

Although organizations do not constitute a homogeneous group, they all share broad economic concerns. The key questions involve (a) their patterns of expenditures, (b) their other sources of income, and (c) the economic conditions they will face. These questions can be answered by detailed economic study. In the case of a company, for example, central questions would be, "what are its products, its costs and its prospects? How sensitive is it to the business cycle?" In the case of a museum, the study might begin with an examination of the markets for antiquities. How have these markets behaved, and what plans does the museum have for new acquisitions? Also of great importance is the need to meet current and forecast expenditures of a more prosaic sort, such as those related to maintenance and security. Such a study must be continually updated if the fund is to respond to changes in the economic environment and to changes in the goals and operations of the organization. But, even before the initial study is concluded, it will have important implications for strategic portfolio decisions.

Given an economic profile of the organization, one can begin to structure the overall risk exposure of the portfolio. Expenditures on major commodity groups—on salaries and materials, say—should be compared with the general expenditure pattern in the country as a whole. For example, suppose that the organization spent less on food and relatively more on travel than the average investor. The higher expenditure on travel would render it more vulnerable to energy costs than the typical investor, whereas the lower expenditures on foodstuffs would make it less exposed to food prices.

At the strategic level, these considerations will influence the optimal pattern of risk exposure. To the extent that food prices coincide with general inflation, for example, the optimal portfolio could be less hedged against inflation—i.e., could have a lower inflation beta than a broad-based market average has. Similarly, to the extent that food prices tend to be somewhat independent of productivity risk, the organization could accept a higher sensitivity to productivity risk than a broad-based average has. By bearing more risk in this dimension, the

portfolio could expect a higher return.

The influence of these kinds of considerations on the idiosyncratic risk of specific industry groupings has tactical implications. If the organization is unconcerned about inflation in agricultural prices, it would also wish to skew its portfolio holdings out of this sector. Similarly, a sensitivity to energy costs might lead it to skew its portfolio holdings in the direction of the energy sector. An organization will wish to hold a pattern of investments tailored to its own needs. Its optimal portfolio will therefore have a pattern of investments that is modestly skewed from the broad-based market index owned by the average investor.

It should be emphasized that tactical portfolio adjustments can be accomplished without reducing the average return on the portfolio. The strategic decisions determining the level of exposure to systematic economic factors influence the average return, but the tactical decisions can be made without any sacrifice of portfolio return, because they deal merely with idiosyncratic risk.

Implementing the Strategy

To implement the chosen strategy, the fund may direct the investments itself, or it may select investment managers who will follow established investment policy guidelines. The adoption of the APT approach to strategy has implications for the choice and the evaluation of investment managers. If the strategy dictates that investments should be made in particular sectors, then it would be natural to look for managers who specialize in these sectors.

More generally, managers implicitly tend to choose portfolios that have particular patterns of sensitivities to the economic factors. One manager might, for example, focus on high price-earnings ratio companies, so that his portfolio has a characteristic pattern of sensitivities. Another might be heavily invested in utilities, and this would result in a different pattern of sensitivities. The investment strategy for the portfolio as a whole may be implemented by choosing a portfolio of managers in such a way that pooling them together results in the desired pattern of sensitivities. If, for example, Manager A's portfolio typically has an inflation beta of two and manager B's portfolio has an inflation beta of one, then a desired inflation of beta 1.4 for the overall strategy could be achieved by placing $0.40 with manager A for every $0.60 given to manager B.

Of course, the complete manager evaluation issue is more complicated than this. Given that a manager has a certain pattern of risk exposures we also want to know whether he or she accomplishes this in the least costly fashion and with the least amount of idiosyncratic risk. This is the subject of performance evaluation, which is well-developed in the APT framework but is beyond the scope of this article.

Finally, a fund's choice of investments will generally be constrained by legal and other considerations. Typical of such constraints is the requirement that all investments be of a certain grade or from an approved list, or that the investments include bonds or equities from a particular issuer. The APT approach to strategy is particularly well-suited to these situations; because of its flexibility, it can be adapted to special situations when many traditional approaches cannot.

For example, suppose that the portfolio is constrained to hold a significant portion of its investments in the equities of the bonds of a particular company or government agency. For two related reasons it will generally be the case that this constraint is binding, in the sense that the fund would rather reduce its holdings of this security. First, the large holding subjects the fund to a substantial amount of idiosyncratic risk and, second, the fund may already be implicitly subject to much of the risk associated with the issuer.

The total risk of this security, however, can be substantially mitigated if the remainder of the portfolio is explicitly selected to offset its influence. If the security in question has a lower than desired sensitivity to inflation risk—e.g., a beta of 0.6 when the desired beta is 0.9—then the influence of the holding on the inflation exposure of the portfolio may be countered by choosing alternative investments with inflation betas in excess of 0.9. As a result, however, the fund may be subjected to idiosyncratic risk, which would not be a problem if the constraints were absent.[5]

Summary

The APT approach to the portfolio strategy decision involves choosing the desirable degree of exposure to the fundamental economic risks that influence both asset returns and organizations. This focus differs from that of traditional investment analysis and is ideally suited to the

management of large pools of funds.

Choosing the optimal degree of risk exposure requires an understanding of the level of risk exposure of the organization. Optimally, the pattern of risk exposure in the fund will balance the organization's current level of risk exposure. The fund should be positioned to hedge the organization against the economic uncertainties it faces.

Implementing this strategy may involve either choosing managers according to their typical pattern of exposure to economic risks and their ability to offer excess returns with low idiosyncratic risk or by choosing assets directly according to estimates of their exposure characteristics and relying upon diversification to remove idiosyncratic risk. The former approach is "active APT," whereas the latter approach may be quasipassive, inasmuch as systematic exposure is planned and implemented but there is no attempt at selection based on anticipated abnormal returns.

Footnotes

1. Arbitrage Pricing Theory was originated by Stephen A. Ross in "The Arbitrage Theory of Capital Asset Pricing," *Journal of Economic Theory,* December 1976, pp. 341-360. Theoretical refinements have been made by the following: Gregory Connor, "A Factor Pricing Theory for Capital Assets" (Working paper, Northwestern University, 1981); Gur Huberman, "A Simple Approach to Arbitrage Pricing Theory," *Journal of Economic Theory,* October 1982, pp. 183-191; Nai-fu Chen and Jonathan E. Ingersoll, Jr., "Exact Pricing in Linear Factor Models with Finitely Many Assets: A Note," *Journal of Finance,* June 1983, pp. 985-988; Philip H. Dybvig, "An Explicit Bound on Deviations from APT Pricing in a Finite Economy," *Journal of Financial Economics,* December 1983, pp. 483-496; Mark Grinblatt and Sheridan Titman, "Factor Pricing in a Finite Economy," *Journal of Financial Economics,* December 1983, pp. 497-507; Robert Stambaugh, "Arbitrage Pricing with Information," *Journal of Financial Economics,* November 1983, pp. 357-369; Gary Chamberlain and Michael Rothschild, "Arbitrage and Mean/Variance Analysis on Large Markets," *Econometrica,* forthcoming; and Jonathan Ingersoll, Jr., "Some Results in the Theory of Arbitrage Pricing," *Journal of Finance,* forthcoming.
2. Empirical testing with equities is described in the following: Richard Roll and Stephen A. Ross, "An Empirical Investigation of the Arbitrage Pricing Theory," *Journal of Finance,* December 1980, pp. 1073-1104; Nai-fu Chen, "Arbitrage Asset Pricing: Theory and Evidence" (Dissertation, Graduate School of Management, University of California at Los Angeles, 1981); Mark R. Reinganum, "The Arbitrage Pricing Theory: Some Empirical Results," *Journal of Finance,* May 1981, pp. 313-321; Patricia Hughes, "A Test of the Arbitrage Pricing Theory" (Working paper, University of British Columbia, August 1981); Lawrence Kryzanowski and Minh Chan To, "General Factor Models and the Structure of Security Returns," *Journal of Financial and Quantitative Analysis,* March 1983, pp. 31-52; and Stephen J. Brown and Mark I. Weinstein, "A New Approach to Testing Asset Pricing Models: The Bilinear Paradigm," *Journal of Finance,* June 1983, pp. 711-743. Tests with Treasury bills are presented in George Oldfield, Jr. and Richard J. Rogalski, "Treasury Bill Factors and Common Stock Returns," *Journal of Finance,* May 1981, pp. 337-350. Issues of testability are discussed by Jay Shanken, "The Arbitrage Pricing Theory: Is it Testable?" *Journal of Finance,* December 1982, pp. 1129-1140; Philip H. Dybvig and Stephen A. Ross, "Yes, the APT Is Testable" (Working paper, Yale University, June 1983); and Gunter Franke, "On Tests of the Arbitrage Pricing Theory" (Working paper, Universitat Giessen, 1983).
3. See Nai-fu Chen, Richard Roll and Stephen A. Ross, "Economic Forces and the Stock Market" (Working paper, University of California at Los Angeles, 1983).
4. The systematic, and idiosyncratic, risks at the heart of the APT approach to investment strategy have been identified in technical econometric work. For assets on which data are available, the pattern of exposure of each asset is known.
5. In some countries other than the U.S., constraints on investments are so stiff as to preclude achievement of the desired overall pattern of systematic risk exposure.