Investment Management: A Science to Teach or an Art to Learn? (a summary)

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Published 2014 by the CFA Institute Research Foundation
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In the aftermath of the 2007–09 financial crisis, mainstream finance theory was criticized for having failed to either prevent or forecast the market crash, which resulted in large losses for investors. Worse, the suggestion was made that the crash itself was the result of bad or poorly applied theory. Although markets have since recovered, surpassing precrisis levels as of the end of 2013, the investors enjoying the recovery are not always the same investors as those who suffered the losses. So, in many cases, the crash caused permanent impairment of wealth.

This crash is particularly interesting in that finance theory, not simply the practices of the financial services industry, has been directly blamed. This book explores current critiques of mainstream theory and discusses implications for the curricula of finance programs at business schools and universities. It is based on conversations with academics and practitioners in the industry and a review of the literature.[1]

Has mainstream finance theory—which many consider an idealization that does not take into account market reality—failed investors? Do we need to reconsider the theory and how it is taught?

Finance Theory: Do We Have a Science to Teach?

Many would argue that financial economics belongs not to the realm of empirical natural science but to the realm of the social sciences. Economics and finance have as their subject a human artifact—the economy or the markets—not the laws of nature. The artifact is context specific: It is not independent of social or political objectives. Hence, separating empirical laws from statements of principles is difficult.

Why is mainstream finance theory considered to be so unrealistic by so many? The answer is, not only because its main assumptions—efficient markets, rational expectations, the representative agent, and optimization,

[1]The full book contains a list of persons whose opinions (expressed either in interviews or in publicly available documents) are cited in the book. The many gracious human resources managers at asset management firms who helped us were promised anonymity and are not listed.

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which form the basis of general equilibrium theory—are unrealistic but also because the entire theoretical construct is not related to observable quantities. For example, a fundamental theoretical variable, price, is defined as the discounted present value of an infinite stream of future quantities that are not observable. The fact that finance theory makes impossible demands on the knowledge of economic agents is a crucial point that affects all mainstream general equilibrium theories.

In addition to this fundamental issue, the critique of mainstream finance theory can be summarized in three key points:

- First, no real agent has perfect knowledge of the future, not even in a probabilistic sense. Hence, the notion of rational expectations is unrealistic.
- Second, the representative agent is not a sound concept because one cannot aggregate utility functions and obtain a utility function with all the characteristics needed to justify equilibrium.
- Third, economies are rarely in a state of equilibrium. Joseph Stiglitz, professor of economics and University Professor at Columbia University and a corecipient of the 2001 Nobel Prize in Economics, has counted approximately 100 financial crises worldwide in the past 30 years.

Attempts have been made to address these problems within (or alongside) the existing theory. For example, although mainstream economists fail to recognize the existence of bubbles, some observers do attempt to explain market crashes, integrating into finance factors from outside classical finance theory. Specifically, the role of liquidity in the formation of sharp upward and downward market swings is now widely recognized, but will adding liquidity to mainstream finance theory be enough to achieve a complete understanding of markets? A longer list of what is needed to rethink finance theory, taking into consideration the real world, might also include leverage, bad behavior, bad incentives, and delegated management.

As for the role of human behavior in explaining large market swings, Robert Shiller, professor of economics at Yale University and corecipient of the 2013 Nobel Prize in Economics, explored how psychological factors drive stock markets in *Irrational Exuberance*.[2] More recently, he has suggested that bubbles might best be referred to as speculative epidemics: Enthusiasm spreads from person to person like a contagion and, in the process, amplifies stories that might justify asset price increases.[3]

[2]Robert J. Shiller, *Irrational Exuberance* (Princeton, NJ: Princeton University Press, 2000; 2nd ed., 2005).

[3]Robert J. Shiller, "Bubbles Forever," *Project Syndicate* (17 July 2013): http://www.project-syndicate.org/print/the-never-ending-struggle-with-speculative-bubbles-by-robert-j--shiller.

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Andrew Lo, professor of finance at MIT's Sloan School of Management, developed what he calls the "adaptive market hypothesis."[4] He argues that by applying the principles of evolution (competition, adaptation, and natural selection) to financial interactions, it is possible to reconcile economic theories based on the efficient market hypothesis with behavioral economics.

Another way to improve finance theory would be to establish a link between financial markets and the real economy—a link that many find lacking in today's theory.

One might ask: Can the debate on the tenability of today's finance theory be resolved with the methods of empirical science? Will the debate remain at the level of dogma, as with the conflict between different views of political economics? Or will the debate remain at the epistemological level, centered on the question of what the cognitive value may be of a model that, in the best case, captures only some general features of the real economy and real markets?

Mainstream economic and finance theories make *probabilistic* predictions, but to test these predictions is difficult when samples are small and contain much noise. The late Fischer Black famously wrote, "Noise makes it very difficult to test either practical or academic theories about the way that financial or economic markets work. We are forced to act largely in the dark."[5]

Ultimately, the debate on general equilibrium models in economics and finance theory may be an empty one. Clearly, general equilibrium models are not empirically validated in terms of the characteristics and interactions of real agents. Given any asset-pricing model that does not admit arbitrage, however, we can always formulate an equivalent abstract general equilibrium model.

If prevailing theory indeed fails to represent the world as it is and has effectively proved to be of little *practical* use, can we consider our economic and finance theory to be hard science? Would it not be better to reinstate economics and finance as *social sciences* (albeit, given the inherently quantitative nature of the data, quantitative social sciences)? In this case, would we allot a reduced role to complex mathematics and modeling because of the problems with the theory behind the mathematics?

There are two arguments against considering economic and finance theory to be a mathematical science. The first is that economics and finance are dominated by single events that cannot be predicted or even described in mathematical terms. The second argument is that the dynamics of economic and financial phenomena are simply too complex to be captured by mathematical formulas—at least by today's mathematics. Perhaps the phenomena are too complex to admit a parsimonious mathematical

[4]Andrew W. Lo, "The Adaptive Markets Hypothesis," *Journal of Portfolio Management*, vol. 30, no. 5 (30th Anniversary, 2004):15–29.

[5]Fischer Black, "Noise," *Journal of Finance*, vol. 41, no. 3 (July 1986), p. 529.

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description. Forcing "mathematization" can actually impoverish, rather than enrich, knowledge.

The problem is not that economics is too mathematical; the problem is that the mathematics we use in economics is much too simple to capture the complexities of economic interrelationships. This situation calls for greater use of non-mathematical reasoning in managing assets. The likelihood is that economics and financial economics are only partially mathematical theories; they need to be complemented with less formal reasoning. For example, we might not have a lot of data on rare events, such as market crashes and depressions, but we can formulate reasonable scenarios that can, in turn, be mathematically represented.

Whereas some argue that economics and finance should be considered social sciences, others argue for a stricter adherence to the paradigm of empirical science. Again, the impact on the curriculum would not be negligible. The invention of high-performance computers marked a new epoch in the application of mathematics to science and ushered in the application of computational mathematics. Instead of being limited to closed-form solutions of differential equations, we could actually create, through simulation, structures of numbers or symbols that mimic the structure of reality. This advance greatly enlarged the areas of the practical applicability of mathematics. Nevertheless, many complex phenomena, such as the economy, still cannot be represented in detail by using mathematics. Various reasons account for this situation: chaos and sensitivity to initial conditions, objective complexity (the extent to which a phenomenon is close to randomness), and our ignorance of the laws. But these are moving targets.

If we follow the road of stricter adherence to the paradigm of empirical science, we can broadly distinguish three main subfields of scientific economics: (1) econometrics and signal processing applied to financial economics, (2) statistical mechanics applied to economics, and (3) complex system theory and network theory.

Econometrics is the oldest application of scientific principles to economics and finance. It is based on applying statistical methods—in particular, time-series analysis—to empirical data. The key problem is the amount of noise present in empirical finance data, which makes estimates highly uncertain. The diffusion of electronic transactions and the consequent availability of high-frequency and tick-by-tick data have enabled new methods of time-series analysis borrowed from the field of signal processing. Econometrics and signal processing can be considered applications of the scientific method in restricted domains, such as trading and execution in investment management. These techniques are based on collecting data, constructing hypothetical models, and then testing the models.

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The application of statistical mechanics to financial economics is a relatively new field. Of the results obtained, perhaps the best known is the celebrated presence of fat tails in most economic data distributions. Fat tails of distributions imply that large events have a non-negligible probability of happening. Fat tails play a fundamental role in investment management, with important implications for the notions of diversification, risk–return optimization, and risk management.

Network theory is being used to model aggregation and contagion phenomena that may explain crashes. Some researchers argue that with the growing connectivity of economies and markets, aspiring risk managers would do well to study network theory to capture the system dynamics at work in a connected world.

The Theory and Practice of Investment after the Crisis: Need for Change?

Current mainstream finance theory is embodied in general equilibrium models that are idealized mathematical representations of markets populated by rational agents who have perfect knowledge of all possible contingencies now and into the infinite future and who optimize the utility derived from consumption and production. Agents are coordinated solely by price signals.

Even many of the theory's advocates acknowledge that these models are unrealistic (or simplistic) and require the consideration of additional "pieces." Among the additional pieces are the banking system, liquidity, employment and wages, instabilities arising from cascades of interactions, and crises.

The 2007–09 crisis has taught us some lessons. The lessons with relevance to investment management apply mostly to the following categories: diversification, optimization, the capital asset pricing model, the efficient market hypothesis, and risk measurement and risk management.

Diversification. Since the pioneering work of Harry Markowitz, diversification has been a fundamental concept in asset management and asset-pricing theories.[6] From a statistical point of view, diversification is summarized in two mathematical facts: (1) The appropriate choice of weights—that is, the proportion of funds invested in each asset—can reduce the variance of a portfolio while maintaining unchanged the portfolio's expected return, and (2) the variance of the portfolio that has the minimum possible variance is smaller than the variance of any of its components.

These properties are purely statistical facts and are, of course, undisputed. It is the *effectiveness* of diversification—at every level of aggregation—that has been questioned. Defenders of diversification argue that, although it might

[6]Harry Markowitz, "Portfolio Selection," *Journal of Finance*, vol. 7, no. 1 (March 1952):77–91.

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occasionally fail because of random fluctuations in market parameters, diversification remains a major component of investment decision making. Critics argue that diversification is ineffective in many economic states, such as when large market swings or crashes occur, because most expected returns in those states are negative. Market parameters change. The key question is how to optimize diversification strategies in markets characterized by changing parameters.

In addition, critics argue that diversification is a mathematical concept that is theoretically valid but whose application is difficult. Diversification requires the estimation—more precisely, a forecast—of the covariance matrix of returns. But the estimation of covariance matrices is subject to many uncertainties. In large portfolios in particular, empirical covariance matrices are very noisy because of the large number of entries.

Optimization. In the methodology of neoclassical finance, "efficient diversification of portfolios" is accomplished through mean–variance optimization (MVO). Broadly, optimization refers to a family of approaches to portfolio construction that include the use of alternative risk measures, such as tracking error and value at risk (VaR), the consideration of transaction costs, portfolio management constraints, and analyzing sensitivity to the estimates of expected returns and covariances.

As with diversification, the mathematics of MVO is not at issue. The question is, Does the mathematics of MVO correspond to the empirical reality of investments? The problem is whether or not we can find, empirically, a meaningful separation between diversifiable, unrewarded risk and non-diversifiable, rewarded risk. The defenders of MVO maintain that we can. Others observe, however, that MVO is of little use because it addresses only "benign" risks—namely, expected fluctuations in asset values as measured by standard deviation. It does not address systemic risks that can result in large losses.

The Capital Asset Pricing Model. The capital asset pricing model (CAPM) is an asset-pricing theory based on the assumption that all investors share the same rational expectations and use mean–variance optimization to choose portfolio weights. The key quantitative finding of the CAPM is that the expected excess return of each asset is proportional to the expected excess return of the market. The proportionality factor is the covariance between the returns of each asset and market returns.

In practice, however, the CAPM is often confused with a one-factor model. Many defenders of the CAPM view the poor performance of the model during the 2007–09 financial crisis as an expression of normal statistical fluctuations. Practitioners who consider the CAPM to be, in practice, a one-factor model observe that a one-factor model is a poor approximation of reality.

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The Efficient Market Hypothesis. The efficient market hypothesis (EMH) is made up of two distinct hypotheses: (1) Asset prices have theoretical values (that is, an asset has a "fair price"), and (2) market prices coincide with theoretical prices. The link between the EMH and asset pricing is provided by the notion that the theoretical value of an asset is the present value of its future discounted cash flows. Markets are efficient if the price of each asset equals or comes close to the present value of its future discounted cash flows. But because we have no way to forecast cash flows into the distant future, some argue that the EMH is an empty idea.

The EMH is the concept that has raised perhaps the most debate after recent market crises, including the 2007–09 crisis. It is an academic hypothesis that markets are "efficient" in the sense that market prices are always equal to theoretical prices. But it seems to be at odds with the reality of a market that lost 57% of its value from its peak in October 2007 to its bottom in March 2009 and then bounced back to its precrash high within four years.

The twin hypotheses of asset pricing and the EMH are not verifiable.

Risk Measurement and Risk Management. Risk management, too, was in for criticism following the recent financial crisis. It is not the *concept* of risk management that is questioned, however, but our tools and what we measure. First, the adequacy of our risk measurements and models is questioned. For example, most asset management firms still use measurements based on the assumption of normality, such as the risk metric VaR. Second, the scope of risk management may be too narrow. In particular, the tools fail to take into consideration systemic risk—a key failure in light of the wide use of derivative products that can propagate risk in ways that are difficult to understand and control.

Mainstream theory maintains that the economy and markets are in a state of general equilibrium and that only large, unpredictable exogenous events can disturb this equilibrium. Attempts to explain crises that are not explained by mainstream theory have taken two approaches. One approach starts with the observation that economies and financial markets are unstable complex systems. Far from being self-correcting equilibrium systems, economies and financial markets have endogenous mechanisms that may lead to a crisis when many interacting units (e.g., financial institutions) form networks in which very large connected components occur. A high density of connections can lead to cascading effects. Researchers working in this field apply complex system theory to identify potentially dangerous thresholds of connectivity.

The other approach goes back to Hyman Minsky, who maintained in his financial instability hypothesis that crises are generated by an excess of money, which fuels speculation and causes asset price inflation, followed by

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debt deflation.[7] Researchers attempting to model bubbles and crashes following Minsky's hypothesis are applying tools from nonlinear dynamics.

Teaching Finance: Can We Do Better?

Should the recent financial crisis, which contradicted so many central "truths" of modern economic and finance theory, change how we teach investment management? What should we be telling students about our theories and our models? Do we need to teach a new investment paradigm, as some have argued? What do we include in and what do we exclude from the curriculum of students whose objective is to manage other people's money? And has anything changed since the start of the 2007–09 financial crisis?

The overall perception of the academics and practitioners we surveyed is that not much has changed to date. Two reasons are given: First, not everyone is persuaded that changes are called for. Many academics believe that the current framework is solid and that we need only make minor adjustments. Second, some academics believe that throwing 40 years of research out of the curriculum straightaway is not so easy. These academics are trying to gradually rebalance their approach to teaching finance and the curriculum.

Given the widespread criticism of mainstream finance theory based on an idealization of markets, however, we ask: If our financial economics and finance theory are indeed of little practical use, in that they do not describe market reality, is it appropriate to teach the theory to students who, for the most part, are in school for practical purposes? And if the practical applicability of mainstream theory is so poor, why teach the difficult mathematics in which the ideas of general equilibrium, market efficiency, modern portfolio theory, and continuous-time asset pricing are cast?

Those in favor of keeping our theory argue that, although the theory is imperfect (it is still a work in progress), it is the *way* we teach the theory (too simplistic) that needs to change. Most (not all) sources we interviewed in our study agree that today's theory provides a useful framework for thinking about economic and finance problems but has limitations. Because today's finance theory has limitations, many suggest that it be taught less dogmatically, more pragmatically, than it is currently taught.

What specifically should we do in terms of changing the way we teach finance theory—in particular, the way we teach finance to students aspiring to be investment professionals?

Consider general equilibrium theory, which states that the economy and markets are in a state of general equilibrium, meaning that the market for every

[7]See Hyman P. Minsky, *Stabilizing an Unstable Economy* (New Haven, CT: Yale University Press, 1986) and "The Financial Instability Hypothesis," Working Paper No. 74, Jerome Levy Economics Institute of Bard College (May 1992).

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good and service clears at a price where the quantity supplied equals the quantity demanded; this equilibrium can be disturbed only by large unpredictable exogenous events. The recurrence of financial crises led David Romer at the University of California, Berkeley, to conclude, however, that financial shocks are more commonplace than exceptional. Some believe that because financial markets are essentially nonstationary and unstable, we are neither teaching the right concepts nor giving the appropriate tools to future investment managers.

For example, diversification is widely held to be a sound probabilistic concept, but the benefits of diversification may change as market states, correlations, or expected returns change. In the case of market corrections or crashes, even a well-diversified portfolio is not protected against large losses. Students are taught about diversification, but they are not taught what might be done when the correlations among markets grow and diversification does not work—or works less well than it has been working. Nor are students taught how to deal with chaos or non-normal distributions, which is another illustration of the fact that we are not preparing students to handle events outside the theory of general equilibrium. In teaching diversification, we would benefit students if we talked about structural breaks and estimation errors of the variance–covariance matrix and their implications for the composition of efficient portfolios and if we focused on how to reduce estimation error, account for fat-tail correlations, and perform extreme-event stress testing.

Another theory, the CAPM, is a flawed partial equilibrium theory, and the one-factor model is sloppy econometrics. Yet, despite the fact that the tenets of the CAPM have been invalidated in numerous empirical studies, the model is still widely taught as a theoretical framework for asset pricing. Should we continue to teach the CAPM?

The academic emphasis on asset-pricing models, which focus on precise asset pricing as opposed to pragmatic decision making, has also been questioned. The argument here is that asset pricing is an intellectual exercise; focusing on decision making forces one to think pragmatically and gives priority to forecasting and uncertainty.

Some practitioners and academics believe there is an overdependence on a theoretical framework that does not describe real markets. They seek empirical verification and are in search of a different type of theory, one that is more in line with the paradigm of the physical sciences and thus of more practical use. For example, Andrew Ang, professor of business at Columbia Business School, considers factor theory central to asset management. He believes that understanding factors is the key to understanding returns.

That the reality of markets should be the primary object of study is perhaps the key adjustment that needs to be made to both the theory and the teaching of finance.

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Finally, risk measures commonly used in asset management, such as standard deviation and VaR, have come under criticism for their inadequacies—particularly because of their reliance on the assumption of a normal distribution. These commonly used measures are considered too narrow in scope because they are typically limited to a statistical measurement of market risk. The focus on market risk measurement is questioned: Most of the literature and especially investment texts have focused on *equity markets* and two-tailed risk, even though the largest collapses of the last two decades or so (the failure of Long-Term Capital Management and the subprime mortgage crisis) occurred in the fixed-income markets. In short, not enough attention is being paid to credit risk evaluation, collapse models, and cross-market contagion.

What about market crashes? The potential impact of a crisis on a portfolio can be enormous. Crises occur, but they do not find their place in mainstream finance's general equilibrium theory. Perhaps these events should be factored into the risk structure.

What's Missing in the Curricula for Future Investment Professionals?

We asked academics and practitioners what, in the wake of the most recent financial crisis, needs to be reinforced or (re)introduced in programs preparing students for jobs in investment management.

Clearly, to pack additional courses into the typical two-year MBA finance program would not be easy. Another problem in discussing the curriculum is the diversity of roles. Is there any common body of knowledge that should be shared among market participants and, therefore, reflected in the curriculum? Yet another problem is today's emphasis on theories and models not based on empirical evidence.

As for PhD programs in finance, the main concern is that too much time is allotted to mastering difficult mathematical methods at the expense of developing broad knowledge of economics and finance.

Clearly, any educational program is a compromise between time constraints and a potentially long series of topics to cover. Here is the list of subjects (in order of number of mentions) that our sources believe should be reinforced in or (re)introduced to the curriculum:

- macroeconomics, including a historical perspective on macroeconomics,
- the history of financial markets and economic history,
- behavioral finance,
- statistics beyond the use of the normal distribution,

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- risk management, and
- ethics.

The current interest in macroeconomics and its history is probably a reaction to the recent financial crisis, which (unduly) surprised so many academics and market participants. Despite its importance, macroeconomics—not any particular approach or ideology—is widely considered to be poorly covered in current curricula. Rather than the formalism and mathematics of the general equilibrium theory, or anomalies in capital markets, what would be beneficial to students is more exposure to macroeconomics and its related fields, such as interest rates, exchange rates, and inflation. Many of our sources believe that a mix of judgment and nonquantitative macro/markets analysis is required to identify regularities and patterns in events and to recognize regime shifts.

There are two other compelling reasons for reinforcing macroeconomics in the curriculum. First, in the end, the economy drives financial markets. A disconnect between economies and financial markets generally implies that financial profits are being created artificially, thus bringing about a situation of instability. Second, in the wake of the 2007–09 financial crisis and ensuing Great Recession, governments are playing a growing role in the economy and markets.

Another important subject frequently mentioned as missing from the curricula for future investment professionals is the history of finance and of financial markets. The 2007–09 financial crisis alerted many to the role of history as a measure and model of crises. Teaching the history of finance and of financial markets would give students a long-term perspective, allow them to learn from past crises, and provide illustrations of, for example, the effect of financial euphoria on markets. It would also provide a way of testing our conventional hypotheses.

In addition to history, learning from current affairs (in particular, with regard to the recent crisis) was singled out by our sources as an oft-neglected area.

The need to include more on behavioral finance in the curriculum for future investment professionals was also noted. Behavioral finance began to move into finance programs even before the 2002 Nobel Prize in Economics was awarded to the behavioral psychologist and economist Daniel Kahneman. The objective of behavioral finance is to improve our understanding of markets and our forecasts by attempting to explain market movements as the result of cognitive biases (deviations from so-called rational judgment) on the part of market participants. How do we teach behavioral finance? What do we expect to be able to do with it?

The increasing relevance of statistics, mathematics, and modeling in finance programs arises from the greater availability of market and economic data and low-cost computing power. The issue of teaching these subjects to future investment professionals has two sides: Some curricula put too much

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emphasis on statistics, mathematics, and modeling, so students risk losing the big macroeconomic picture; others do not teach enough statistics, mathematics, and modeling, so students receive insufficient training and are unable to work with large datasets, apply the appropriate modeling techniques, and interpret the results. Learning how to collect and evaluate data (skills not always taught by the school), as well as how to create models (if only with simple modeling methods), should be part of every finance student's formal education.

Finally, with respect to risk management, portfolio management is based on the notion of optimizing the risk–reward trade-off. Risk management, therefore, is at the heart of asset management. But although things have begun to change since the 2007–09 financial crisis, many believe that risk management is not sufficiently taught in most finance programs. Risk management entails more than risk–return optimization. First, as proposed by Benoit Mandelbrot more than 50 years ago, the notion of portfolio risk should be based on non-normal (as opposed to normal) distributions.[8] Second, accounting is an important source of risk that deserves more attention in curricula than it has been receiving. Third, risk management is asset/liability management, not asset management alone. The role of liabilities and the interaction between assets and liabilities are not well covered in business schools, except in the few insurance programs that exist. The "meta-risk" of model failure and systemic risk are other categories of risk that have been given little consideration in most risk management curricula.

Landing a Job in Investment Management

In the recruitment of recent graduates for jobs in investment management, the emphasis is now being placed on solid economic reasoning and understanding of the "big picture," including the global macro and (geo)political situations. The growing importance of good macroeconomic reasoning represents something of a change from recent years. Firms, including quantitative asset management firms, are now looking for economic reasoning skills *and* math in the same person. Moreover, they are apparently having difficulty finding that combination of attributes. From the point of view of business schools and universities preparing students (including PhDs) for jobs in investment management, this trend calls for a well-rounded curriculum that encompasses a broad spectrum of fundamental knowledge and quantitative skills.

One criticism of most current finance programs is that too little attention is paid to creativity and out-of-the-box thinking in developing students' ability to understand, to critique, and to find new angles to a problem. Students need to be exposed to various ideas and points of view in order to develop

[8]Benoit Mandelbrot, "The Variation of Certain Speculative Prices," *Journal of Business*, vol. 36, no. 4 (October 1963):394–419.

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the mental flexibility that is required to think outside of established schemas. Many human resources managers find these qualities lacking in graduates coming from traditional business schools that teach (often dogmatically) mainstream economic and finance theory.

In addition, many finance programs, especially mathematical finance programs, are criticized for putting too much emphasis on models. The criticism is that these programs are divorced from events in the real world and produce recruits who have an equation for everything but who lack broader knowledge.

According to human resources managers, although the school does count, recruitment is a question of the individual. Business school graduates with an MBA are typically "top picks" in the United States. The situation is different in Europe, where some report that they have seen negative added value in MBA hires. That is, the cost of recruits from these programs is high, and the value they add is not sufficient to cover the cost.

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