Quantum Mechanics and Capital Market Theory

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The kinship between quantum mechanics and capital market theory is a natural one since both disciplines deal with methods of predicting group outcomes for statistically random variables. Thus while predictions for a single component (the next position of a molecule; or the return on stock "XYZ" a year from now) are subject to enormous error, predictions for large scale aggregates [quantum-molecular-systems or well diversified portfolios] can be extremely accurate if correct parameters for the relevant probability distributions are known. Thus, in the case of securities, investors have been advised that:

> If returns were uncorrelated and their variances bounded, sufficient diversification would bring virtual certainty of return
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> Harry Markowitz (1952)

> Diversification provides substantial risk reduction if the components of a portfolio are uncorrelated. In fact, if enough are included, the overall risk of the portfolio will be almost (but not quite) zero!
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> William Sharpe (1982)

A key difference between quantum mechanics and capital market theory, however, is that the former deals with specific phenomena for which it appears randomness, per se, is endemic while no one contends that investment returns comprise a class of phenomena for which no causal explanation exists -- at least in the scientific sense of the word.

For example, if the Capital Asset Pricing Model (CAPM) is correct, it is appropriate to say that the expected return on every investment is solely a function of its expected risk -- defined as its expected covariance with an efficiently priced portfolio of securities comprised of the entire spectrum of available investments. In theory, at least, this reduces to the assertion that realized returns across *all* stocks, *all* portfolios, *all* investors and *all* time periods can be explained (or predicted) by their covariance with the market and chance, i.e. random, unanticipated and undiscounted events. For "poorly diversified" portfolios comprised of a few stocks the random component or prediction error will be very great; while for "well-diversified" portfolios comprised of a large number of stocks the prediction error might be exceedingly small.

Random events in the context of the CAPM, however, do not differ from what transpires when an apple falls to the ground, a fair coin is tossed or a roulette wheel is spun -- insofar as a distinct chain of causation is deemed to underlie such outcomes. Thus, investment returns obviously do not arise as a result of the unwinding of a *mindless clock* which is analogous to the succession of innumerable events (outside the quantum domain) in physics. Rather, statistical randomness for the time series of stock returns is deemed attributable to an efficient market in which stocks are correctly priced and adjust instantaneously to the appearance of new information. In addition to market efficiency, the CAPM is consistent with the assumption that all investors behave as Markowitz recommended in his landmark work, *Portfolio Selection*.

In this regard, Markowitz provided a description of rational behavior consistent with the use of mean-variance-covariance estimates for identifying efficient portfolios and choosing among them based on one's preferences for risk versus return (or vice versa).

> The theory of rational behavior is usually presented as a study of the principals upon which a rational man would act. This rational man...makes no errors in arithmetic, or logic, in attempting to achieve his clearly defined objectives...Every action is perfectly thought out; every risk is perfectly calculated...Another interpretation can be given to the theory of rational behavior. Rather than visualizing a Rational Man we can visualize a perfect computing machine with unlimited speed and capacity...The study of rational behavior can be viewed as an inquiry into the principals by which we would have this perfect computing machine proceed...When objective probabilities are known for all contingencies, the rational man, following the axioms, maximizes expected utility.

To put the linkage between the mathematical models for investment selection developed by Markowitz in perspective with the CAPM consider the following:

> Three philosophically distinct phases stand out in the development of efficient market theory. The first was the essential contribution of Markowitz in 1952. He suggested that both risk and return be considered, provided a formal method for measuring both and showed how relationships among security returns could be taken into account in the analysis...A series of subsequent contributions increased the practicality of Markowitz's procedure...
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> The second major phase began in 1964 with papers by Sharpe, Lintner and Mossin. Investors were assumed to be equally well informed and to be following markowitz's recommendations. Given such a world what could be said about security prices? What types of risks would be rewarded and what types would not? The Capital Asset Pricing Model was intended to provide answers to such questions.
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> The third phase is in process today. Given a market almost, or entirely, consistent with the implications of the capital asset pricing model what sorts of policies should an investment organization adopt?..Almost all informed discussion of investment policy can be considered part of this phase.
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> William Sharpe (1975)

Much has transpired since the above words were written. Thus, a number of more recent studies have cast grave doubt on the belief that the CAPM is the Rosetta stone for explaining all differences in investment returns across *all* stocks, *all* portfolios *all* investors and *all* time periods while taking risk into account.

> Capital market theory is an exercise in positive economics…the realism of the assumptions matters little. If the implications are consistent with observed phenomena the theory can be said to “explain” reality.
>
> William Sharpe (1970)

Despite the above disclaimer embracing positivism, a number of doubters argued at the outset that the CAPM was highly suspect because of its bizarre assumptions. Indeed, those assumptions were analogous to *fictional* conditions and lawful relationships that lent an aura of causality (or scientific integrity) to a mathematical model whose equations could not be expected to function without them. We will pursue discussion of this point in a later section.

Meanwhile, this paper offers a diversion by highlighting the relationship between capital market theory (effectively the CAPM which embraces MPT and EMH) and quantum mechanics. The analogy is based on citations. from the work of two physicists, David Bohm and Bernard d'Espagnat. To facilitate the comparison, the scientists' remarks have been "extended" with phrases CAPITALIZED in parenthesis to highlight the strong association that exists. The first citation is from *Causality and Chance in Modern Physics*, by David Bohm:

> 0ne of the earlier experimental indications of the reality of random molecular (STOCK PRICE) motion came from a study of Brownian motion (THE FINDING THAT STOCK PRICES FOLL0W A RANDOM WALK) ...Finally, after many hypotheses had been tried, it was shown (ASSERTED) that Brownian motion (RANDOM WALKS IN STOCK PRICES) could be explained both qualitatively and quantitatively as an effect of chaotic molecular motion (THE RANDOM APPEARANCE OF NEW INFORMATION IN AN EFFICIENT MARKET) ...This was the first example in physics (FINANCE) of a qualitatively new aspect of the laws of nature (CAPITAL MARKETS) ; namely that large scale overall statistical regularities (PORTFOLIO RETURN IS A FUNCTION OF SECURITY COVARIANCES) that can appear at the microscopic level which are largely independent of the precise details of the complicated and irregular motions (SPECIFIC RETURNS ATTRIBUTABLE TO NEW INFORMATION) occuring at the atomic (INDIVIDUAL STOCK) level. Because this kind of regular over-all statistical law has by now become most common, not only in physics but also in many other fields, we shall give here a fairly detailed analysis of how such laws arise...
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> We see, then, that if we seek to make a detailed description (PREDICTION) of the behavior of an individual system (PORTFOLIO) containing something on the order of 10^23 molecules (128 STOCKS) we shall be stopped on all sides. On the other hand, the very same factors that make such a detailed prediction impossible are also those that make possible a general prediction of the over-all microscopic properties (MARKET RELATED COVARIANCE AND RETURN) of the system (PORTFOLIO) without the need for precise information about what the individual molecules (STOCKS) are doing.

> We note that microscopic average quantities (PORTFOLIO BETAS) are extremely insensitive to the precise motions and arrangements (SPECIFIC RETURNS) of the individual molecules (SECURITIES) .This insensitivity originates, at least in part, in the fact that an enormous number of different motions and arrangements (SPECIFIC RETURNS) in space (IN A GIVEN PORTFOLIO) will lead to practically the same (ZERO SUM) value for these quantities...
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> Thus, irregular motions will produce fluctuations the effects of which tend, in the long run and on average, to cancel out. Indeed the above considerations are verified in quantitative detail in studies carried out in the science of statistical mechanics (CAPITAL MARKET THEORY) which show that almost all possible initial conditions. for the molecular positions and , velocities (SECURITIES IN A WELL DIVERSIFIED PORTFOLIO) lead to irregular motions in which the large scale averages fluctuate very closely (REASONABLY NEAR) to practically determinate (BETA PREDICTED) mean values. Because the mean values depend almost entirely only on the overall properties of the molecules (STOCKS), such as mean density (MARKET COVARIANCE), the mean kinetic energy (EXTRA MARKET COVARIANCE), etc., which can be defined directly at the large scale level, it becomes possible to obtain regular and predictable relationships involving the large scale level (PORTFOLIO RETURN) alone.

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The next comparison, which will presented in the same manner as before, is based on *The Quantum Theory and Reality* by Bernard d'Espagnat:

> Any successful theory in the physical sciences is expected to make accurate predictions. Given some well defined experiment, the theory should correctly specify the outcomes or should at least assign the correct probabilities to all the possible outcomes. From this point of view quantum mechanics (THE CAPITAL ASSET PRICING MODEL) must be judged highly (SOMEWHAT) successful.
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> Apart from experimental confirmation, however, something more is generally demanded of a theory. It is expected not only to determine the results of an experiment but also to provide some understanding of the physical events (CAPITAL MARKET STRUCTURE AND THE BEHAVIOR OF INVESTORS) that are presumed to underlie the observed results. In other words, the theory should not only give the position of a pointer on a dial (ASSERT THAT A STOCK'S PRICE EQUALS ITS TRUE INTRINSIC VALUE) but explain why the pointer (PRICE OF THE STOCK) takes up that position. When one seeks information of this kind in the quantum theory (CAPM) certain conceptual difficulties arise...

Because of ambiguities such as this, many physicists (PORTFOLIO MANAGERS) find it sensible to regard quantum mechanics (THE CAPM) as merely a set of rules (DESCRIPTIVE EQUATIONS) that prescribe the outcome of experiments (PORTFOLIO RETURNS). According to this view, the quantum theory (CAPM) is concerned only with observable phenomena (DIFFERENCES IN SECURITY AND PORTFOLIO RETURNS) and not with any underlying physical state (THE VALUATION METHODS INVESTORS USE FOR DETERMINING A STOCK'S INTRINSIC WORTH).

It now turns out that even this renunciation (QUALIFICATION) is not entirely satisfactory. Even if quantum mechanics (THE CAPM) is considered to be no more than a set of rules, it is still in conflict with a view, of the world many people would consider obvious or natural. (GIVEN CHRONIC UNCERTAINTY ABOUT INTRINSIC VALUES, NOT TO MENTION FUTURE RETURNS, INVESTORS FALL PREY TO HOPE, FEAR AND GREED CAUSING THEM TO ACT IRRATIONALLY)

A mere description of data is not all that should be required of a theory. Even an empirical rule for predicting future measurements (RETURNS) is not enough. The mind demands something more; not necessarily determinism -- there is nothing intrinsically irrational about randomness -- but at least objective explanations of observed regularities, or in other words causes...If this refusal to seek underlying causes of observed regularities is applied consistently, it trivializes the entire scientific enterprise. Science is reduced to a set of recipes for predicting future observations from a knowledge of past ones. Thus, one can imagine a physics (THE CAPM) grounded on positivist principals that would predict all possible correlation's of events (MARKET RELATED PORTFOLIO RETURNS) and still leave the world (THE PROCESS OF PRICE DETERMINATION AND INVESTOR MOTIVATIONS) totally incomprehensible. Thus:

Practitioners must live with the particular--
The unknown value and chronic variability
of individual stock prices.
Day in and year out.
While academics have the luxury
Of evaluating this activity as history;
Looking only at portfolio returns--
Sweeping generalizations of what has occurred.

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ADDENDUM

Alfred North Whitehead on the Dual Nature of Positivism

> There is, however, a motive of unrest which urges scientists beyond mere satisfaction with the simple description, beyond even the general description. It is the desire to obtain the explanatory description which may justify the speculative extension of Laws, beyond actual, particular instances of observation. There remains the Positivist doctrine concerning law, namely; that a law of nature is merely an observed persistence of pattern in the observed succession of natural things; Law is then merely description...There is an attractive simplicity about this doctrine. Without doubt this Positivist doctrine contains a fundamental truth about scientific methodology. For example consider the greatest of all scientific generalizations, Newton's Law of Gravitation -- Two particles of matter attract each other with a force directly proportional to the product of their masses and inversely proportional to the square of their distance...the form of the law...is strictly based upon observed fact...*without a shadow of a doubt, all science bases itself upon this procedure. it is the first rule of scientific method--enunciate observed correlations of observed fact...*
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> At one stage, the method of all discovery conforms to the Positivist doctrine. There can be no doubt that, with this restriction of meaning, the positivist doctrine is correct...Certain branches of science halt for centuries in this stage.

Alfred North Whitehead
Adventure of Ideas

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Bernard d' Espagnat on Causation as Distinct from Correlation (the bedrock of positivism)

> Whenever a consistent correlation between events is said to be understood. ..the explanation offered always cites some link of causality. Either one event causes the other or both events have a common cause. Until such a link has been discovered the mind cannot rest satisfied. Moreover it cannot do so even if empirical rules for predicting future correlations are already known.
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> A correlation between the tides and the motion of the moon is observed in antiquity; and the [Friedmanesque/positivist] rules were formulated for predicting future tides on the basis of past experience. The tides could not be said to be understood, however, until Newton introduced his theory of universal gravitation. The need to explain observed correlations is so strong that a common cause is sometimes postulated *even when there is no evidence for it beyond the correlation itself* .

Bernard d' Espagnat
Causality and Chance in Modern Physics

Conclusion

The key difference between positivism when applied to economics, as distinct from the physical sciences, is that when the scientist returns to nature's laboratory he can readily establish the antecedent/causal conditions just as they were in the last experiment. But that is not true in financial markets where the antecedent conditions include investor psychology (such as motivations, expectations and rational thinking) are not only in dispute but are constantly evolving. Going forward, therefore, capital market theory faces the following question: Will a new model of investor and stock price behavior arise from the ashes of the CAPM’s assumptions or will a modified version of Keynes classical description of investor behavior prevail?

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