Real Options *in* Economic Systems and the Demise of Modern Portfolio Theory

Abstract: "I contend that rational expectations theory totally misinterprets how financial markets operate. Although rational expectations theory is no longer taken seriously outside academic circles, the idea that financial markets are self-correcting and tend towards equilibrium remains the prevailing paradigm on which the various synthetic instruments and valuation models which have come to play such a dominant role in financial markets are based. I contend that the prevailing paradigm is false and urgently needs to be replaced." *George Soros.* 2008.

This conceptual paper will take on the Soros challenge, using the concepts and methodologies of "real options *in* economic systems" and adding fresh thinking about data sources and the meaning of risk. It will examine the shortcomings and fallacies associated with modern portfolio and capital market theory and classical economics and ask many disquieting questions. General solutions, based in real options thinking, will be proposed and extended to the outer edge of global economic systems as found in the underground economies of the developing world.

Real Options “in” Economic Systems and the Demise of Modern Portfolio Theory

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From a Citibank flyer, received on the streets of the Boston Financial District,
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Distressed, stunned, shocked. However portrayed, the mood was extraordinarily subdued when 2,500 business and political leaders gathered in Davos, Switzerland, January 27 through February 1 for the 39th annual meeting of the World Economic Forum. If exuberance ignited the financial meltdown in 2008, anguish described those now picking through the debris.

. . . Yet above all, Davos denizens sought tangible solutions to the immediate challenges brought on by the crisis. In years past, company executives offered management prescriptions from their own experience. This year, many were humbled, hungry for fresh ways forward. . . .

. . . Many in Davos concluded their commentary by saying that these extraordinary times demanded more than ordinary leadership. If we can summon up that leadership to surmount this crisis, said British Prime Minister Gordon Brown, we will be far better equipped to attack the even more threatening challenges of climate change and global sustainability. In doing so, we want to reward “responsible risk taking,” not “*irresponsible* risk taking.” Most of all, he said, we can free markets but we don’t want value-free markets.”

“Snapshots from Davos: Seeking Opportunity in Crisis.”
Knowledge@Wharton, February 4, 2009. pp. 1, 3-4.

Hedge funds are largely unregulated investment vehicles that have become increasingly important in the global financial markets. Currently there are nearly ten thousand funds that collectively have over two trillion dollars under management. Although hedge funds pursue a great variety of investment strategies, they have two key features that we shall focus on here. One is the fee structure . . . [The second is] a lack of transparency: they need not, and often do not, disclose their positions or trading strategies to investors; all they are required to provide is regular audited statements of gains and losses.. . . [I]t is quite easy to ‘game’ standard measures of performance such as the Sharpe ratio, Jensen’s alpha, and the appraisal ratio (Goetzmann, Ingersoll, Spiegel, and Welch, 2007; Gusaoni, Huberman, and Wang, 2007). . . .

We shall show that a version of [the David Gale *strategy-stealing* (Gale, 1974) argument holds in financial markets with options trading. *Namely, a trader with no skill can mimic the returns being generated by another (more skilled) trader for an extended period of time without knowing how the skilled trader is actually producing these returns.*

Foster & Young. “The Hedge Fund Game: Incentives, Excess Returns, and Performance Mimics.”
Working Paper, November 2007 (revised September 2008).
Department of Statistics, University of Pennsylvania
and Department of Economics, University of Oxford. pp. 3, 4, 5.

One month into 2009, job cuts by corporations have become a major news story around the world. In one week along, almost 100,000 jobs were eliminated. These included 20,000 layoffs at NEC, 19500 at Pfizer, 15,000 at Metro, 10,000 at Boeing and 8,000 at Sprint Nextel. Thousands more from Starbucks, Ericsson, Kodak, Philips, Microsoft, Caterpillar, Home Depot, and other added to the total. According to an estimate by outplacement firm Challenger, Gray & Christmas, layoff in January totaled 241,749, up 45% from December and the highest month in seven years [since 2001]. . . .

Peter Cappelli, director of the Center for Human Resources at Wharton, says the problem is that the crisis is forcing many managers to focus only on the short term. "At least in the U.S., companies don't seem to be thinking about much besides the immediate impact. To some extent, this could be because of the pressure to manage operations to conform to quarterly performance expectations. It could also result from the fact that the negative effects of layoffs – such as the long-term costs associated with hiring again in upturns; delays in getting performance back up; and morale [issues] – are hard to track. And it also may results from the implicit assumption that the workforce is really just-in-time resource – that it will be easy to bring in new workers when business picks up."

Nevertheless, the track record of companies that have gone through job cuts is terrible. "Virtually all studies show a decline in performance associated with layoffs." Cappelli notes. "But the caveat is that layoffs are a proxy for the fact that companies which decide to do them are already in trouble. . . ."

. . . Now comes the hard part. For all the companies that have announced job cuts, operations will become significantly harder to manage in the months ahead, as they work through the process of notifying workers, supporting them, and, not the least, finding ways to compensate staffing changes through existing or new business processes. All these efforts will take a significant amount of management bandwidth, and at the same time many important projects will potentially be either understaffed or delayed. And all of this comes at a time when companies can least afford distraction.

"Half-a-Million Job Cuts: Is There a Strategy Behind the Layoffs?"
Knowledge@Wharton. February 4, 2009. pp. 1, 2-3.

While *ex post* we can certainly say that the system-wide increase in borrowed money was irresponsible and bound for catastrophe, it is not shocking that consumers, would-be homeowners, and profit-maximizing banks will borrow more money when asset prices are rising; indeed, it is quite intuitive. What is especially shocking, though, is how institutions along each link of the securitization chain failed so grossly to perform adequate risk assessment on the mortgage-related assets they held and traded. From the mortgage originator, to the loan servicer, to the mortgage-backed security issuer, to the CDO issuer, to the CDS protection seller, to the credit rating agencies, and to the holders of all those securities, at no point did any institution stop the party or question the little-understood computer risk models, or the blatantly unsustainable deterioration of the loan terms of the underlying mortgages.

A key point in understanding this system-wide failure of risk assessment is that each link of the securitization chain is plagued by asymmetric information . . . Computer models took the place of human judgment . . . With the ability to immediately pass off the risk of an asset to someone else, institutions had little financial incentive to worry about the actual risk of the assets in question.

. . . .

An AIG executive said as late as August 2007 that “It is hard for us, without being flippant, to even see a scenario within any kind of realm of reason that would see us losing one dollar in any of those [CDS] transactions.” Just over a year later, the federal government provided AIG with an $85 billion loan to cover losses it faced on its CDS contracts (then followed by an additional $38 billion).

Especially since 2000, the business of insuring mortgage-related assets, along with corporate bonds and other assets, grew exponentially. . . . The size of the outstanding CDS reached a staggering $60 trillion in 2007. As of September 2008, AIG, a financial guarantor, had itself sold nearly $500 billion worth of CDS – most of it insuring ill-fated CDOs. As the CDS market ballooned, so did the share of CDs sold by leveraged institutions like hedge funds and investment banks, relative to more capital-intensive mono-liner insurers. According to Fitch (2007), hedge funds drove nearly 60 percent of CDS trading volume in 2006. As the CDS market spread further into the unregulated, opaque financial world, its enormous scale and systemic implications went largely unnoticed until the crisis hit in August 2007.

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The lack of transparency of CDOs made the market reliant on the grades of ratings agencies as a signal of the risk of CDO assets. Regulators were not involved in these markets, so rating agencies essentially acted as proxies for regulators; indeed, an office as high as the U.S. Office of the Comptroller of the Currency, which regulates nationally chartered banks, depended on rating agencies to assess CDO quality. Furthermore, CDOs are themselves such complex instruments that independent judgment of risk is very difficult.

The principal rating agencies – Moodies, Fitch and Standard & Poor’s – used complex quantitative statistical models called Monte Carlo simulations to predict the likely probability of default for the mortgages underlying the CDOs and eventually to structure the CDO (or MBS) . . . At the outset, this approach was problematic in that the historical default rates used in these models were largely from the years 1992 until the early 2000s – a period when mortgage default rates were low and home prices were rising. . . .

Unlike the case of corporate bonds, where a ratings agency passively rates the risk of a company, with structured products the agencies “run the show.” The ratings agencies advised CDO issuers on how to structure the CDO with the lowest funding possible. To do so, CDO issuers would work with the agencies to optimize the size of the tranches in order to maximize the size of highly-rated, lower yielding tranches. Since the agencies were receiving substantial payments for this service, it created a clear conflict of interest. . . . According to the *New York Times*, Moody’s profits tripled between 2002 and 2006 to $750 million, mostly because of the fees from structured finance products. According to Coval et al (2008), fees from structured finance products made up 44 percent of Moody’s revenue in 2006.

While the rating agencies appear to have faced perverse incentives, it was the opacity of the entire system that magnified the effect of their poor judgment and “ratings inflation.” Not only did markets in CDOs and other structured products become so complex that ratings became the only way investors could judge risk, but most institutional investors face rules that only allow them to purchase investment-grade assets, as judged by the rating agencies. Thus the three agencies became the effective “arbiters of risk” for the entire market in structured finance products.

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The infrastructure of the financial system needs to be overhauled.

Baily et al. “The Origins of the Financial Crisis.”
Brookings Institution, Initiative on Business and Public Policy.
Fixing Finance Series – Paper 3. November 2008. pp. 8, 9, 32-25, 44.

Introduction

One year ago, I presented by way of introduction to a paper on real options a passage from the McKinsey Global Institute fourth annual report on global capital markets as a single example of the ever-increasing complexity, interdependency, and riskiness of early 21st century economic systems. I stated that "Changes in the environment continue at warp speed, outpacing the theoretical and practical developments necessary to describe, discuss, manage, and harvest them effectively. Various stakeholders are applying vast amounts of intellectual and financial capital to the tasks at hand. However, they have inherited a static, linear, deterministic design space from traditional economics and finance that is no longer adequate to meet the challenges facing it. Oddly enough, financial accounting, that 500-year old 'linguistic' platform critical to all economic endeavors, has been targeted as the source of the problem, while the real source has been generally ignored." (von Helfenstein, 2008: 2). At that time, my goal was to introduce the tsunami of the radical reform of financial accounting under SFAS 157, "*Fair Value Measurement*," with its fallout effects on finance, economics, valuation, and the markets, and suggest possible uses of real options in economic systems as one means of properly addressing these and other related challenges.

One year later, as the introductory quotes to this paper briefly imply, we face what the pundits, the politicians, and the press claim to be the breakdown of an entire system, perhaps of capitalism itself. This is serious business.

The solution proposed? More Government: interference; ownership; oversight; "help;" production of the only economic good it can produce – paper currency. Desperate times require desperate measures. For, as we hear day by day, corporate leadership and market capitalists are incompetent, rapacious, self-serving, and greed-obsessed and individual workers and investors (market participants) unable to take care of themselves and easily duped. Under such conditions, only a magnanimous, all-knowing, all-forgiving and truly objective, "extraordinary" (e.g., political) leadership, focused solely on what it believes to be the good of the governed, can raise us from the "debris" of our excesses, protect us from experiencing the effects of our bad choices, ensure that the markets are not "value-free," and bring us salvation. In short, the same solutions are being offered that have been brought to the table for at least sixty years, with few exceptions, and with no better results in sight.

While it is not the intent of this paper to be a political diatribe, it is worthy to remember that the political/regulatory sphere can and does inflict unforeseen injuries to the very economic systems to which it owes its existence – world-wide. Free market economic system participants must become better informed about and more actively involved in the intersection of politics and the markets, rather than accepting the naïve but widely-held belief that Government is and should be their "provider-protector of [first and] last resort." This change of mind, in turn, will flow over into to our efforts to aid the developing world.

Those of us in the real options community and other "edge" communities have developed tools of thought and practice that could meet the urgency of the times. If we are willing to step outside familiar, comforting, but specious solutions and begin to review the theoretical structure of the systems we have built, we could identify certain critical errors and propose potential workable solutions that could genuinely begin to turn things around.

To simplify the discussion herein, we will use the acronym ROiES for "real options *in* economic/engineering systems."

Structure of this Paper

This conceptual paper revisits the challenges faced by economic systems in the early 21st century. It identifies a potential source of dysfunction, found in the tenets of modern portfolio theory, and asks discomforting questions that prove just how dysfunctional fundamental financial and classical economic theory may be. It proposes fresh insights drawn from computer science/complexity theory and suggests applications of real options *in* economic systems as a way forward. It concludes with avenues for future research and application.

Since the subject under consideration is vast and has received decades of attention, research, data-gathering, practical application, and so forth, the intent of this paper is not to offer an encyclopedic, point-by-point refutation of modern portfolio theory. Its purpose is, rather, to highlight certain salient areas of weakness in such theory, indicate that a range of market participants also consider these to be weaknesses, and offer suggestions for thought and further research.

I. Problem Statement

The "Financial Crisis of 2008" emphatically illustrates the complexity, interdependence, and risk of modern economic systems. A wide array of cogent reasons for this latest crisis have been offered. However, there may be one fatal flaw in the "state of the system" that goes unnoticed because it is at such a fundamental level. I suggest that flaw is the failure of modern portfolio theory, grounded in linear, deterministic classical economics, to provide the proper theoretical base for decision-making within modern economic systems.

The following are some of the attributes of the "state of the system" that are having a profound effect on the ongoing viability of modern portfolio theory/capital market theory and classical economics.

<u>Increased complexity and turbulence – creating increased, and different, sources of risk, as well as new sets of questions.</u>

1: The exponential increase in market and transaction complexity. Increasingly sophisticated investment vehicles, enhanced computer-based trading and desk-top trading, 24x7 markets, global currency flows, Internet collaboration, consolidating exchanges and exchanges that operate as public companies – these all have profound effects on the traditional functions of markets. However, while traders build innovative algorithmic models to describe and manipulate new market functions, the fundamental financial theory on which they are built remains the same.

2: The increased presence of governmental and regulatory influence over every area of life. Organizations are expending massive amounts of time and resources to adapt to and mitigate the requirements of government and regulatory bodies, world-wide. Tax rules and other regulations and laws continue to burgeon. Government acquires massive new sources of debt with no economically viable source of cash inflow to sustain them. And fearful citizens call for even more draconian government oversight. Yet, none of our market decision models make more than a passing effort to include the effects of government on value – a "risk-free" rate, rates of inflation, a nebulous factor called "systematic risk."

3: The exponential growth of global data and "information" that must be considered and processed on a practically real-time basis. Information systems and brilliant programming are taking the place of human interface in order to support warp-speed market decisions in a “data smog” environment. But these systems are only as good as the models used to process and manipulate the data flowing into them.

4: The explosion of operating and financial complexity in economic systems worldwide. Industry and cross-industry consolidation, globalization, and new and exotic markets, industries and products requires an increasingly broad range of organizational and transaction structures, many of which are highly complex. Market participants must address such complexity in meaningful and accurate ways. While they build increasingly opaque and complex models to do so, they continue to use model assumptions that may no longer be capable of handling the task.

5: The influence of intangible assets on organizational structure, growth, complexity and value. As market attention has shifted toward intangible assets and away from tangible ones as the source of firm value, market participants face a dilemma. They must devise methods of measuring and managing the influence of such assets on the organization and its benefit streams (i.e. outputs), as well as quantify their influence on organizational projects and costs of capital. Yet, most of these assets are neither separable nor transferable, two attributes necessary for resource measurement and management.

6: The increased potential of unforeseen and/or unforeseeable random acts of violence, or systemic “surprises” (i.e., Black Swans) that disrupt economic systems on a global scale.

These challenges beg such questions as: Do modern economic systems actually function in the ways that are commonly described in the traditional literature? If they do not, how should we describe them? Can modern economic systems afford to view risk and complexity in the traditional way? Should portfolio/market/economic theory and quantitative finance more explicitly reflect the dynamism, complexity and risk inherent in system and organizational resources and activities?

II. Review of the Relevant Literature

The thinking and research underlying this paper has been ongoing for over a decade, initiated by a profound sense of discomfort with currently held notions such as "statistics as another form of mathematics," "economics as another form of the natural sciences," "market equilibrium," "efficient markets," and "stock market pricing as the only accurate signal of company value." There seemed to be some sense of realism missing in such concepts.

While the research began with the contributions of academia and has crossed back through that territory many times, it became clear that most research efforts were focused on variations of the same problem and solution set.

This could also be said for practitioner manuals, MBA and CFA educational materials, and practical discussions, debates, and insider tips found in the popular press from "The Street." The financial press, major consulting and public accounting firms, major investment banks, brokerages, advisors, and stock analysts, the blogsphere, and numbers of other reputable commentators all provided daily, weekly, or quarterly updates of "Finance, Keynesian Econ, and Markets Lite," reiterating the same themes with similar conclusions. Each group was actively pursuing its "angle" on this common problem-solution set, while it seemed that no one was stepping outside the box to ask questions at the fundamental level. Even the real options community, whose insights and contributions have been so innovative and valuable, seemed to focus on increasingly complex analyses and mathematical models based on one single set of unquestioned assumptions.

Sometimes, to discover a new solution set or recalibrate a problem, one must step outside the immediate discipline of interest and learn to view the "state of the system" with different paradigmatic eyes. Thus, this research flowed out into other related and unrelated fields –

organizational behavior and development, corporate strategy, behavioral finance, "New Economy" concepts, quantum physics, chaos theory and complexity science.

A tour of duty with the Department of Defense Office of Force Transformation, developing ways to bring financial market concepts and real options analysis to bear on capabilities planning for network centric warfare, provided another market system to understand. This market system was characterized by extreme risk, volatility, uncertainty and required a broad range of research to master enough of the warfare/defense market system to make a meaningful contribution to it.

Meanwhile, for over a decade as change agent within the financial valuation profession and would-be high tech entrepreneur, I remained embroiled in the flow of ideas that were changing our perceptions of our culture and world.

The most recently, the direction of the research was deeply influenced by two events. The first was attending a presentation by Dr. Richard de Neufville and one of his students, Tao Wang, on real options "in" engineering systems during the 2004 International Real Options conference in 2004. Here at last was real options thinking that could be applied to systems design problems that so concerned me. The second was my re-introduction to the Austrian School of economics where I found a proper theoretical home in economics for the other avenues of inquiry.

Given the highly non-traditional pathway to the concepts presented in this paper and the voluminous and eclectic reading/research involved, providing a traditional review of the literature is counter-productive. Therefore, each section of the following paper will cite work that has been of both current and/or lasting influence to me in that particular topic.

III. Revisiting the Quantitative Foundations of Finance

Section III presents certain uncomfortable challenges to the everyday practice and interpretation of quantitative finance and classical economics. It closely examines certain dysfunctionalities in our use of quantitative analysis that affect the way in which economic/market theory is built and used and market decisions are made.

Preface

Statistical analysis is the underlying quantitative tool by which all discussion of economic systems and tenets of modern portfolio theory is conducted. It appears, however, that, while many or most participants in economic systems utilize statistics to discuss, describe, and quantify market information and activities, they do so by rote, without a clear understanding of its strengths and shortcomings. We tend to attribute to statistics the aura of objective fact, when its statements and conclusions more closely belong to the category of subjective judgment. This may lead to insufficient, false or harmful conclusions, decisions, and initiatives.

The same can be said of other types of quantitative analysis used in our field.

Statistics is not mathematics; economics is neither mathematics nor a natural science

Statistics is not mathematics. The formulation and use of statistics is not strictly mathematical, though it employs cardinal numbers in "equations" that appear mathematical. "Mathematics is the study of quantity, structure, space, change, and related topics of pattern and form. Mathematicians seek out patterns whether found in numbers, space, natural science, computers, imaginary abstractions, or elsewhere." (Wikipedia) Mathematics involves counting and measurement and its hypotheses can be verified (or, better, proven wrong) by testing using measurable and, often, observable data.

Statistics is the probabilistic study of relationships between data sets and among the data in a set. It is based, not on measurement of specific data, but on the gathering, description, and comparison of ranges of data (populations and samples). The results of statistical analysis are not "solutions." They are pictures of the probabilities of certain relationships occurring in a hypothesized manner within a specified range or ranges. Thus, statistical analysis embeds uncertainty, variability, and subjective judgment.

We cannot manipulate statistical "equations" in the same manner as we manipulate mathematical ones without the danger of losing the sense of the relationships they describe. However, we can manipulate the data inputs in statistical analyses in ways that misrepresent reality and mislead the user, while appearing to remain tightly within the given statistical parameters. Using statistics, we gain general understandings, rather than build irrefutable conclusions.

Economics is neither mathematics nor a natural science. "There are, in the field of economics, no constant relations, and consequently no measurement is possible. If a statistician determines that a rise of 10 per cent in the supply of potatoes in Atlantis at a definite time was followed by a fall of 8 per cent in the price, he does not establish anything about what happened or may happen with a change in the supply of potatoes in another country or at another time. He has not 'measured' the 'elasticity of demand' of potatoes. He has established a unique and individual historical fact. . . . The impracticability of measurement is not due to the lack of technical methods for the establishment of measure. It is due to the absence of constant relations. . . . Economics is . . . . not quantitative and does not measure because there are no constants. Statistical figures referring to economic events are historical data. They tell us what happened in a nonrepeatable historical case." (von Mises, 1949: **55-56**)

"The fundamental deficiency implied in every quantitative approach to economic problems consists in the neglect of the fact that there are no constant relations between what are called economic dimensions. There are neither constancy nor continuity in the valuations and in the formation of exchange ratios between various commodities. Every new datum brings about a reshuffling of the whole price structure." (von Mises, 1949: **118**)

Furthermore, " Praxeology [the science of human action] does not deal with the external world, but with man's conduct with regard to it. Praxeological reality is not the physical universe, but man's conscious reaction to the given state of the universe. Economics is not about things and tangible material objects; it is about men, their meanings and actions. Goods, commodities, and wealth and all the other notions of conduct are not elements of nature; they are elements of human meaning and conduct. . . . [F]rom the human point of view action is the ultimate thing. . . [M]an chooses and acts and . . . we are at a loss to use the methods of the natural sciences for answering the question why he acts this way and not otherwise.

"Natural science does not render the future predictable. It makes it possible to foretell the results to be obtained by definite actions. But it leaves impredictable two spheres: that of insufficiently known natural phenomena and that of human acts of choice. Our ignorance with regard to these two spheres taints all human actions with uncertainty . . . The most that can be attained with regard to reality is probability." (von Mises, 1949: **92, 105**)

Economics and the "scientist" error. Economists attempt to "imitate as closely as possible the procedures of the brilliantly successful physical sciences. . . . Unlike the position that exists in the physical sciences, in economics and other disciplines that deal with essentially complex phenomena, the aspects of the events may be accounted for about which we can get quantitative data are necessarily limited and **may not include the important ones**. [emphasis added] While in the physical sciences it is generally assumed, probably with good reason, that any important factor which determines the observed events will itself be directly observable and measurable, in the study of such complex phenomena as the market, which depend on the actions of many individuals, all the circumstances which will determine the outcome of a process . . . will hardly ever be fully known or measurable. And while in the physical sciences the investigator will be able to measure what, on the basis of a *prima facie* theory, he thinks important, in the social sciences often that is treated as important which happens to be accessible to measurement. This is sometimes carried to the point where it is demanded that our theories must be formulated in such terms that they refer only to measurable magnitudes.

“. . . We know: of course, with regard to the market and similar social structures, a great many facts which we cannot measure and on which indeed we have only some very imprecise and general information. And because the effects of these facts in any particular instance cannot be confirmed by quantitative evidence, they are simply disregarded by those sworn to admit only what they regard as scientific evidence. They thereupon happily proceed on the fiction that the factors which they can measure are the only ones that are relevant. . . .

“ . . . In some fields, particularly where problems of a similar kind arise in the physical sciences, the difficulties can be overcome by using, instead of specific information about the individual elements, data about the relative frequency, or the probability, of the occurrence of the various distinctive properties of the elements. But this is true only where we have to deal with . . . ‘phenomena of unorganized complexity,’ in contrast to those ‘phenomena of organized complexity’ with which we have to deal in the social sciences. Organized complexity here means that the character of the structures showing it depends not only on the properties of the individual elements of which they are composed, and the relative frequency with which they occur, but also on the manner in which the individual elements are connected with each other. In the explanation of the working of such structures we can for this reasons not replace the information about the individual elements by statistical information, but require full information about each element if from our theory we are to derive specific predictions about individual events. Without such specific information about the individual elements we shall be confined to . . . mere pattern predictions – predictions of some of the general attributes of the structures that will form themselves, but not containing specific statements about the individual elements of which the structures will be made up." (von Hayek, 1974)

Black Swans and the effects of fallacies in human reasoning on finance and economics

> Four and a half years after my graduation from Wharton . . . , on October 19, 1987, I walked home from the offices of the investment bank, Credit Suisse First Boston in Midtown Manhattan to the Upper East Side. I walked slowly, as I was in a bewildered state.
>
> That day saw a traumatic financial event: the largest market drop in (modern) history. It was all the more traumatic in that it took place at a time when we thought we had become sufficiently sophisticated with all these intelligent-talking Platonified economists (with their phony bell curve-based equations) to prevent, or at least forecast and control, big shocks. The drop was not even the response to any discernable news. The occurrence of the event lay outside anything one could have imagined on the previous day – had I pointed out its possibility, I would have been called a lunatic. It qualified as a Black Swan, but I did not know the expression then. (Taleb, 2007: **18**).

Currently Distinguished Professor of Risk Engineering at Polytechnic Institute of New York University, Dr. Nassim Taleb was a former practitioner of quantitative finance and specialist in financial derivatives on Wall Street. His book, *The Black Swan*, discusses the effects of fallacies in human reasoning on finance, economics, and financial decision making, as abbreviated following.

Black Swans. A Black Swan is an event with three attributes: a) it lies "outside the realm of regular expectations and nothing in the past can convincingly point to its possibility;" b) it "carries extreme impact;" c) "in spite of its outlier status, human nature makes us concoct explanations for its occurrence *after* the fact, making it explainable and predictable. . . . Black Swan logic makes *what you don't know* far more relevant than what you do know." (Taleb, 2007: **xvii, xviii, xix**)

We exhibit blindness to the Black Swan because: (Taleb, 2007: **50, 89**)

1. "We focus on preselected segments of the seen and generalize from it to the unseen – the error of confirmation."

2. "We fool ourselves with stories that cater to our Platonic thirst for distinct patterns – the narrative fallacy."

3. "We behave as if the Black Swan does not exist – human nature is not programmed for Black Swans" (i.e.. non-linearity) even though "nonlinear relationships in life are ubiquitous."

4. "What we see is not necessarily all that is there. History hides Black Swans from us and gives us a mistaken idea about the odds of these events – this is the distortion of silent evidence."

5. "We 'tunnel' – that is, we focus on a few well-defined sources of uncertainty, on too specific a list of Black Swans (at the expense of others that do not easily come to mind)."

Triplet of Opacity. "History is opaque. You see what comes out, not the script that produces events . . . The human mind suffers from three ailments as it comes into contact with history . . . They are: a) the illusion of understanding, or how everyone thinks he knows what is going on in a world that is more complicated (or random) than they realize; b) the retrospective distortion, or how we assess matters only after the fact, as if they were in a rearview mirror (history seems clearer and more organized in history books than in empirical reality); and c) the overvaluation of factual information and the handicap of authoritative and learned people, particularly when they create categories – when they 'Platonify.'" (Taleb, 2007: **8**)

Two types of uncertainty/randomness, e.g. non-scalable and scalable. There are two types of uncertainty/randomness. We tend to confuse them and to consider all uncertainty/randomness we encounter in finance and economics as Type 1, when, in reality, it is always Type 2. Our quantitative analysis, thus, is misdirected and provides unrealistic results.

Type 1 randomness (non-scalable) Taleb calls *Mediocristan* and describes it as a "utopian province" in which "When your sample is large, no single instance will significantly change the aggregate or total." In Mediocristan, what you can know from the data grows as rapidly as the supply of information. Its concerns are focused on physical quantities such as weight, height, calorie consumption, gambling profits, and mortality rates.

Type 2 randomness (scalable) Taleb calls *Extremistan* and describes it as the realm of social matters, in which "inequalities are such that one single observation can disproportionately impact the aggregate, or the total." In *Extremistan*, knowledge grows slowly and erratically at no given rate. Its concerns are focused on informational quantities such as academic citations, wealth, company size, populations of cities, financial markets, commodity prices, economic data. (Taleb, 2007: **32-35**)

The ludic fallacy. We use games to test reality and to discuss both chance and human response to risk when games and reality exhibit widely divergent types of uncertainty and randomness.

Gambling is "sterilized and domesticated uncertainty . . . 'The casino is the only human venture . . . where the probabilities are known, Gaussian (i.e. bell-curve), and almost computable.' . . . Yet we automatically, spontaneously associate chance with these Platonified games. . . . In real life you do not know the odds; you need to discover them, and the sources of uncertainty are not defined. . . . Furthermore, assuming chance has anything to do with mathematics, what little mathematization we can do in the real world does not assume the mild randomness represented by the bell curve, but rather scalable wild randomness. What can be mathematicized is usually not Gaussian, but Mandelbrotian.

"Now, go read any of the classical thinkers who had something practical to say about the subject of chance, such as Cicero, and you find something different: a notion of probability that remains fuzzy throughout, as it needs to be, since such fuzziness is the very nature of uncertainty. Probability is a liberal art; it is the child of skepticism, not a tool for people with calculators on their belts to satisfy their desire to produce fancy calculations and certainties." (Taleb, 2007: **127-128**)

The scandal of prediction. We are prone to "epistemic arrogance," that is, our "hubris concerning the limits of our knowledge." This, in turn, affects our ability to make accurate forecasts. "The most interesting test of how academic methods fare in the real world was run by Spyros Makridakis, who spent part of his career managing competitions between forecasters who practice a 'scientific method' called econometrics – an approach that combines economic theory with statistical measurements. Simply put, he made people forecast *in real life* and then he judged their accuracy. This led to the series of 'M-Competitions' he ran, with assistance from Michele Hibon, of which M3 was the third and most recent one, completed in 1999. Makridiakis and Hibon reached the sad conclusions that 'statistically sophisticated or complex methods do not necessarily provide more accurate forecasts than simpler ones.' . . . [They were also] to find out that the strong empirical evidence of their studies has been ignored by theoretical statisticians. . . . 'Instead, [statisticians] have concentrated their efforts in building more sophisticated models without regard to the ability of such models to more accurately predict real-life data,' Makridiakis and Hibon write." (Taleb, 2007: **154-155**)

Reflexivity and fertile fallacies

> I contend that rational expectations theory totally misinterprets how financial markets operate. Although rational expectations theory is no longer taken seriously outside academic circles, the idea that financial markets are self-correcting and tend towards equilibrium remains the prevailing paradigm on which the various synthetic instruments and valuation models which have come to play such a dominant role in financial markets are based. I contend that the prevailing paradigm is false and urgently needs to be replaced.

In a tiny volume, *The New Paradigm for Financial Markets: The Credit Crisis of 2008 and What It Means*, George Soros, currency speculator, investor, businessman, philanthropist, and political activist, discusses the shortcomings of classical financial theory and models for modern economic systems. Offered almost apologetically for its lack of academic prestige, the book is a thoughtful work, based on a long – and successful – life spent in some of the most risky and stressful trenches of the U.S. and international financial markets. The following are a summary list of its propositions:

Fallibility. "People are participants, not just observers, and the knowledge they can acquire is not sufficient to guide them in their actions. They cannot base their decisions on knowledge alone. . . . . The capacity of the human brain to process information is limited, whereas the amount of information that needs to be processed is practically infinite. The minds is obliged to reduce the available information to manageable proportions by using various techniques – generalizations, similes, metaphors, habits, rituals, and other routines. These techniques distort the underlying information but take on an existence of their own, further complicating reality and the task of understanding it." (Soros, 2008: **26**)

Reflexivity. " . . . [S]ocial events have a different structure from natural phenomena. In natural phenomena there is a causal chain that links one set of facts directly with the next. In human affairs the course of events is more complicated. Not only facts are involved but also the participants' views and the interplay between them enter into the causal chain. There is a two-way connection between the facts and opinions prevailing at any moment in time: on the one hand, participants seek to understand the situation (which includes both facts and opinions); on the other, they seek to influence the situation (which again includes both facts and opinions). The interplay between the cognitive and manipulative functions intrudes into the causal chain so that the chain does not lead directly from one set of facts to the next but reflects and affects the participants' views. Since those views do no correspond to the facts, they introduce an element of uncertainty into the course of events that is absent from natural phenomena. That element of uncertainty affects both the facts and the participants' views. . . . Reflexivity . . . [describes] a two-way connection between the participants' thinking and the situation in which they participate." (Soros, 2008: **7-8**)

The human uncertainty principle. "Reflexivity bears some resemblance to Werner Heisenberg's uncertainty principle in quantum physics, but there is one important difference: quantum physics deals with phenomena that do not have thinking participants. Heisenberg's discovery of the uncertainty principle did not change the behavior of quantum particles or waves one iota, but the recognition of reflexivity may alter human behavior." (Soros, 2008: **31**)

The Enlightenment fallacy. "The philosophers of the Enlightenment put their faith in reason; they saw reality as something separate and independent of reason, and they expected reason to provide a full and accurate picture of reality. Reason was supposed to work like a searchlight, illuminating a reality that lay there, passively awaiting discovery. The possibility that the decisions of thinking agents could influence the situation was left out of account because that would have interfered with the separation between thoughts and their object. In other words, the Enlightenment failed to recognize reflexivity." (Soros, 2008: **32**)

Fertile fallacies. "Fertile fallacies abound in history. I contend that all cultures are built on fertile fallacies. They are fertile because they flourish and produce positive results before their deficiencies are discovered; they are fallacies because our understanding of reality is inherently imperfect. We are, of course, capable of acquiring knowledge; but if that knowledge proves useful we are liable to over-exploit it and extend it to areas where it no longer applies." (Soros, 2008: **34**)

Abandoning the unity of scientific method. The pursuit of truth. The term "unity of scientific method" posits that the same methods of inquiry apply to both the natural and social sciences.

". . . [W]e can recognize a difference between the natural and social sciences, and we can introduce the pursuit of truth as a requirement for an open society. The postmodern attitude toward reality is much more dangerous [than that of the Enlightenment]. While it has stolen a march on the Enlightenment by discovering that reality can be manipulated, it does not recognize the pursuit of truth as a requirement. Consequently, it allows the manipulation of reality to go unhindered. Why is this so dangerous? Because in the absence of proper understanding the results of manipulation are liable to be radically different from the expectations of the manipulators." (Soros, 2008: **38-39**)

"Reality is a moving target, yet we need to pursue it. In short, understanding reality ought to take precedence over manipulating it. As things stand now, the pursuit of power tends to take precedence over the pursuit of truth." (Soros, 2008: **43**)

Data mining effects on fundamental research

"When a researcher tries many ways to do a study, including various combinations of explanatory factors, various periods, and various models, we often say he is 'data mining.' If he reports only the more successful runs, we have a hard time interpreting any statistical analysis he does. We worry that he selected from the many models tried, only the ones that seem to support his conclusions. With enough data mining, all the results that seem significant could be just accidental. . . .

"Data mining is not limited to single research studies. . . . Data mining is most sever when many people are studying related problems.

"Even when each person chooses his problem independently of the others, only a small fraction of research efforts result in published papers. By its nature, research involves many false starts and blind alleys. The results that lead to published papers are likely to be the most unusual or striking ones. But this means that any statistical tests of significance will be gravely biased.

"The problem is worse when people build on one another's work. Each decides on a model closely related to the models others use, learns from the others' blind alleys, and may even work with mostly the same data. Thus in the real world of research, conventional tests of significance seem almost worthless.

"In particular, most of the so-called anomalies that have plagued the literature on investments seem likely to be the result of data mining. We have literally thousands of researchers looking for profit opportunities in securities. They are all looking at roughly the same data." (Black, 1993: **9**)

These kinds of considerations, supported by many voices within the marketplace, indicate that we may want to reassess the effectiveness of the theoretical bases on which our quantitative analyses and related market decisions are being made.

IV. Revisiting Concepts of the Markets and Capital Market Theory

Section IV reviews basic capital market concepts and presents certain disquieting questions about them. We can conclude that force-fitting 21st century economic systems into 20th century "universal" models or ignoring them altogether (and pretending all systems have remained the same indefinitely) may not be appropriate.

Preface

People in all walks of life and all occupations discuss "the markets." Scholars and students study them extensively; traders and others in the financial services industry "make" them and are made by them every day; and commentators of all sorts offer the latest and greatest views on what all this activity means.

But what are markets?

> "The Market" is a term that covers a wide range of concepts from the whole universe of available investments to the public stock markets to specific market indexes such as the Dow Jones Industrial Average or the Standard & Poors 500. The following are some of the commonly used definitions and assumptions about the market.
>
> A "complete" market is one in which all trades can be made using available securities. An "incomplete" market is one in which some trades cannot be made using available securities. Market prices are determined by real people making real trades. Market equilibrium is the state in which all investors have chosen some combination of a market portfolio plus borrowing or lending and face only one source of risk – the performance of the market as a whole. The market portfolio should contain all forms of capital – human, intangible, tangible, and financial. But it does not because it is still too difficult to value anything but tangible and financial capital. Market risk is the risk related to the overall size of the pie, while private (non-market) risk is related to the size of individual pieces of that pie. Non-market (diversifiable, unsystematic) risk is not rewarded with higher expected returns because it can be eliminated by diversification of the market portfolio (Sharpe, 2004 website).
>
> An efficient market is one in which ". . . there are large numbers of rational, profit-maximizers actively competing, with each trying to predict future market values of individual securities, and where important current information is almost freely available to all participants. In an efficient market, competition among the many intelligent participants leads to a situation where, at any point in time, actual prices of individual securities already reflect the effects of information based both on events that have already occurred and on events which, as of now, the market expects to take place in the future. In other words, in an efficient market at any point in time the actual price of a security will be a good estimate of its intrinsic value" (Fama, 1965). (Nelson, 2005: **27-28**)

The markets are composed of many classes and sub-classes of agents (market participants), all of which are providing information, making decisions and taking actions that affect market prices. “Agents” include individual investors who invest for their own accounts and institutional investors who invest huge pools of money on behalf of institutions or large groups of clients. Institutional investors (including investment banks and insurance companies) run mutual funds, pension funds, hedge funds, private equity funds and unit investment trusts. Behind/within all of these entities are traders and specialists whose activities move markets minute by minute. While they are focused on investing other people’s capital, their compensation is tied to their successes in generating excess returns (i.e., *alpha*). All agents involved in creating and implementing market strategies are supported by hosts of research analysts who compete with each other for providing the best analysis. Research analysts have, or are supposed to have, far-reaching influence over trading strategies and decisions. Institutional and other organizational agents invest in increasingly complex quantitative models and information systems to help select optimized portfolios and wring elusive *alpha* out of the system. This means that computers and the algorithms they apply become yet one more form of “investor” influencing market movements. Investors of all classes scan the globe for opportunities to achieve *alpha* and invest wherever their strategies, research, cultural outlook, and instincts take them.

Von Mises describes markets thus: *A process set in action by the interplay of the actions of various market participants cooperating under the division of labor within a social system of the division of labor under private ownership of the means of production.* Every market participant acts on his own behalf but with the satisfaction of both his and his fellow citizens’ (i.e. customers) needs in mind. “The forces determining the – continually changing – state of the market are the value judgments of these individuals and their actions as directed by these value judgments. The state of the market at any instant is the price structure, i.e. the totality of the exchange ratios as established by the interaction of those eager to buy and those eager to sell." (von Mises, 1949: **258-259**)

Capital Markets and Investor Assumptions

One subset of markets thus described are the capital, or financial, markets. There are two forms of capital markets: 1) primary markets, in which new issues of securities are offered by either companies whose shares are already trading in the marketplace or by companies who are entering the public markets for the first time; and 2) secondary markets, where securities are traded after their initial offerings in the primary markets. Secondary markets provide liquidity and continuous pricing signals for investors operating within them.

Markets are efficient, or are they? It is said that a well-functioning secondary market has four key attributes: 1) accurate and timely information on the price and volume of past transactions and current supply and demand for securities; 2) The ability for investors to buy and sell rapidly at a known price, with prices that are stable from one transaction to the next, barring news that might affect price continuity; 3) informational efficiency that allows prices to adjust quickly to new information; 4) internal efficiency that keep transaction costs low. The ever-increasing insertion of sophisticated, globally-networked information systems into market activities has ensured that attributes #1-3 remain in effect.

Q1: *At what point does the exponential growth of near real-time information availability and the equally enormous growth in the speed at which transactions can and do take place, both on a global basis, reduce or negate market efficiency and produce unmanageable increases in market noise and, thus, the effects of reflexivity? How has this affected financial theory and models? How has/can real options analysis contribute here?*

Or, another voice speaking about efficiency: "Efficiency exists only in relation to certain ends or objectives. . . . Let us take a given individual. Since his own ends are clearly given and he acts to pursue them, surely at least *his* actions can be considered efficient? But no, they may not, for in order for him to act efficiently, he would have to possess perfect knowledge – perfect knowledge of the best technology, of future actions and reactions by other people, and of future natural events. But since no one can ever have perfect knowledge of the future, no one's actions can be called 'efficient.' We live in a world of uncertainty. Efficiency is therefore a chimera.

"Put another way, action is a learning process. As the individual acts to achieve his ends, he learns and becomes more proficient about how to pursue them. But in that case, of course, his actions cannot have been efficient from the start – or even from the end – of his actions, since perfect knowledge is never achieved, and there is always more to learn." (Rizzo et al, 1979: **71, 90**)

Q2: If these statements about efficiency are true about individuals, would they not also be true of collections of individuals, i.e., the markets? Are markets "learning organizations" rather than machines characterized by "weak form" or "strong form" efficiency? If they are, how would this affect theory and practice? Can real options analysis contribute here?

Markets are based on deterministic principles such as "expectations," under which they seek, find, and maintain equilibrium by wringing uncertainty out of the system, or are they? "As they have come to be treated in conventional economic literature, expectations refer to the 'outside world,' to the environment in which an economic agent finds himself. The agent is allowed or required to have expectations about a predefined set of properties of a predefined set of entities . . . Expectations are thus a way of characterizing and dealing with uncertainty." (Rizzo et al, 1979: **35**)

“*Uncertainty* conveys the suggestion that there is a determinate future preexisting choice and independent of it, needing only to be found out. If this were all, what meaning could be found in choice, what peculiar mechanism of error and ignorance would destiny be using in mockery of human effort, to bring about its preordained results? It seems plain that if the future merely waits to be revealed, the business of choice is merely a response to signals . . . History is not predetermined, merely waiting to be discovered. Rather, history is continuously *originated* by the pattern and sequence of human choice.” (Rizzo et al, 1979: **27, 34**)

And, *imagination* generates the elements from which choice is made. “However, imagination unconstrained is a necessary but insufficient basis for decision. A pure fiction can give pleasure, but is irrelevant for action unless it constitutes an imagine course of some possible history-to-come, a history whose possibility depends upon some action of the chooser. To be seen as possible, this imagined history must be consistent with the chooser’s knowledge or beliefs about his own resources, the nature of the world, the likely actions of others, etc. . . . [O]nly this special subset of imagined futures, the subjectively possible ones, attain the status of expectations.

“ . . . [E]xpectations do not refer to entities of the world as it is, nor yet to *predefined* entities of the world as it might be, but to entities existing in, and created by, the imagination of each decision maker. In other words, the raw material for expectations is provided not by the world directly, but by imagination at work on the world. For this reason, a man may have expectations about future events and actions that have not occurred to anyone else.” (Rizzo et al, 1979: **36**)

Q4: If we build deterministic models based on deterministic expectations and then give them to computer to execute, are we acting in blind contradiction to the nature of the market *environment, thus courting disaster? How might real options analysis better reflect "imagination," choice, and "expectations" as defined by the Austrian School?*

Markets facilitate the exchange of valuable assets, or do they? Since post-WWII, the secondary capital markets have experienced an exponential growth in "financial innovation," in which an increasingly vast array of investment opportunities (called "products") become available. The list is long, including: domestic and international equity and fixed income securities (including government securities of every kind), hybrid securities such as convertible debt, derivatives (options, futures, forwards, swaps, collateralized debt obligations, contingent claims), currencies, mutual funds, exchange-traded funds, real estate, venture capital, hedge funds, closely-held companies, distressed securities, and commodities. Each asset ("product") class just listed has a broad spectrum of sub-classes as well.

Many of these products are exotic, i.e. highly complex. Each has its own set of trading rules and are traded on different exchanges or simply over-the-counter. Some products are tightly regulated by government and some are not. They all have varying risk and tax attributes and are amenable to varying types and degrees of financial leverage. In addition, there has been an increasing commingling of investment opportunities from developed and developing nations, adding layers and types of risk and complexity across all markets. Many, or all, products are directly or indirectly interdependent and can/will affect the market value of the others.

Q5: *At what point does the variety and complexity of products offered and their interdependencies make it difficult or impossible to determine the actual risk profiles of specific products and assess their intrinsic values? Do some or most of these products have intrinsic value at all? Would it be possible to design better products and better model their interdependencies using ROiES?*

Markets are populated by "Markowitz" investors, or are they? In his 1952 paper, "Portfolio Selection," published in the *Journal of Finance,* Dr. Harry Markowitz, Nobel Laureate, developed a set of theories about the functioning of the capital markets and optimal portfolio choice within them. These were groundbreaking at the time and have continued as the fundamental theoretical base for the capital markets to this day. Underlying modern portfolio theory are the following assumptions about investor behavior:

1. Probabilistic returns distribution. Investment opportunities are viewed by investors as probabilistic distributions of expected returns over a given investment horizon.

2. Maximization of expected utility. Investors seeks to maximize their expected utility over a given investment horizon and their utility curves exhibit the effects of the diminishing marginal returns of wealth.

3. Risk is defined as variability. Risk is defined by investors as the variability (variance, standard deviation) of returns around a mean expected return.

4. Only risk and return are considered. Investors only consider the risk/return attributes of an investment when making decisions. Thus, investors are indifferent to other characteristics of the distribution of returns, such as its skew (i.e., the degree of asymmetry in the distribution) or kurtosis (i.e., the thickness of the distribution tails, or, "fat tails").

5. Investors are risk averse. Given two assets that offer the same expected return, investors will prefer the less risky one and, given the same level of risk for two assets, an investor will invest in the one that provides higher returns. Therefore, investors will take on increased risk only if compensated by higher expected returns.

Classical economics assumes that investors are governed by rational expectations, i.e. that they take all available information into account in forming expectations. Such expectations may turn out to be incorrect, but they will not deviate systematically from market equilibrium results. It also assumes that investors make rational choices, i.e. they choose the best action possible within the stable preference functions and constraints available to them.

Yet both of these assumptions may not reflect reality. "Participants are supposed to choose between alternatives in accordance with their scale of preferences. The unspoken assumption is that the participants *know* what those preferences and alternatives are. . . . [T]his assumption is untenable. . . . Nowhere is the role of expectations more clearly visible than in financial markets. Buy and sell decisions are based on expectations about future prices, and future prices, in turn, are contingent on present buy and sell decisions. . . . Anyone who trades in the markets where prices are continuously changing knows that participants are very much influenced by market developments. Rising prices often attract buyers and visa versa. . . . [S]uch trends are the rule rather than the exception. . . . Participants act not on the basis of their best interests but on their *perception* of their best interests and the two are not identical." (Soros, 2008: **54-56**)

Q6: *Given this description of the investor (market agent) universe with its potential for widely divergent goals, strategies and attitudes toward risk, can we be comfortable with Markowitz and classical economics investor assumptions any longer? If we are not, what could we substitute that would be meaningful?*

The markets "know" more than the individual agents within them, enabling them to be self-correcting and return to equilibrium, or not? While individual agents may violate rational expectations theory and make mistakes, all agents still operate from the same set of assumptions and relationships (i.e., model) and individual deviations from the model will end up converging back to it over time.

Again, this view of market function may not represent reality. "I contend that financial markets are always wrong in the sense that they operate with a prevailing bias, but in the normal course of events they tend to correct their own excesses. **Occasionally, the prevailing bias can actually validate itself by influencing not only market prices but also the so-called fundamentals that market prices are supposed to reflect.**" [emphasis added.] (Soros, 2008: **57**)

Q7: What if classical market equilibrium does not exist? What if market biases do, in fact, influence the fundamentals that market prices are supposed to reflect? What, then, do market prices represent? How could we more accurately discuss the relationship between price and value?

Modern Portfolio Theory, Capital Market Theory

The basic concept of modern portfolio theory is that rational investors will diversify the assets they hold in their portfolios to optimize these portfolios and lower/minimize risk. Based on this general investor strategy, risky assets within the portfolios can be priced. Both asset and portfolio returns are random variables that can be analyzed by statistics. Again, variability, or volatility, around a mean is the measure of risk and the measure of return is future (expected) returns.

The "Markowitz Efficient Portfolio is one in which no added diversification can lower the portfolio's risk for a given return expectation (alternately, no additional expected return can be gained without increasing the risk of the portfolio). The Markowitz Efficient Frontier is the set of all portfolios that will give the highest expected return for each given level of risk." (Wikipedia definition) The Markowitz Efficient Portfolio (MEP) holds every risky asset, weighted by the market value of that asset as a percent of the total portfolio's market value. Thus, it is the ideal case of a fully diversified portfolio.

Modern portfolio theory indicates that, since the risks (variability) specific to each asset in the MEP are not perfectly correlated with each other, they will, in effect, cancel each other out. The risk that disappears from the portfolio is called *unsystematic* risk. The risk that remains is termed *systematic risk* (or, market risk). While no one knows exactly how many securities a portfolio needs to hold to diversify away all unsystematic risk, the number is significantly less than all the securities available on the market. Currently, most market agents use the S&P 500 as the proxy for the MEP.

To suit their risk/return preferences, all rational investors must do is vary the proportion of their investment in a MEP and in the risk-free asset. The capital market line represents all combinations of the MEP and the risk-free asset. The addition of the risk-free asset causes modern portfolio theory to transition into capital market theory.

These preceding tenets of modern portfolio/capital market theory are based on certain assumptions, following. Relaxing any of these assumptions creates dysfunctionalities in the asset pricing models that are derived from capital market theory.

1. All investors are risk averse.
2. All investors are Markowitz investors and want fully diversified portfolios that lie on the efficient frontier.
3. Investors can borrow or lend unlimited amounts at the risk-free rate. The cost of borrowing and lending is identical.
4. When investors consider a security, they all see the same risk/return distribution.
5. All investors have identical investment horizons (i.e. holding periods).

6. All investments are infinitely divisible and perfectly liquid.
7. There are no investment-related taxes or transaction costs.
8. There is no inflation. Interest rates do not change.
9. The capital markets are and remain in equilibrium.

Q8: Does portfolio diversification truly mitigate everything but systematic risk? Is it possible to add increasingly risky assets to a portfolio to a level at which the portfolio becomes unstable or takes on the risk attributes of its riskiest assets? Might a concept of "bounded diversification" be more useful than "full diversification?"

Q9: Could we use real options thinking to relax capital market assumptions and build more a useful/realistic model of the market portfolio?

Q10: If ***"Profit exists only in a world of uncertainty and disequilibrium."*** *[emphasis added] (Rizzo et al, 1979:* ***10****), are real investors risk averse and primarily focused on risk avoidance and risk mitigation?*

The Valuation of Assets Under Capital Market Theory

Simplistically, the valuation of assets under capital market theory involves discounting the benefit stream generated by an asset over a given forecasted time period and a terminal period, using a discount rate (also called cost of capital or rate of return) specific to that asset. While there are ongoing debates within the financial and valuation communities regarding whether asset risk should be captured entirely in the benefit stream (and discounted using the risk-free rate), partially in both the benefit stream and discount rate, or primarily in the discount rate, capital market theory provides the context and parameters by which this discount rate can be developed.

Since the discount rate is a means by which to express the riskiness of the subject asset, the traditional definition of risk equates risk with uncertainty as follows: risk is the “degree of uncertainty (or lack thereof) of achieving future expectations at the times and in the amounts expected. . . . Inasmuch as uncertainty is within the mind of each individual investor, we cannot measure the risk directly. Consequently, participants in the financial markets have developed ways of measuring factors that investors normally would consider in their effort to incorporate risk into their required rate of return.” (Pratt & Grabowski, 2008: **40**)

Such factors are incorporated in two slightly different methodologies for discount rate development, the build-up method and the capital asset pricing model (CAPM). Since the CAPM is directly derived from capital market theory and almost universally used, I will focus on it.

The CAPM is the sum of the risk-free rate, a risk premium for the market (called the equity risk premium) and a factor that expresses the systematic risk of the asset being valued (called a Beta). It takes the form:

$$k_e = r_{rf} + \beta(r_m - r_{rf})$$

The equity risk premium (r_m) is the expected return on a fully diversified portfolio of equity securities (most often, the S&P 500) in excess of the expected return on a risk-free security. While the equity risk premium is forward looking, it is often estimated by using historical data from the capital markets. As it turns out, realized equity returns have consistently exceeded expected ones, sparking a long-term debate regarding the cause of the excess.

Beta (β) is a controversial factor. Much debate has taken place about its existence and what it actually means. It can be developed by: *1) Using a regression equation:* The regression equation is a standard linear, slope-intercept algebraic equation in the form [y = a + bx] in which we regress the excess returns on the security against the excess returns on the market, as follows:

$$[r_s - r_f] = \alpha_s + \beta_s[r_m - r_f] + \xi_s$$

where:

$y = [r_s - r_f]$	= the dependent variable = the excess returns on security *s*
a = or α_s	= the intercept = the location where the excess returns on the market are zero and we have the 'pure' excess returns on security *s*
$b = \beta_s$	= the slope = the beta of security *s*
$x = [r_m - r_f]$	= the independent variable = the average excess returns on the market
ξ_s	= the standard error of the regression coefficient, which measures the extent to which each individual observation in a sample varies from the value predicted by the model

In this case, "excess returns" is defined as the total returns on security *s* or the market less the risk-free rate for the period under investigation. The term "market" refers to a portfolio of securities that is fully diversified and weighted in a manner that creates an exact proxy of actual public market listings.

This regression model requires the analyst to use informed professional judgment to select four variables: 1) the appropriate market proxy (although there may be some latitude regarding which proxy is chosen because the correlation across all market indexes is very high); 2) the length of time over which excess returns should be measured (commonly, 5 years or less); 3) the incremental time periods to be used for capturing excess returns (commonly, monthly returns); and 4) the risk-free rate from which to calculate excess returns.

In this model, β_s indicates how sensitive the excess returns on security *s* are to a 1% change in the average excess returns on the market.

2) Using a statistical equation: The statistical equation calculates beta as follows:

$$\beta = \frac{Cov(r_s, r_m)}{Var(r_m)}$$

In this model, β reflects the contribution of the subject asset to the risk of a fully diversified portfolio. Since a fully-diversified portfolio removes all unsystematic risk at no cost, β represents the systematic risk contribution of the subject asset.

Betas can be developed top-down or bottom-up and adjusted for company financial and operating leverage. They can be modified to incorporate industry norms, to incorporate a timing lag effect, and can be calculated for assets other than equity securities. Financial reporting services calculate betas differently, making it hard to assess the usefulness and comparability of the betas provided by these services.

When a discount rate is needed to value whole companies or portfolios of assets that contain other than common equity, the CAPM must be modified by adding beta factors, risk premia and tax attributes for non- common equity assets. A risk premium for company size and even company-specific risk may be added. However, the CAPM's viability depends on retaining the strong assumptions required by capital market theory.

Q11: Are risk and uncertainty equivalent? Does Beta actually represent systematic risk? Can we learn more from the CAPM and use it more realistically than it is currently being used?

The role of time in capital market theory

"The notion of time is so primitive and basic an element in man's experience that its neglect by much economic theory constitutes an incredible puzzle. This puzzle is attributable, perhaps, to the almost irresistible lure of formalism – particularly one that cannot adequately handle time. The twin goals of manageability and formalism, then, have transformed the crucial questions that economists ask. So, if we are not careful, the question of time is not one which can even be asked. To consider the role of time in economic life, therefore, often requires that we step outside of the conventional models . . . Time, as we shall see, is so intimately connected with every aspect of economic theory that it is only a heroic artificiality that has kept it form occupying center stage." (Rizzoet al, 1979: **1**)

Capital market theory and its pricing models are based on the concept of market equilibrium. Within this system, capital is conceived as purely physical and exhibits a yield ("price") called a rate of interest. A form of time is taken into consideration under the rubric of discounting to "present value" or calculating a "future value." However, time in this sense is uni-dimensional, linear, and deterministic. The focus of such analyses is on comparison of "steady states" rather than processes of change.

Q12: Leland Yeager, in his essay "Capital Paradoxes and the Concept of Waiting," makes the following statements: ". . .[W]aiting for value over time [i]s a scarce factor of production whose rationing by the interest rate is quite in accord with the logic of a price system. Waiting cannot be measured in purely physical terms, and the amount of it required in a physically specified production process does depend partly on its own price. . . . [However,] interpreting capital abstractly, as waiting, helps to clear up bothersome paradoxes. . . It gives intelligible meaning to such familiar phrases as 'interest on capital,' 'the cost of capital,' 'the capital market' . . . It brings the interest rate within the purview of ordinary theories of supply and demand and of functional income distribution. . . . It helps show what sort of opportunity cost the interest rate measures." (Rizzo et al, 1979: **192, 193, 194**)

Why have we locked ourselves into models that take no account of the powerful influence of time and choice? Should we consider Yeager's approach to time in economic systems? Are there other approaches that will benefit our understanding and decision-making? How can real options analysis address such concerns?

V. Real Options 'in' Economic Systems as an Alternative to Capital Market Theory

Preface

"Options" thinking has played a role throughout time in the world of choice (the markets). Financial options – market-traded contracts granting the buyer the right but not the obligation to exercise the contract terms within a given time – are a current market product resulting from the work of Robert Merton and Myron Scholes in the early 1970s. Financial options are a form of investment whose value is derived from the value of an underlying asset, in this case, equity securities. The Black-Scholes options pricing model is based on assumptions as strict as those for the CAPM, and much like them:

1. It is possible to borrow and lend cash at a known constant, the risk-free interest rate.
2. There are no transaction costs.
3. The underlying securities do not pay dividends.
4. All underlying securities are perfectly divisible.
5. Equity prices follow a continuous-time stochastic process, geometric Brownian motion, exhibiting constant volatility and drift.
6. There are no restrictions on short selling.

Model variables are: the price of the underlying security; the exercise price of the option; the expiration period; the volatility and drift of the underlying stock price; and the risk-free rate. While this model can be expanded to include changing rates and volatility, expiration periods and dividend payouts, it remains a linear and deterministic.

The introduction of options pricing theory into the non-linear, non-deterministic world of "real" assets (v. financial assets) and business investments created the rich field of real option theory and practice. This field has experienced over thirty years of innovation with regards to modifying the linear, deterministic world of capital market theory to fit the realities of business choices and investing. However, in the words of its foremost experts, real options analysis continues to have some noteworthy weaknesses, following: (Nelson, 2005: **18-21**)

> The following detailed list of problems related to developing RO model inputs will provide a richer context for the proposed solutions. These problems have been widely stated in finance and real option literature and clearly defined during panel discussions, presentations, and the keynote speech by Dr. Stewart Myers at the June 2004 Real Options Conference.
>
> 1. Various parties are using different languages and thought processes to develop model inputs and evaluate model outputs for corporate finance.
>
>   a. Real options are driven by value creation while finance and engineering are driven by risk management, creating difficulties in discussing and developing inputs (de Neufville, Presenter, 2004 RO Conference).
>
>   b. Corporations are measured by the markets on predictable growth, while real options analysis (ROAn) estimates value under uncertainty, i.e. the value of strategic flexibility. This means that the client (investor, market) will be looking for one kind of data and value estimate while the supplier (RO analyst) will be providing another (Thursday Panel Discussion, 2004 RO Conference: Antikarov, Monitor Group; Brosch, Boston Consulting; Eapen, Decision Options; Matthews, Boeing; Vardan, ROG, ex General Motors).
>
>   c. Currently, corporations are tracking performance in excruciating detail on a virtually real-time basis, but not within a strategic context. "We were looking in the rear view mirror. Now we can see through the floorboard. But we still need to look through the windshield" (Audience, Thursday Panel Discussion, 2004 RO Conference: Antikarov, Monitor Group; Brosch, Boston Consulting; Eapen, Decision Options; Matthews, Boeing; Vardan, ROG, ex General Motors).
>
>   d. ROAn needs to be positioned within the context of normal capital budgeting language, such as IRR and PBP (Alesii, Presenter, 2004 RO Conference).
>
> 2. There are "quality of data" issues with which to contend.
>
> 3. Valuation of the underlying asset is extremely difficult.
>
>   a. It is difficult or impossible to replicate the underlying asset for real options analysis by using a market portfolio (Myers, Keynote, 2004 RO Conference).
>
>   b. It is difficult to develop appropriate estimates of the net present value of cash flows of the underlying assets. Examples: Assets that currently produces little or no cash flow; the changing nature of an organization's

c. It is difficult to develop an appropriate and defensible rate by which to discount the expected cash flows of the underlying asset for the base case. This requires subjective assessment of various risk factors (maturity risk, inflation risk, size risk, non-marketability risk, and so forth) and invites massaging to suitable levels (Myers, Keynote, 2004 RO Conference; Mun, 2002; Nelson, 2004).

4. Capturing the volatility (risk) of projects is extremely difficult. For example, the risk profiles for the organization and project or asset may differ from each other and also from original estimates over time.

5. It is difficult to determine how to modify traditional theoretical assumptions to fit real options settings and/or fit real options analysis to traditional theoretical assumptions.

   a. The underlying assets of real options do not follow prescribed stochastic processes required for options theory to operate, making discrete event simulation more appropriate.

   b. The theoretical assumptions fundamental to portfolio and options theory are all violated by real options – marketability, tradability, infinite borrowing and lending, no taxes, no transaction costs, a perfectly risk-free asset, a hedge-able and arbitrage-free portfolio."

One theoretical development, "real options *in* engineering systems," has allowed us to move away from linear, path-dependent, and deterministic models and address some of these weaknesses. Real options *in* engineering systems offers a way to model not just investment choices at the macro level but investment design at the micro level. It is this area of real options theory and practice that provides a foundation for new thought regarding the capital markets at a systems level.

To pursue this thesis, I will retrace our path through capital market theory as presented in Sections III and IV and demonstrate areas in which ROiES can make a contribution. In addition, I will introduce a new source of data and new definition of risk that I suggest are better suited to our task than what is currently available.

<u>Quantitative Foundations of Next Generation Finance</u>

Preface. "Economists really do not have a choice as to whether they will use equilibrium concepts. The notion of equilibrium is as indispensable a tool of analysis as it is a pervasive one. Indeed, "there is no means of studying the complex phenomena of action other than first to abstract it from change altogether.' . . . The lack of 'realism' of a concept is not a sufficient argument against its use. In fact, the abstraction involved in all thinking is quite incompatible with a high degree of 'realism.' What matters, though, is whether the conceptual apparatus is adequate for its assigned task." (Rizzo et al, 1979: **2**) Current equilibrium models have ceased to be adequate for their assigned tasks.

ROiES. Real options *in* economic systems begins with a notion of dynamic equilibrium. It has to contend with the same set of "garbage in – garbage out" data issues and human fallacies and biases as all other models. What is appealing about its approach is that it incorporates the flexibility of the real options problem structure into a three-stage "design" space endogenous to the system under consideration. In this way, the analyst can use his imagination and logic to sort through large sets of path-dependent variables to identify those most relevant and useful to the system. The following describes ROiES and this three-stage methodology. (von Helfenstein, 2008: **18-21**)

> First, the distinction between real options "on" systems (as traditionally computed) and real options "in" systems must be understood. Real options "on" systems "treat the technology as a black box," i.e. offer no consideration of or insight into the inner workings of the systems/projects they are valuing. [Wang, 2005: 106] Real options "in" systems consider the inner workings of system/project design to identify and provide flexibility (i.e., options) from the inside out.

The reason why real options "in" projects are of special interest to the study of engineering systems is that large-scale engineering projects share three major features that are particularly amenable to real options analysis. "They:

- Last a long time, which means they need to be designed with the demands of a distant future in mind;

- Often exhibit economies of scale, which motivates particularly large construction;

- Yet have highly uncertain future requirements, since forecasts of the distant future are typically wrong.

"This context defines the desirability of creating designs that can be easily adjusted over time to meet the actual needs as they develop." [Roos, 2004 in Wang, 2005: 107] Only some form of real options analysis could capture and quantify the flexibility required by such systems.

The top layer of Wang's approach is a screening model that answers the question: Which of the many options that present themselves in an engineering system are "most important and justify the resources for further study? The engineering system he uses as his test case is a dam building (i.e., water resources planning) project.

"The screening model is established to screen out the most important variables and interesting real options (flexibility). The screening model is a simplified, conceptual, low-fidelity model for the system. Without losing the most important issues, it can be easily run many times to explore an issue, while the full, complete high-fidelity model is hard to establish and costly to run many times. From another perspective . . . we can think of it as the first step of a process to reduce the design space of the system." [Wang, 2005: 138] The screening model involves simplifying assumptions such as allowing all sub-projects to be built at once and removing the stochasticity from all variables being explored (in this case, water flow and the price of electricity). If an important aspect of the project has been simplified in this manner, it should be studied in depth later, after the screening model is complete. In cases in which feedback exists in the system, the screening model must take it into account in order to ensure accurate results.

The screening model uses non-linear programming to perform sensitivity analysis on key system parameters. Once optimal designs have been identified for each set of parameters, they are reviewed and compared for real options that are both "good" for all sets and also conducive to optimal value creation.

The next layer in the overall model is a high-fidelity simulation model, through which the selected candidate designs are put. "Its main purpose is to examine, under technical and economic uncertainties, the robustness and reliability of the designs, as well as their expected benefits. . . . This process leads to refinement of the designs identified by the screening model." [Wang, 2005: 140] Standard water resource planning simulations use historical records to simulate stochastic variation in water flows. Wang's model simulates both water flow and economic uncertainties in order to fully understand the role economies of scale should play, or not play, in the final design.

Once the most promising real options in the project design have been identified, these options must be valued so that a primary strategy and related contingent strategies may be set. Wang suggests "recasting [a standard binomial lattice] in the form of a stochastic mixed-integer programming model [in which the binomial tree is maximized] subject to constraints consisting of 0-1 integer variables representing the exercise of the options (=0 if not exercised, =1 if exercised." [Wang, 2005: 141, 142] "[S]uch reformulation empowers analysis of complex path-dependent real options 'in' projects for engineering systems.

"Technical constraints in the screening model are modified in the real options timing model. Since the screening and simulation models have identified the configuration of design parameters, these are no longer treated as design variables. On the other hand, the timing model relaxes the assumption of the screening model that the projects are built together all at once. It decides the possible sequence of the construction of each project in the most satisfactory designs for the actual evolution of the uncertain future." [Wang, 2005: 152]

To assist those readers who do not have an expertise in the kinds of programming used in this analysis, Wang provides the following descriptions: "Mathematical programming studies the mathematical properties of maximizing or minimizing problems, formulates real world problems using mathematical terms, develops and implements algorithms to solve the problems. Sometimes mathematical programming is mentioned as optimization or operations research. . . . Stochastic programming is the method for modeling optimization problems that involve uncertainty. . . . In stochastic programming, some data are random, whereas various parts of the problem can be modeled as linear, non-linear, or dynamic programming. . . . A mixed integer programming problem is the same as the linear or non-linear problem except that some of the variables are restricted to take integer values while other variables are continuous." [Wang, 2005: 39, 40, 41, 42] One deficiency of stochastic mixed-integer programming is that it is difficult to tell if the result is a global or a local optimum. However, Wang maintains that the solution provided by this computational methodology, while it may be a local rather than a global one, is superior to the solutions offered by traditional methodologies or human intuition. In addition, once the problem is programmed, it can be executed easily and rapidly on an ordinary laptop computer.

Rather than using increasingly complex mathematical models to attempt to capture system complexity and path dependencies, this approach suggests using sophisticated computer modeling techniques to simplify the design space throughout the analysis process, making it more transparent with each successive layer. In addition, this approach does not tie system analysis and design to specific stochastic models but allows for flexibility. If we accept the assumption that engineering systems and economic systems have much in common and are therefore mutually amenable to this approach, it appears that some or all of the quantitative shortcomings that plague modern capital market theory and practice could be overcome. The basic structure of these theories might remain the same, but the assumptions, modeling, and insights would take place very differently.

Suggested improvements to data inputs for ROiES, and a new look at risk. During a project focused on bringing capital market concepts to the "market" of network-centric warfare, it became clear that complexity theory could be applied to finance in a way that would provide more transparency regarding the value of organizational processes, intangible and knowledge assets, and the organization itself. Since these data and related analyses could be developed from within (i.e., endogenous to) the organization, rather than by reference to exogenous entities and forces, I called it sub-corporate finance.

Concepts of sub-corporate finance are still in their infancy. Its core proposition was developed in the early 1990s by Dr. Valery Kanevsky (mathematics) and Dr. Tom Housel (computer science) to solve a practical problem in valuation, e.g. the inability to assign "value," or benefit streams, to processes within the organizational structure, making organization design and process reengineering difficult or impossible. Simplistically, the core proposition states:

1. Organizational human capital and information technology take inputs and change them into outputs through core processes. The "value" added to the organization by core processes is proportionate to the amount of change required to produce process outputs. Therefore, if we can identify a common unit of measure by which to count the amount of change required to produce process outputs we will also be able to quantify the "value" added to the organization by process outputs by assigning benefit streams to such units.

2. Complexity theory establishes a relationship of proportionality between units of change, units of complexity, and information bits. Since information bits can theoretically be

observed and counted, we can use bits or their reasonable proxy as the common unit by which to measure the change required to produce process outputs.

While the details of how these units of change are determined are not pertinent to this paper and while operationalization of the core concepts has never been successfully achieved, the data required to perform sub-corporate valuations is abundant and readily accessible. This makes the insights provided by extending the core proposition into the structure of sub-corporate finance both worth understanding and amenable to empirical testing. Sub-corporate finance allows us to propose certain important revisions to modern portfolio theory that may assist in resolving the previously stated problems.

<u>Risk, uncertainty, and returns</u>. Ludwig von Mises states, “Human action is purposeful behavior. Or we may say: Action is will put into operation and transformed into an agency, is aiming at ends and goals, is the ego’s meaningful response to stimuli and to the conditions of its environment, is a person’s conscious adjustment to the state of the universe that determines his life.” (von Mises, 1949: **11**) Another way of stating this is that the universal activity of humans is changing “inputs” into “outputs.” This is true of investing as well as all other human activities.

Complexity theory indicates that change creates Kolmogorov Complexity (and its equivalent, information), where Kolmogorov Complexity is the “universal product,” a universal measure of changes in the form of matter, and a universal property of matter as well (Housel and Kanevsky, 1998).

Entropy is the term that describes the reduction of energy to a state of maximum disorder in which each individual movement (activity) is neutralized by statistical laws. Left to itself, an isolated system tends toward a state of maximum disorder, i.e. higher probability. Boltzmann stated, “In an isolated system, the system will evolve to its most probable state, that is, the one with the most homogeneous probability distribution," (e.g. the Law of Large Numbers). In a state of homogeneity (or, highest entropy or uncertainty), we have no indication at all to assume that one state is more probable than another.

Information is a probabilistic measure of reduction in uncertainty (entropy). The following formula, developed by Claude Shannon, expresses the probabilistic relationship between entropy and information, for all possible states 1 . . . *n* :

$$\mathrm{H}(x) = -\sum_{i=1}^{n} p(i)\log_2 p(i)$$

Where:

H = Entropy

x = A discrete random event

p = Probability distribution

i = Outcome

H is maximized if all states are equi-probable (a state of homogeneity), since when there is no pattern, there is no information and entropy and information are opposites. H is 0 if $p(i) = 1$, since the system is in a state of maximum certainty or complete information.

Randomness, entropy, probability, and uncertainty are equivalent terms. Their opposites are pattern, complexity, information, and certainty which are also equivalent terms.

Since the most basic activity of humans, technology, organizations, and industries is change, economic systems of all kinds can be viewed as open systems that can: (1) Exchange raw inputs (substance, information, or energy) with the environment; and (2) change the structure of raw inputs into outputs (final products/services). This structural change is described in terms of the way process "*P*" structures input "*a*" to be output "*b*." It creates a series of proportionalities in which the ΔE (change in entropy, uncertainty) ≈ $K(y|x)$ (conditional Kolmogorov complexity) ≈ bits ≈ common units of process change.

Sub-corporate finance chooses to define "common units of process change" in terms of the knowledge assets of the company and notates them K_μ. The K_μ related to *P* are the "value" added by *P* and, because they are common to all processes in all organizations, they can be monetized.

In investing activities, we could call process *P* a "transaction" that structures input *Asset A* into output *Asset B*. The structural change that occurs during a transaction (*T*) involves a change in uncertainty (entropy, Kolmogorov complexity) as *Asset A* undergoes a state transformation to become *Asset B*. The monetization of this change in uncertainty from *Asset A* to A*sset B* is what we commonly call "return on investment." It is also the "value" added by *T*.

If we look at traditional concepts of risk and return from the perspective of complexity theory, *risk* is no longer equivalent to uncertainty. It becomes a descriptor for the *change in uncertainty* ($\Delta\Phi$) related to the state transformation of *Asset A* into *Asset B* via *T*. As such, it is a rate and is composed of two elements: (1) *volatility*, the magnitude of change in uncertainty; and (2) *growth, or, drift*, the direction of change in uncertainty. Using this way of thinking, an "expected return" (i.e., expected $\Delta\Phi$) for the state transformation of *Asset A* into *Asset B* via *T* becomes the benchmark against which to assess and match risk (i.e., actual $\Delta\Phi$).

This decoupling of risk and uncertainty is helpful because it makes sense out of what we already know about them, e.g. that the band of uncertainty (probability, randomness) regarding *T* outcomes increases over time, while the level of risk estimated for the underlying asset may remain the same throughout the period.

If we apply the proportionalities we just described, and we agree that risk is the actual change in uncertainty ($\Delta\Phi$), risk and K_μ are also proportionate to each other. This implies that measuring the process outputs of the organization in common units, K_μ, is equivalent to measuring the risk of the organization, linking risk measurement *directly* to the knowledge assets of the organization. Extending this thought further may provide beneficial insights into organizational value, perhaps relieving us of dependence on educated guesswork using exogenous benchmarks and variables.

It might also more properly represent the reasoning of investors in the markets. It has always been puzzling that traditional finance focuses on risk aversion as the key attribute of investors when the real world seems to indicate quite the opposite. If risk aversion were the primary or only motivation of investors, there would be no disequilibrium, no reason for so many investment products to exist, no bubbles, no entrepreneurial or arbitrage profits to be made – perhaps no markets. If, on the other hand, risk is viewed as a change in uncertainty (not the uncertainty itself) and return is the expected (estimated) change in uncertainty between *Asset A* the investor holds today and the one he anticipates having in the future, three things might result.

1. The investor's feelings about real risk (not the phony laboratory type that involves nickels and dimes) might be influenced by his sense of his own ability to assess such change in uncertainty, since he can apply his reason, logic, and "street smarts" to incremental change more comfortably than he can to the "risk" related to an entire organization, set of organizations, or system. Risk as a change in uncertainty might appear less threatening. It would certainly have more resemblance to options thinking and to the way trading is actually done.

2. At the same time, the notion of a large expected change in uncertainty (return) provides human nature with the excitement of the chase, whether buyer or seller. Yet, because this large change is incremental and not a change to whole organizations or system, it feels manageable, perhaps even prudently undertaken – a horse one could ride.

3. “Epistemic arrogance” and reflexivity could justifiably take over because the investor is assessing and acting upon incremental changes, not absolute ones. Bubbles and busts could be more comfortably explained based upon concepts of investor imagination about the rewards related to incremental change becoming overheated and self-influencing.

Finally, if this change in uncertainty, both actual and expected, could be linked to a common unit of measure endogenous to the firm and substantially comparable across all firms that could be monetized to reveal the value added by a transaction, investors might continue to trade the same way but reduce their margin of error. Whether this would enhance profit-making or make it more difficult is not clear.

At the quantitative level, we conclude that if we could populate a ROiES model with better quality data that was abundant, accessible, and tied risk to the “genes” of the firm, we might have some interesting and helpful avenues from which to improve the theory and function of the capital markets.

Concepts of the Markets and Next Generation Capital Market Theory

What are markets? Capital market theory and classical economics treat “the Market” as a closed system, perfectly efficient and complete. All the information available about its parts exists everywhere within it. All of its parts are in equilibrium or near-equilibrium and they are fully diversified, meaning that all of their risk-creating actions or interactions cancel each other out. The only risk that remains is that which happens to “the Market” itself, i.e. systematic risk. Though not clearly defined in the literature, it appears that systematic risk is produced primarily by the actions of governments and regulators, who are actors/agents within “the Market.” Systematic risk takes the form of inflation, budget deficits and the like.

These constructs seem to be based on several misconceptions: 1) "the Market" is not itself capable of effecting change of any kind or creating or adding value. That is the job of the many agents within it; 2) while government and regulatory actions affect all Market agents, these should be effectively cancelled out by diversification, e.g., how one agent manages the effects of systematic risk will cancel out how another agent manages it. If this is the case, systematic risk, as we know it, disappears.

In addition, if we describe closed systems using complexity theory, "the Market" will be steadily moving toward a state of complete probability (uncertainty) or homogeneity, in which all agents and their actions and interactions will be equally probable, no information will be available by which to make choices, and risk (i.e., $\Delta\Phi$) will reach 0%. Under such conditions, "the Market" would stagnate and die.

Since reality indicates that there is no such thing as an absolute "Market" and that markets are not closed systems, we might re-define a market as: *An open, complex, adaptive economic system at a global, national, industry, or organizational level that facilitates the dynamic, continuous exchange of goods, services, and information among and between agents within the system, based on valuations performed and choices made by these agents that are expressed in a variety of units of exchange but measured in units of currency.*

Such a market is filled with information and unsystematic risks (i.e., $\Delta\Phi$). Such risks do not cancel each other out. Instead, they exhibit a kind of homeostasis. Pockets of undiversified or undiversifiable $\Delta\Phi$ create profit opportunities. The actions and interactions of governments and regulators become just one more form of risk, not the entire risk of the system. Government/regulatory risk would be generally mundane and involve a low $\Delta\Phi$. While it would affects all agents within the market, it is slow taking effect and can usually be planned for far in advance. Thus, various agents absorb it as part of their total risk profile, their "cost of doing business." Since they will probably pass it along to consumers and clients, it does not need to be compensated.

Dying firms, new entrepreneurial entrants, and acts of God (such as September 11 and the 2008 financial disaster) change the structure of the markets regularly.

Capital markets and investor assumptions. Next generation capital markets are not efficient. They exhibit noise, data smog, information asymmetry, high costs of obtaining critical information, and reflexivity. Information is not always timely (i.e. the Bernard Madoff scandal) and while trades may be executed rapidly, creating the appearance of liquidity, trading may have more to do with profit-taking than the values of the underlying assets. With the growth of derivatives and other complex investment vehicles, investors may not always be certain of the intrinsic value of their investments. Their goals may, thus, be more tightly linked to profit-taking than to acquiring valuable assets or avoiding risk. Reflexivity and other fallacies may cause asset mispricing, bubbles, and eventual market repricing. Diversification by adding increasing levels of risk via increasingly risky assets may not cancel out risk at all because the kinds of risks being added may augment rather than mitigate each other. Statistical correlation may not be adequate to demonstrate this augmentation properly or at all.

Next generation portfolio theory/capital market theory and the valuation of assets. Changing our views of markets, the composition of risk and reward, and investor attributes will, or should, have a profound effect on how we view and use financial theory and perform valuations. The following are two examples of possible effects, in which we may:

1. Redefine the "risk-free" rate, thereby making it more informative: Currently, capital market theory states that "[A]ny contingent claim on an asset, whether traded or not, can be

priced in a world with systematic risk by replacing its actual growth rate with a certainty equivalent rate, by simply subtracting a risk premium that would be appropriate in market equilibrium and then behaving as if the world were risk-neutral. Intuitively, since in a risk-neutral world all assets would be expected to earn just the risk-free return (i.e., risk premia would not be offered), equilibrium expected growth rates would therefore be less in the risk-neutral world than they actually are in our risk-averse world" (Trigeorgis, 1996: **103**).

However, if we assume that the complexity theoretic view of risk as a change in uncertainty is meaningful, then a risk-neutral world, in which only the risk-free return is earned, is one in which no $\Delta\Phi$, no structural state transformation, occurs and no value is being added by transactions. Thus, the risk-free rate would quantify a static state in which agents of change (investors) were indifferent to the level of value added (uncertainty resolved) during state transformations. This appears to be a remote fit with reality.

A simple change in definition could resolve this. A "risk-free" rate of return could be described as a benchmark value for *certainty-equivalent risk*. Like the "risk-free" rates we currently use, benchmarks for certainty-equivalent risk can be chosen from data that have been observed to be 99% certain over a prescribed period of time. The new definition will remind us that risk has not "disappeared" but that uncertainty is low and will exhibit little change during state transformations. Under this definition, if government securities prove to be more risky than we imagined, we might chose another benchmark for certainty-equivalent risk that was more appropriate. We would not necessarily continue to have to link a baseline risk premium with an infinite ability to tax and "manage" the economy.

2. Redefine β, thereby making it more informative and useful. Currently, beta indicates how sensitive a particular company's equity price is to a 1% change in the average equity price

of the market portfolio. Since modern portfolio theory claims that a company's unsystematic (company-specific) risk can be diversified away, beta represents only the effects of systematic risk.

If, however, the effect of full diversification of the market portfolio is to create a proxy for a meta-firm that is the average of all the firms in the portfolio, then, since betas are different for all companies, the attributes that cause the $\Delta\Phi$ for a single company to differ from the meta-firm $\Delta\Phi$ must, logically, be unique to that company. Pooled risk (i.e., systematic risk) that affects the meta-firm would not produce unique betas for portfolio companies.

This, in turn, indicates that beta might capture the effect of a company's *intangible assets (uniqueness)* on its performance, rather than that of government or the meta-firm. In a universe in which investors were profit-seeking as well as risk-averting and could pass the cost of systematic risk on to customers, the only risk for which they would expect to be compensated would be the risk unique to each specific investment. Unique or company-specific risk creates disequilibrium and profit opportunities. Systematic risk simply creates cost.

While beta is difficult to develop as it is now defined and calculated, ROiES appears to have the capacity to capture and estimate beta in some interesting new ways. This might provide not only better quality, more consistent betas than we have now, but also provide us with valuable insights into the effects of company intangible assets (uniqueness) and a practical way of including those in cost of capital estimations.

The role of time in next generation models

If ROiES were to be used to create next generation models for markets, portfolio management, and even cost of capital estimates, the capabilities of the suggested programming tools would allow for a richer investigation into and representation of the effects of time on value. This, alone, would be a significant contribution to market valuations and portfolio management.

The Obstacle of Computational Complexity

As stated in "Love, Death and Taxes: Applications of Real Options "in" Economic Systems," computational complexity is a very real obstacle to the further exploration and utilization of the proposed model for ROiES.

"The question we must ask ourselves again is whether it is preferable to make increasingly complex, sequential, and subjective adjustments to various traditional model variables in order to attempt to capture market, portfolio, and firm complexity or to explore and build complex computational models that can be run on an average laptop computer and embed the ability to investigate the effects of all variables simultaneously. The former eventually leads us so deeply into a maze of informed professional judgment that we lose all sense of reality concerning the specific economic system we are creating or evaluating. The latter, while requiring the use of informed professional judgment in structuring the rules by which the programming models are built, might allow us to explore large design/valuation spaces while minimizing the role of subjectivity and/or speculation.

"Simple, deterministic computations built on convoluted estimates and opinions, or complex, dynamic computations built on simple rules and judgment calls? That may be the choice facing us in this matter." (von Helfenstein, 2008: **XX**)

VI. Where do we go from here and why does it matter?

ROiES could provide a way of thinking and a method of quantitative analysis that could change how we build portfolios, invest, create investment vehicles, assess the value of investments. It is not a "magic" bullet, any more than real options *on* projects is. Its use involves a willingness to rethink market relationships at a fundamental level and step out of comfort zones. We would be required to consider the influence of time, imagination, intangible assets and synergies in our valuations and our choice-making.

The exciting part is that ROiES appears to be up to the task, where familiar theory, approaches and methods have us locked into a closed, linear, deterministic, time-free box. ROiES is already being successfully used to design airports. Airports are as complex an engineering system and microcosmic economic system as can be imagined. They include the intrusive effects of government/regulatory risk as well. This indicates that ROiES is already considering the kinds of variables and path-dependencies that characterize the financial markets and the firm.

There may be other theoretical and mathematical models and approaches that would work as well. However, real options analysis is one that so nicely configures with the way human beings think about the world. This, alone, puts ROiES far in advance of approaches that require highly specialized education and training.

Utilizing data from deep within the economic system of the firm, grounded in its intangible assets, and thinking of risk in a new way might also beneficially enhance the use of ROiES.

What needs to be done? 1. A great deal of rigorous empirical research must be done. There is an abundance of data at all levels of the economic systems that must be investigate and analyzed. 2. The real options frameworks by which to structure the problem must be developed, along with any new theory necessary to support it. 3. Programming models need to be built. The level of programming sophistication available in our great universities and on “The Street” is enormous. So, the talent is there.

Why does it matter? As a part of the research underlying this paper, I investigated two extreme edges of the global economic system: a) the causes and proposed cures of poverty in the developing world; and, b) the causes of the collapse of complex societies throughout history.

There are markets in the developing world, and entrepreneurs seeking profits at the micro level. So much entrepreneurial potential and underground wealth remains unlocked. Yet, it seems as though the society and economic systems that have provided the basis for the greatest wellbeing for the broadest citizenry in history are about to collapse. Tragic irony.

For a century or more, the West has tried its own formulas on developing nations. Those formulas have been based on concepts of equilibrium, classical economics, and financial theory that do not fit the cultures, complexity, chaos, and dynamism of the hidden markets in these nations. Our policies, our theories, and our money have not worked there, and no longer seem to be working at home.

We must step outside of our comfortable paradigms to listen and learn. While real options analysis is just a humble tool to be used in the service of commerce, it is also a tool that requires listening and learning, a different way of approaching familiar problems. ROiES was developed with an eye toward what it calls "social stochasticity," or the social effects of engineering projects. Why could its application to economic systems not only help restructure economic/capital market theory in the developed world to make it more sustainable but also provide a tool to help unlock the mystery of capital for marginalized people elsewhere?

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