

# REAL OPTIONS “IN” ECONOMIC SYSTEMS: EXPLORING SYSTEMIC DISTURBANCE CAUSES AND CURES<sup>☆</sup>

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## ABSTRACT

*As global economic systems become increasingly more complex and dynamic and the universal language of historical accounting is being profoundly altered, the theory and tools we use in neo-classical economics, traditional finance, and valuation are beginning to prove inadequate to the tasks being required of them. Hence, there is a need to consider new avenues of thought and new tools. In this conceptual chapter, I explore the use of real options “in” engineering systems design as a means to achieve more rigorous and insightful results in the design and valuation of economic systems, particularly that of the firm. In the process, I gain further insight into the causes and cures for systemic disturbances generated by the presence and selection of real options in economic systems.*

<sup>☆</sup>This work is a tribute to Dr. Richard de Neufville, whose seminal contributions to his and our fields provide new avenues for theoretical exploration and critical problem-solving.

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Globalization of financial markets is a trend that is often discussed but rarely quantified. The growth of cross-border capital flows—or the value of purchases and sales of financial assets by investors from different countries—is one vivid illustration of financial globalization at work ... The growth of capital flows is having a profound impact on financial markets and economies around the world. Much attention has focused on the risks that cross-border investments create – such as the ‘hot’ money that can surge into a country suddenly and rush out just as fast, leaving financial ruin in its wake. More recently, concern has grown as increasingly powerful state investors from Asia and oil-exporting nations buy ever-larger investments in US, European, and other markets ... Since 1990, global capital flows have grown faster than the value of world trade, world GDP, or the world’s financial assets ... The growth of large, sophisticated institutional investors and other new financial intermediaries has ... contributed to the rise in cross-border capital flows. These investors – more than individuals – seek investment opportunities globally. In 2006, McKinsey Global Institute (MGI) estimates that pension funds, mutual funds, and insurance companies around the world had \$59.4 trillion in assets under management, nearly triple their size in 1995. Over the past five years, hedge funds and private-equity firms have also tripled in size, reaching \$2.2 trillion in assets under management by the end of 2006. Farrell et al. (2008, pp. 43–44)

## 1. INTRODUCTION

The prior passage from the McKinsey Global Institute fourth annual report on global capital markets is but a single example of the ever-increasing complexity, interdependency, and riskiness of early 21st century economic systems. 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, and deterministic design space from neo-classical economics and traditional 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.

This conceptual chapter discusses a number of the challenges generated by the increasing scope and pace of change. First, it suggests more realistic definitions of economic systems and the firm as an economic system. It then provides several examples of the effects of the existence and exercise of real options within economic systems. Several approaches to firm organizational design and valuation are described, with a focus on using applications of real options “in” engineering systems as the possible solution to the difficulties inherent in these processes. It concludes by discussing the

relevance of real options “in” economic systems to systemic disturbances and suggests avenues for future research.

## 2. PROBLEM STATEMENT

Modern economic systems are experiencing exponential growth in complexity, interdependence, and risk, as well as equally diminishing transparency. The events creating such dramatic shifts in the environment have been broadly discussed and analyzed by a range of stakeholders. But effective solutions do not yet exist because a paradigm shift is required to identify and develop them.

Instead of concentrating on the problems created by the current linear, deterministic paradigm promoted by neo-classical economics and traditional finance, the financial regulators have recently added fuel to a burning platform by moving financial accounting away from its historical transaction basis (i.e., cost and cash) toward a prospective valuation basis (i.e., estimates and opinion). This imposes upon economic systems, at all levels, a potential Tower of Babel effect in which agents within these systems no longer speak a common language, while appearing to use a common unit of measure.

Assuming that the direction and pace of change cannot be altered, economics, finance, and valuation will have to develop better theory and tools to accomplish the mandates set before them. Real options analysis may offer a solution. A detailed discussion of this problem statement follows.

### *2.1. Financial Accounting is on Trial*

Basic financial accounting is structured on a set of generally useful rules by which all agents within economic systems can describe themselves, their net resources, and their activities in a common language. This common language enables transactions to take place at all levels in the markets on a reasonably level playing field. It provides for the exchange of more or less complete information between parties. It provides the base on which strategic planning and competitive games can be designed and implemented. While the taxing and other regulatory authorities have introduced high levels of complexity into basic accounting systems, it is accounting systems that allow them to set their “handicaps” (game restrictions) and fund their activities. Current financial accounting rules are complicated but workable because, in the end, every agent resource and activity can be traced back

to cash, the fundamental unit and common denominator of real-world exchange.

Although financial accounting serves a critical purpose that cannot be eliminated or replaced, dynamic shifts at the meta-system, system, and sub-system level have created communication issues regarding the effects of such changes on both systems and agents. As financial accounting is the common language for business resources and activities, it has got routinely criticized for not measuring up to the challenges in the environment, for not being able to represent the intangible and the esoteric in a universally accepted way. While no one has asked if any other discipline could do better, accounting regulators worldwide have made the decision to opt for “relevance” over “reliability” and invented a new discipline, Fair Value Accounting, codified in November 2007 in Statement of Financial Accounting Standards No. 157 (SFAS 157), “Fair Value Measurement.”

To those not interested or embroiled in accounting or valuation, it seems an innocuous move. Many in the finance community have welcomed it as an improvement over the “dinosaur” of historical cost basis accounting. Whether we know or care about SFAS 157, it is about to change all worlds. In effect, it has altered the foundational language of economic systems radically, in favor of constructed markets and hypothetical events built on valuation principals, rather than real-world ones based in actual transactions. While for years valuation professionals and in-house corporate finance teams have grappled with how to assign values to specific firm resources and projects without ignoring the other resources and projects that contribute to such values, this problem was primarily confined to the context of business acquisitions and certain types of business entities. The new Fair Value standard subjects the entire balance sheet (and income statement) of all firms to such treatment on an ongoing basis, effectively disaggregating the firm.

As the contents of financial reports flow back into the markets as information on which real-world decisions are made at every level, Fair Value accounting and reporting will create significant and unforeseen effects on the state of the system. New approaches to collecting and analyzing market and firm data will be required to manage the introduction of increased levels of subjectivity into these data. A painful example of this is the “mark-to-market” accounting rule that replaces historical asset costs with current valuations on the balance sheet. “Mark-to-market” has been credited with greatly exacerbating the financial collapse of 2008, on both the upward and the downward paths of the real estate bubble.

The following is an abbreviated list of system shifts that have caused so much frustration to be directed at financial accounting.

*2.1.1. The “Discovery” and 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, financial accounting faces a dilemma. It has to devise methods of measuring and recording the influence of such assets on the organization and its benefit streams (i.e., outputs). Yet, most of these assets are neither separable nor transferable, two attributes necessary for resource measurement, management, and exchange.

*2.1.2. 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 require an increasingly broad range of organizational and transaction structures, many of which are highly complex. Financial accounting has been asked to address such complexity in meaningful and accurate ways.

*2.1.3. The Exponential Increase in Market and Transaction Complexity*

Increasingly sophisticated investment vehicles, enhanced computer-based trading and desktop trading, 24 × 7 markets, global currency flows, Internet collaboration, consolidating exchanges, and exchanges that operate as public companies all feed on and generate financial information on a real-time basis. It has become increasingly difficult to trace cash and value from the inception of a transaction to its final reflection in financial statements. Financial accounting is being asked to incorporate high levels of complexity and speed into procedures and processes that were designed for lower levels of both.

*2.1.4. 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. Tax rules continue to burgeon, constantly threatening organizational viability. Financial accounting must keep pace with the constant turbulence.

*2.2. Financial Valuation, Yesterday’s Red-Headed Stepchild, has Become Today’s Darling as We Attempt to Quantify and Resolve Such Issues. But is She Ready?*

Financial valuation, an esoteric hybrid of all business disciplines, is currently practiced in a linear, deterministic, but prospective, manner with

varying degrees of rigor. There are many theoretical and practical issues on which no two valuation analysts fully agree. For this field, governed by informed professional judgment, beauty is truly in the eyes of the beholder. SFAS 157 institutes financial valuation as the arbiter of value for the net resources, and related benefit streams, of the firm for financial reporting purposes. Yet, financial valuation has its own set of disabilities that have not been resolved. Two such disabilities follow.

*2.2.1. Traditional Valuation Approaches no Longer Suffice to Capture the Complex Realities of Dynamic Economic Systems*

These same approaches will also be inadequate to meet the demands of fair value accounting. If we have no means by which to measure resources and activities in dynamic systems, we may not be able to manage them either. This will introduce more randomness and higher risk into the system.

*2.2.2. Non-Linear Valuation Approaches, Such As Real Options Analysis, Contain Complexities, and Challenges that are Beyond the Average Practitioner*

Some of these challenges are: difficulties in developing fundamental inputs for the models; difficulties of creating consistent structure and repeatability of real options problems and solutions; a low level of computational transparency for average users; and no standardized methods for checking projected results against actual ones. What makes the post-SFAS 157 world different is that these same challenges will now inhere in all aspects of accounting, a non-finance discipline. This, in turn, will ensure that a high degree of subjectivity and complexity will become embedded in both financial reporting and market prices, leading to decreased capacity for rational decision-making by system agents.

*2.3. There is Increased Potential of Unforeseen and Unforeseeable Disturbances and Random Acts of Violence that Disrupt Economic Systems on a Global Scale*

Dr. Nassim Taleb calls these random events “black swans” and suggests that there is “an ingrained tendency in humans to underestimate outliers ... Left to our own devices, we tend to think that what happens every decade in fact only happens once every century, and, furthermore, that we know what’s going on” (Taleb, 2007, p. 141).

#### *2.4. Increased Complexity and Turbulence Create Increased, and Different, Sources of Risk, as Well as New Sets of Questions*

Can modern economic systems afford to view risk and complexity in the traditional way? Should financial reporting more explicitly reflect the complexity and risk inherent in organizational resources and activities? Do we need better methods of describing both the state of the system and the economic systems functioning within it? Do modern economic systems actually function in the ways that are commonly described in the traditional literature and financial reporting? If they do not, how should we describe them? These are just a few of the issues that arise from the scale and scope of change within the global economic environment.

### **3. REVIEW OF THE RELEVANT LITERATURE**

The fundamental research for this chapter takes an eclectic approach, drawing on academic research, academic books, practitioner manuals, and papers; Financial Accounting Standards Board pronouncements; the popular press; and insider tips from “The Street.” Readings cross various disciplines such as economics, valuation, real options analysis and risk management, physics and complexity science. I sought to (a) explore the manner in which various agents within global economic systems describe, structure, leverage, and create/harvest value from increasingly complex and risky systems; (b) identify what appear to be the most powerful and genuinely useful approaches to solving the stated problems. As the scope of the research was substantial, only those readings that are directly applicable to the focus of this chapter have been used herein.

#### *3.1. Overview of Findings*

Research findings are as widely varied as the readings themselves. Overall, we discover that economies, markets, and firms are systems that undergo significant disturbances generated by endogenous optionality that is either not recognized (causing inadequate decision-making), not understood (causing short-sighted or disingenuous decision-making), or not measured from the correct paradigmatic base (causing model and system failure).

At the level of national/international economic systems and markets, we find that the Austrian School of Economics provides a theoretical structure more amenable to reality than that offered by neo-classical economics. At the levels of the firm and of field practice, we find that quantitative approaches to measuring and managing firm and market economic systems seem to pursue three general directions: (1) build complex models to describe and manage increasing complexity; (2) build simplified models to describe and manage increasing complexity; and (3) build layered models that reduce complexity as they progress through a sequence. All of these practical approaches involve varying degrees of computational complexity and potential/actual “black boxes,” that is, lack of transparency. The remainder of this chapter further explores these findings.

## 4. ECONOMIC SYSTEMS

### *4.1. General Description*

Simplistically, economic systems come in many sizes and forms. They can be as large as the global marketplace, a national economy, an industry, or a firm. They can be as small as a family unit, although no smaller because any system requires more than one agent to exist. Similar to other systems, economic systems are governed by explicit and implicit rules that affect all agents within the system in varying ways. The kinds and combinations of rules governing a particular economic system classify it under monikers such as “capitalism,” “market,” “oligopoly,” or “start-up.” Discussion and management of economic systems requires consideration of “social stochasticity” (Wang, 2005, p. 38), that is, the social consequences and uncertainties surrounding agent decisions and initiatives.

Unlike the static, closed, equilibrium models propounded by neo-classical economics and traditional finance, real-world economic systems are open, complex, and adaptive – living. If they are not, they may be kept on life support, but eventually they will die (as in the demise of the Iron Curtain) or rupture open in an unmanageable chaos of birthing (as with the hyper-capitalism being born out of that closed system, the People’s Republic of China). Why? Because economic systems are created by and built upon open, complex, adaptive, living biological systems, called human beings, and life must beget life.

The very life-bearing properties of these systems, however, have created a dilemma. Until fairly recently, only limited means have been available to

describe them quantitatively without the use of highly simplified, linear, deterministic models. While much of this is due to a general absence of powerful yet accessible technological tools, most of it is due to the fact that it is just plain more direct and less time-consuming to think about and use deterministic models. A broad-brush approach has been considered sufficient for most decisions and transactions. In addition, until fairly recently, those guardians of national economic systems, the regulators, agreed. It appears that systemic disturbances leading to increasingly draconian oversight by these regulators may push theoreticians and practitioners in the financial disciplines to finally embrace approaches and methodologies that properly reflect the true nature of the economic systems they describe, measure, and manage. Real options analysis is one such approach.

#### *4.2. The Firm as an Economic System*

There are almost as many theories of the firm as there are researchers to build them. Such theories have been amply explored elsewhere and do not need re-examination. The goal here is to establish a solid foundation for the use of real options “in” the firm as an economic system. To accomplish this, we need to demonstrate that the inner life of the firm is open, dynamic, complex, and adaptive, that it resembles the economic system of a market in which risk and reward are critical determinants of value.

##### *4.2.1. The Inner Life of the Firm Resembles a Market System*

I suggest that the firm is a complex adaptive system, rather than just a portfolio of resources, options, rights, knowledge assets, or projects. The following description draws the parallel between the firm and what we know about market systems.

Firm core processes are market participants, or agents, and are dynamically combining and recombining into portfolios of capabilities, while also competing for scarce resources (capital, knowledge assets, and infrastructure). Each core process is made up of a portfolio of sub processes (e.g., “supply chain”) that enables it to carry out activities and produce outputs. Each core process is affected by the risk and uncertainty, the availability of resources, the property rights, the transaction costs, and the real investment options available to the firm and to other core processes within the firm.

The firm is more than the sum of its parts (processes), since these parts are constantly overlapping, competing, and shifting dynamically internally and externally as they interact with stakeholders and competitors. In addition, the firm and its agents

(processes) are characterized by change, uncertainty, and risk. Differences between exogenous markets and endogenous markets with regards to change, uncertainty and risk are a matter of degree not kind. It is arguable as to which market experiences a higher degree of change, uncertainty and risk.

The [firm] is created and maintained by various kinds of individual, institutional, and organizational investors and stakeholders ... Top management functions much like an investment fund or portfolio manager, deciding where to allocate scarce resources and add or divest investments that allow the firm to continue to function with varying degrees of health. Each core process has its own management team that also functions much like a portfolio manager. (Nelson, 2005, p. 39)

These characteristics of the endogenous market of the firm are virtually identical to those of the exogenous market. Thus, we may assume that the firm is an economic system with market attributes.

#### *4.2.2. As for All Market Systems, Risk and Reward are Key Determinants of Firm Value*

There are many commonly discussed and important sources of risk and reward to the firm. Some are exogenous and some endogenous to it. All must be considered when discussing corporate strategy, considering corporate projects or transactions, attempting to identify the key value drivers of a firm or value the firm itself, invest in it or close it down. The challenging and ever-changing nature of risk and its relationship to reward is perhaps the biggest source of discussion and debate in the boardroom, the halls of academia, the offices of practitioners, and on “The Street.” Measurement of risk and reward is a key component of assessing value. Yet, as the economic system of the firm becomes increasingly complex and sophisticated and path dependencies between sources of risk and reward increase, traditional measurement approaches and techniques have less and less appeal.

One possible solution comes from the fields of computer and complexity science and quantum physics. It has been named sub-corporate finance.

While attempting to resolve an intractable problem in process reengineering, Drs. Valery Kanevsky (mathematics) and Tom Housel (computer science), proposed that it is possible to describe all organizational outputs in terms of common units of change that can be linked to the knowledge assets of the firm (Housel & Kanevsky, 1995; Kanevsky & Housel, 1998). This nugget of theory became the foundation for the application of principles of finance to the firm at a sub-corporate level in Nelson (2005). Kanevsky and Housel suggest that

Businesses are open systems – systems that exchange substance and energy with their environments. As such, businesses have the capability, through their processes, to change

the structure of raw material inputs (i.e., substance, energy, information) into final products/services. In the language of thermodynamics, this change in structure can be measured in terms of the corresponding change in entropy, when the input state  $a$  is transformed into output state  $b$  by process  $P$  (i.e.,  $b = P(a)$ ). Assume that this change can further be represented as a set of ‘elementary’ changes that are minute enough to become identical in terms of the corresponding amount of entropy they cause. This assumption about the equivalence of elementary changes can be expanded across any finite number of processes with predetermined outputs. This allows the comparison in terms of entropy among any set of processes by means of elementary changes ...

This concept can be applied to calculating the value added by business processes by calculating the entropy of K-complexity caused by the process to transform an input to its process output. To accomplish this, we will employ the parallelism between business processes and computations ... (Kanevsky & Housel, 1998, pp. 278–280)

They also suggest that

Since a unit of K-complexity represents a unit of change and is equivalent to a unit of Shannon information, all process outputs can be standardized by describing them in terms of the number of units of Shannon information (i.e., bits) required to produce them, given the state of the technology used in the process.

All outputs can also be described in terms of the time required by an ‘average’ learner to learn how to produce them. ‘Learning Time’ can be considered a surrogate for the amount of organizational knowledge required to produce the outputs ... [allowing us to] describe outputs in terms of learning time [and to assign] a common unit, the Knowledge Unit ( $K_\mu$ ), ... to represent the amount of organizational knowledge required to produce the outputs. (paraphrase in Nelson, 2005, p. 7)

This proportionality between units of change, units of Kolmogorov Complexity, units of information, and units of organizational knowledge has profound implications for the concept of the firm as an economic system and the quantitative measurement of risk and reward.

Sub-corporate finance proposes that, based on the concept of common units of change that can be counted and monetized as firm or system processes transform “inputs” of various kinds into “outputs” of other kinds, *risk* becomes a descriptor for the *expected change in uncertainty* that will occur during such process state transformations. *Reward* (ROI, value added) thus becomes a descriptor for the *actual change in uncertainty* that occurs during state transformations. As a market transaction can be considered a form of process in which one asset undergoes a state transformation into another, risk and reward, as redefined by sub-corporate finance take on new and useful attributes. Taking this concept further,

If we apply the proportionalities we described [earlier] in which  $\Delta E$  (change in entropy, uncertainty)  $\approx K(y|x)$  (conditional Kolmogorov complexity)  $\approx$  bits  $\approx K_\mu$ , and we

agree that risk is a change in uncertainty ( $\Delta\Phi$ ), then risk and  $K_\mu$  are also proportionate and represent the same common unit of measure.

As a result, we suggest that measuring the change in entropy embodied in process outputs of the organization in common units,  $K_\mu$ , is equivalent to measuring risk. This in turn ties risk measurement *directly* to the knowledge assets of the organization and only indirectly to the movements of ‘the market’ and competitors. (Nelson, 2005, p. 31)

This provides a radical but useful link between risk and knowledge assets, a link already implied in the literature. Thus, while sub-corporate finance has not yet been operationalized, it could provide valuable new insights. In addition, the data required to populate its models is abundant and comes from deep within the firm, close to sources and drivers of value. As such, not only does it support the proposition that the firm is a true economic system, complete with its own endogenous, quantifiable sources of risk and reward, but it could eventually provide new data sources for the application of real options “in” the economic system of the firm.

## 5. OPTIONALITY WITHIN ECONOMIC SYSTEMS

As with all open systems, economic systems are pregnant with optionality (i.e., the right, but not the obligation, to pursue different pathways to navigate, manage, and harvest system opportunities and challenges). The dynamics of innovation, “creative destruction,” evolution, revolution, booms and busts, change, complexity, and risk are byproducts of optionality.

Expectations, those elements from which choice is made, drive the scope and scale of optionality. According to Austrian School economists, *imagination* generates 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, 1979, p. 36).

Optionality has two key attributes, uncertainty and flexibility, both with the capacity for creating or destroying systems value. Neo-classical economics and traditional finance recognize and attempt to quantify uncertainty (generally equating it with risk), but find a variety of theoretical and practical rationale for ignoring flexibility at other than the “product”

level (e.g., financial options and other derivatives; market trading algorithms; goods and services available for consumption). As the following examples will demonstrate, this results in sub-optimal decision processes and system-wide disturbances.

### *5.1. Optionality within the Global Economic System*

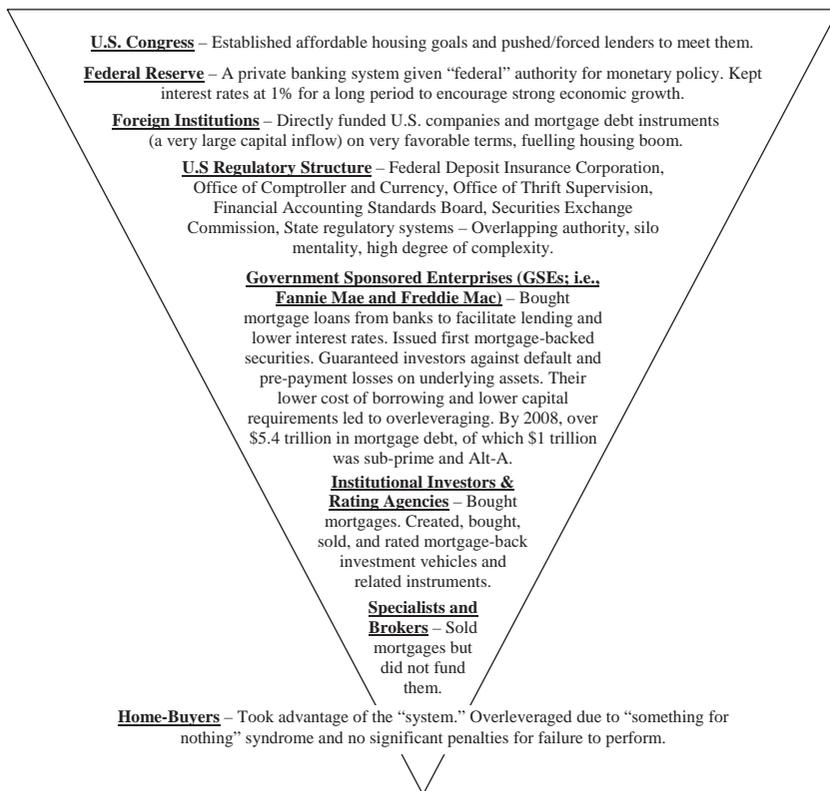
Much has already been written about the causes and effects of the Great Collapse of 2008. The Brookings Institution issued a cluster of papers on this topic, titled the “Fixing Finance Series.” One of these, “The Origins of the Financial Crisis,” provides a concise and thoughtful analysis that we use as a baseline for diagrammatic representations of ignored, misrepresented, and mis-measured optionality in the global economic system (Baily, Litan, & Johnson, 2008).

Fig. 1 describes system participants and roles. Fig. 2 describes system optionality as exercised by various participants.

It is worth noting that down to the level of “Specialists and Brokers,” economic system participants relied on linear, deterministic models and theory based on neo-classical economics and traditional finance as the basis from which to make decisions regarding what they knew was an asset bubble. They pursued the optionality within the system by ignoring the full range of flexibility available to them and mis-measuring the uncertainty involved. Specialists, brokers, and home buyers were culpable participants to the extent that they falsified or stretched the facts to pursue self-interest within increasingly loose mortgage lending standards. However, they operated under information asymmetry with regard to broader systems issues. This, along with dishonesty and a desire to “work the system,” caused them to misunderstand their own option set and make sub-optimal decisions.

### *5.2. Optionality within the Economic System of the Firm*

One of the most crisp examples of optionality within the economic system of the firm is the decision process during mergers and acquisitions. In an M&A scenario, both buyer and seller have a separate set of options to consider, some but not all of them conjoining. Some options are created by tax rules; some by the organizational and operational structures and portfolios of assets and liabilities of the two companies; some by the types and motivations of investors and intermediaries; some by the personal concerns



*Fig. 1.* Financial Crisis System Participants and Roles.

and goals of current owners and top management. Even the regulators have a say in the decision process if either the acquirer or the target is publicly held. Legal, accounting, and valuation advisors also put their imprimatur on deals. This creates a highly dynamic, complex, non-linear environment, and decision process.

However, this process is developed and guided almost entirely by static, linear, deterministic discounted cash flow and valuation models, neo-classical economic thinking, and a tunnel focus on uncertainty/risk mitigation while ignoring system flexibility completely. The consequences of this approach have been well-documented as disastrous. A high proportion of mergers and acquisitions fail. Human capital and

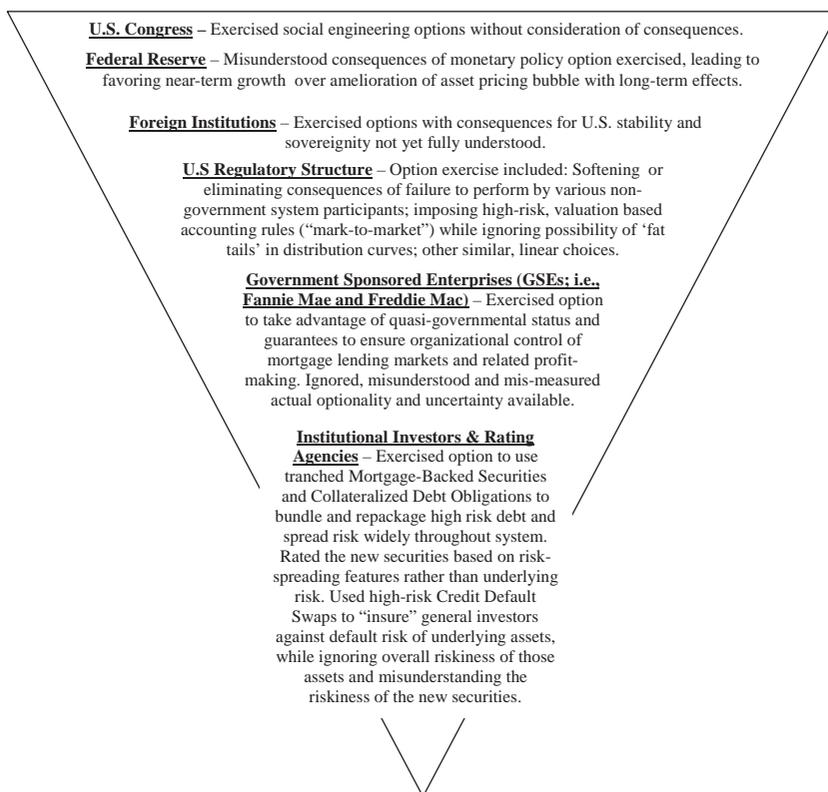


Fig. 2. Financial Crisis Exercise of Optionality by Participants.

infrastructure systems never integrate properly and are often discarded, wasting untold monetary and organizational value. Technologies and products never realize the potential for which they were purchased. High quality projects are abandoned and low quality projects pursued based on turf wars, mistaken priorities, and other never-discussed or mis-measured rationale. The picture is not pretty.

Throughout the system, practical solutions to such problems are being sought. I will first examine two solutions offered from within the current paradigm. I will then discuss two solutions from within the real options paradigm – one in current use and one that I suggest is the most fruitful avenue for future exploration.

## 6. CURRENT PARADIGM – BUILD COMPLEX MODELS TO DESCRIBE AND MANAGE COMPLEX ECONOMIC SYSTEMS

The following are examples of approaches based on building complex models to describe and manage complex systems. They are both taken from the field of valuation and are written by practitioners, and thus are not part of a body of academic literature.

### *6.1. Model A: Valuation of Complex Capital Structures*

Accounting rules such as Mark-to-Market and the move to Fair Value Accounting create major challenges for the valuation of complex capital structures for mergers and acquisitions, financing, and other purposes.

Th[e] growing trend toward fair value presents significant challenges in valuing privately-held companies with complex capital structures. Because it is necessary to first value those securities with superior claims to common equity, many valuation specialists, auditors, and financial executives now find themselves forced to enter a jungle of complex capital valuation. Depending upon the provisions associated with the components of a complex capital structure, accurate valuation of common stock in this environment may require sophisticated simulation models. Until recently, however, there was very little guidance – much less convergence of thought ... within the appraisal community. Even where such guidance exists, it is unnecessarily conflicting, and more important, incapable of handling such commonplace features as cash distributions prior to liquidity events and performance-based vesting. (Chamberlain, Hill, Kamma, & Karam, 2007, p. 1)

To address such challenges, a team of valuation professionals and academics propose a methodology, based in simulation techniques, to integrate two extant valuation methods: the Options Pricing Method (OPM) and the Probability Weighted Expected Return Method (PWERM). These two methods are commonly used in the field, having been propounded in a 2004 AICPA Practice Aid, “Valuation of Privately-Held-Company Equity Securities Issued as Compensation.”

“OPM takes as a starting point the current enterprise value and, using a volatility estimate that captures the market risk of the underlying business, models the stochastic evolution of this value over time. The various equity classes are then viewed as [European] option-like claims on this underlying value ...” (Chamberlain et al., 2007, p. 4). The OPM is performed using the closed-form Black–Scholes option pricing method that does not allow for performance-based vesting or other path-dependent events.

“PWERM explicitly takes into account the random nature and timing of potential future liquidity events—...—[C]urrent enterprise value is the probability-weighted sum of the discounted future liquidity outcomes” (Chamberlain et al., 2007, pp. 4–5). The discount rate utilized is that of the underlying asset (i.e., the company), thus preventing the method from capturing the changes in risk over time and over equity classes.

The integrative method incorporates the following steps: (1) determine the risk-neutral distribution of underlying asset values; (2) simulate future asset values using this distribution and the selected end-points that represent various liquidity events; (3) infer benefit stream paths (EBITDA, cash flow) from these asset value paths; (4) use the benefit stream paths to determine the cash distributions resulting from path-dependent events (such as performance-based vesting) and the effect of such distributions on end-point liquidation values; (5) using traditional priority rules, allocate the enterprise values determined in steps 1–4 to the various equity classes; (6) discount the resulting pay-off values by the risk-free rate (because the underlying asset has been simulated under risk-neutral conditions); and (7) repeat these steps and take an average to conclude a final value for each equity class (Chamberlain et al., 2007, p. 8).

This model allows the analyst to set “conditions believed to resemble the ones that prevail in reality, and [launch] a collection of simulations around possible events,” where there are no constraints on the number of input variables that can be used, and the analyst can “generate thousands, perhaps millions, of random sample paths, and look at the prevalent characteristics of some of their features” (Taleb, 2004, p. 46).

Yet, the model is complex and involves a high degree of informed professional judgment throughout. For the simulation alone, the analyst must select those few variables that demonstrate significant influence over the resulting outputs, check for correlation among these, and ignore the rest. The analyst must also select the probability distribution and parameters for that distribution that represent a “best fit” for input variability. “[B]ut, picking the right distribution and the parameters for the distribution remains difficult for two reasons. The first is that few inputs that we see in practice meet the stringent requirements that statistical distributions demand ... The second is that the parameters still need to be estimated after the distribution is picked ... [yet the available data for this purpose is regularly insufficient or unreliable]” (Damodaran, 2007, pp. 165–167). The act of performing simulations may provide a mistaken sense of having rigorously investigated all aspects of a matter, when the adage “garbage in, garbage out,” still prevails.

While this proposed methodology supplies a real option like attempt to resolve what appear to be conflicting issues in more traditional methodologies and solve an important problem, it increases model risk by increasing model complexity and the need for subjective inputs without the true rigor of a real options approach.

### *6.2. Model B: Valuation of Complex Tax Issues Related to Organizational Form*

A debate has raged in the valuation community for years regarding the effect on value of the tax attributes belonging to Sub-Chapter S-corporations. Should S-corporations be assigned higher values than C-corporations based on their tax attributes? After all, (1) investors in S-corporations avoid paying the dividend tax at the individual level, but C-corporation investors cannot avoid this tax (Note that both investor classes pay taxes on income earned at the corporate level); and (2) S-corporation shareholders can increase the tax basis in their stock through retained earnings, while C-corporation shareholders cannot. Even the Federal Tax Court has entered the debate, issuing a number of decisions since 1999 that have created further confusion and discussion.

To address this issue and more precisely quantify any additional value that S-corporation status might bring to its shareholders, five valuation experts have developed models. Four of these, each named for its progenitor, are complex enough to be virtually proprietary, although they have all made their way into practical use to one degree or another. The fifth method, the “simplified model,” explains and compares the other four and offers a streamlined approach to modeling the same issues.

The fundamental components of the “simplified model” are: “(1) a traditional discounted cash flow (which can be expanded for any holding period or contracted to a single-period capitalization); (2) recognition of the benefit of the avoided dividend tax; and (3) recognition of the capital gains benefit of the ability to build up basis” (Fannon, 2008, p. 4–1). The model requires the analyst to consider, select, and quantify the following assumptions: (1) annual distribution percentages and amounts; (2) the probability that the likely hypothetical buyer, under a fair market value standard, will qualify to maintain the S-corporation status; (3) the level of risk associated with shareholder ability, or lack thereof, to realize basis build-up; (4) the estimated holding period before the hypothetical buyer will “flip” his investment in the company; and (5) the federal income tax rates to

be used for the company and the shareholders (Fannon, 2008, pp. 4–1 through 4–2).

Each assumption requires the analyst to apply varying degrees of informed professional judgment based on varying sets of facts and analyst perspectives. Model complexity and risk are increased due to the number of factors to be considered and path dependencies that cannot be addressed. More importantly, these models may suggest that if a company’s tax attributes have a substantial influence on its value, we should consider modeling the complete range of tax attributes of every company investigated during valuation analysis since companies have widely differing tax attributes based on their economic system design.

This would require an approach to modeling the economic system of the firm that is not currently available within traditional valuation practice.

## **7. THE REAL OPTIONS PARADIGM – A SIMPLIFIED MODEL TO DESCRIBE AND MANAGE COMPLEX ECONOMIC SYSTEMS**

*In Strategic Investment: Real Options and Games*, Drs. Hans Smit and Lenos Trigeorgis synthesize corporate finance, industrial organization, corporate strategy (strategic planning), and value into a simplified model that describes and manages the complexity of the effect of firm optionalities and strategic games on value creation. Their basic premise is as follows:

In the past decade, the strategic management field has seen the development of two main views. One view is that flexibility is valuable. As the competitive environment of most firms changes quite frequently, flexibility in investments should allow firms to optimize their investments and value creation. The other view is that commitment is valuable because it can influence the strategic actions of competitors. This creates the opportunity to realize better payoffs (and shareholder value).

Both views are supported by theoretical arguments and a large body of research. The flexibility view partly draws on the resource-based view of the firm and core-competency arguments: a firm should invest in resources and competencies that give it a distinctive chance to pursue a set of market opportunities ... The commitment view is firmly anchored in industrial organization and game theory, which during the nineties were increasingly adopted in the strategy field.

Since both views have a theoretical justification, a key question is under what circumstances each can inform strategic decisions. (Smit & Trigeorgis, 2004, p. 35)

Their response to their own question is the following model:

$$\text{Expanded (strategic) NPV} = \text{(passive) NPV} + \text{flexibility (option) value} \\ + \text{strategic (game theoretic) value}$$

Conceptually, they consider the firm as a portfolio of options, or “‘bundle of opportunities’ [requiring] a balance between exploiting current cash-generating advantages and generating new options.” The correlations and interactions (“interproject synergies”) and the “intertemporal (compound option) effects” among the firm’s strategic and operational projects (options) as well as the risk attributes of various stages in these projects create the value of the firm (i.e., the portfolio of options). (Smit & Trigeorgis, 2004, pp. 80–81) The value created by and within this portfolio can be quantified using a binomial option pricing model. This approach to valuing the firm’s portfolio of options provides a richer and more realistic assessment of value than traditional, linear discounted cash flow models.

In addition, firms experience a “strategic impact” from the investment decisions they make in contexts in which they are aware of the actions and interactions of rivals that will affect project value. In such contexts, “[g]ame theory can be helpful in analyzing strategic investment decisions... [F]ollowing the rules of game theory can help reduce a complex strategic problem into a simple analytical structure consisting of four dimensions [(1) identification of the players, (2) the timing or order in which the players make their decisions, (3) the available actions and information set, and (4) the payoff structure attached to each possible outcome]... . [G]ame theory is also a helpful valuation tool for strategic decisions because it encompasses a solution concept that can help in understanding or predicting how competitors will behave, and it also provides an equilibrium strategy and values for the strategic decisions” (Smit & Trigeorgis, 2004, pp. 171–172). Smit and Trigeorgis present an integrated model by which to discuss game theory in terms of real options analysis. This holistic model is simplistically described in the following.

When a firm engages in multistage (sequential) games under uncertainty and wishes to analyze its strategic choices using game theory analysis, management will build a strategic decision tree by which to lay out available choices and moves. By moving backward through this decision tree structure, much like the certainty-equivalent binomial tree used in real options analysis, the option value at each node of the tree can be calculated using risk-neutral probabilities and OPM. “This new approach makes it

possible to value complete strategies in a competitive context in a fashion that is consistent with both modern economics and finance theory” (Smit & Trigeorgis, 2004, p. 181). It also provides a simplified, but powerful, framework by which to investigate the effects of market competition and strategic planning on firm value. There are no traditional valuation tools that can address this important issue.

## **8. THE PROPOSED SOLUTION – LAYERED REAL OPTIONS MODELS THAT REDUCE COMPLEXITY DURING USE**

The proposed solution has its origins in the seminal work of Dr. Richard de Neufville, Massachusetts Institute of Technology, in flexibility in engineering systems design. While there are still aspects of this solution that have not been operationalized, the underlying research and accompanying theory is extensive. Sections 8.1 and 8.2 will use the research of two of Dr. de Neufville’s engineering students as a platform for the further exploration of the application of real options “in” economic systems. Both suggest thought-provoking methods for scanning the optionality within the system and reducing design space complexity during use.

### *8.1. The Distinction between Real Options “on” and Real Options “in” Projects*

Before we proceed further, we must identify the difference between real options “on” and “in” projects. Real options “on” projects is the most common application of real options analysis. It is utilized to value projects for which future management decisions regarding project direction (i.e., switch, put on hold, continue to the next stage, shut down, and so forth) have been explored. While it is a fruitful and important means by which to develop more realistic project values, it offers no consideration of or insight into the inner workings of the projects being valued. As these inner workings often have substantial influence over eventual project direction or success, this may be considered a sizeable oversight.

Real options “in” projects, coming out of the field of large-scale engineering systems design, considers the inner workings of projects. Its concern is to identify and provide flexibility (i.e., options) from the inside

out that, while not necessarily focused on optimization, will ensure a high quality/most desirable project design, considering resource and other constraints and the state of the system.

### *8.2. Using Common Analytic Tools and Informed Professional Judgment to Simplify System Design Space*

In his masters thesis, “Facing Reality: Design and Management of Flexible Engineering Systems,” Michel-Alexandre Cardin, PhD candidate, MIT, provides a useful way of thinking about the kinds of problems that inhere in both engineering and economic systems design. His statement of the problem is as follows (Cardin, 2007, p. 15):

Designers of engineering systems always seek for better approaches to improve the value and performance of a system. They seek the best combinations of design elements and management decision rules before selecting a particular design. In doing so, they assume one particular evolution of the uncertain variable(s) affecting their system over its intended useful life ...

One problem with this approach is that the future is uncertain. The uncertain variables affecting the value and performance of the system may turn out completely different than originally assumed. Therefore, it is possible that designers choose a design configuration that performs extremely well under the scenario originally assumed, if it occurs, but very poorly if reality turns out otherwise.

If designers consider several scenarios of the uncertain variables before committing to a particular design, another problem emerges. In addition to considering several possible combinations of design and management decision rules under a particular scenario, they need to find the best combination for each possible scenario ... The number of possible combinations ... can become intractable very rapidly. If flexibility is considered as a way to adapt the system to take even more advantage of unexpected upside opportunities, or to reduce losses in case of downside events, the problem becomes even larger and harder to tackle.

This could equally well describe the problem related to valuation and performance measurement of a complex economic system containing optionality using the tools and models of traditional finance and economics. Cardin proposes a five-stage layered decision model to explore and parse the design space of the system and identify the most promising design solutions, given the state of the system.

### 8.2.1. Critical Definitions

Cardin provides a number of definitions that are foundational to his methodology. They are paraphrased and quoted in the following (Cardin, 2007, pp. 19, 21, 22, 24, 27–29).

*Design elements* are the building blocks of an engineering system. *Management decision rules* codify selected management and operating behaviors for consideration in design models. *Uncertain variables* are “variables outside of designers’ and program managers’ control that can affect the value and performance of the systems ... Such variables can take on different behaviors over the course of a project’s useful life.” An *operating plan* is “a way to manage and operate a system that combines a particular set of design elements and management decision rules under a particular uncertain variable scenario.” The *combinatorial space* represents “the spectrum of all possible combinations of design elements, management decision rules, and uncertain variable scenarios that designers can investigate to find the best design under all possible manifestations of uncertainty.”

As the combinatorial space is too vast to be fully explored, Cardin cites (de Neufville, 2006) as suggesting the choice of a limited set of uncertain variable scenarios, followed by the selection of a limited set of combinations of design elements and management decision rules (i.e., operating plans) that are best suited for these scenarios. “This limited set of operating plans forms a *catalog of operating plans*, where each operating plan is suited to a particular scenario of the uncertain variables.” Optimization is not a desired consideration in forming a catalog. Flexibility is.

*Flexibility* in an engineering system is the system’s capacity to adapt to uncertain and unexpected conditions in a relatively efficient manner that also enhances system value and performance. de Neufville (2005) identifies two primary sources of flexibility in engineering systems: “in” and “on” the system. Flexibility “in” a system is created by properly exploiting technical design elements. Flexibility “on” a system is created by an appropriate and insightful set of management decisions on behalf of the system as a whole, without necessarily affecting elements of design.

### 8.2.2. Methodology

The goal of Cardin’s methodology is to explore the combinatorial space, using tools and concepts familiar to firm, industry, or government managers, to identify, think about, and adopt the catalog of operating plans that will most improve (not necessarily optimize) system value and

performance. He suggests the following five layered stages, quoted and paraphrased in the following (Cardin, 2007, pp. 35–52).

*8.2.2.1. Build an Initial Deterministic Model of the Engineering System.* The main design elements, management decision rules, performance and valuation metrics, and sources of uncertainty (uncertain variables) for the system are identified and selected.

*8.2.2.2. “For Each Source of Uncertainty, Propose a Limited Set of Uncertain Variable Scenarios and Review the Initial Model” in Light of These.* Cardin suggests that simulations be performed on several of the most likely scenarios, using the deterministic projections developed for the above-mentioned step “Build an Initial Deterministic Model of the Engineering System.” Once an adequate number of scenarios have been simulated, they can be analyzed to discover which scenarios provide the most compelling general categories for future consideration. The analysis is conducted using brainstorming and informed professional judgment.

*8.2.2.3. Using Tools such as Engineering System Matrices Brainstorming and Informed Professional Judgment.* Identify the critical sources of flexibility in the system, and position these in the uncertain variable scenario models.

*8.2.2.4. Using a Concept from Statistical Experiment Design Called Factorial Analysis Scan the Combinatorial Space and Create a Catalog of Operating Plans.* Cardin suggests that the requirements of “full factorial analysis” are excessive in light of typical managerial resource and time constraints. Instead, he presents two methods for reducing the number of experiments required to conduct factorial analysis. One of these is fractional factorial analysis, in which “only a subset of [all possible] combinations [of factor levels] is selected to perform experiments and measure the system’s response.” The second, favored by Cardin, is a search algorithm called adaptive OFAT, for which there are two models, one for discrete factor levels and one for continuous factor levels. The discrete model is more suitable for this search problem.

*8.2.2.5. Assess the Expected Value and Performance Added by the Catalog of Operating Plans versus Those Exhibited in the Original, Static, Inflexible Operating Plan.* Monte Carlo simulations are run to develop probability distributions of expected net present values for uncertain variable scenarios

within a catalog. These probability distributions are then recast as histograms and also as cumulative distribution functions using Value at Risk and Gain curves, allowing managers to visualize the exact benefits of flexibility in the proposed system design.

### 8.2.3. Conclusion

While this methodology leaves certain computational issues unresolved, it provides a valuable and practical way to think about and simplify engineering system design space and identify flexibility within the system that enhances value and performance. I suggest it can be applied to economic systems equally effectively.

## 8.3. Using a Layered Computational Model to Simplify System Design Space

“Real Options ‘in’ Projects and Systems Design – Identification of Options and Solutions for Path Dependency,” the Ph.D. dissertation (MIT) by now Dr. Tao Wang, also discusses the identification and use of real options “in” engineering systems design, but from a more purely computational perspective. This section will provide a simplified overview of Wang’s proposed real options model.

### 8.3.1. Another Look at Challenges in Engineering Systems Design

As also stated by Cardin, the design of physical systems, such as large-scale engineering systems, involves identifying and incorporating a vast array of technical constraints (real options, or flexibility, “in” the system) that are highly interdependent and path dependent, conditions that, traditionally, are not and cannot be considered in calculating the value of such projects. These kinds of projects require designs that can be adapted over time due to their longevity, the high degree of uncertainty associated with future system requirements, their sheer size and scope, and the magnitude of the investment. In addition, engineering system scale, scope, and complexity are being profoundly affected by “globalization, new technological capabilities, rising consumer expectations, and increasing social requirements” (Wang, 2005, p. 29).

Much like standard corporate project planning, traditional deterministic engineering systems design makes use of projected expected values of uncertain variables, passive recognition of such uncertainties, and a focus on economies of scale. Flexible engineering systems design of the sort proposed

by de Neufville, Cardin, and Wang considers “sequences of probability functions at multiple points in time,” proactive management of uncertainties, and attention given to strategies other than economies of scale (Wang, 2005, pp. 22–23). The need to consider “social stochasticity,” that is, the economic and social consequences and uncertainties surrounding large-scale engineering projects, has become an increasingly critical design element because “[a]ny technical systems are to serve human’s needs” (Wang, 2005, p. 38).

Thus, engineering systems design and implementation require the consideration of high degrees of complexity, uncertainty, and flexibility (i.e., optionality), none of which is properly captured using traditional linear deterministic methodologies. Wang suggests a layered real options computational model that can address these challenges effectively. His model is described in more detail in the following (Wang, 2005, pp. 138–152, paraphrased and quoted).

### *8.3.2. Layer One – The Screening Model*

The top layer of Wang’s approach is a screening model “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.”

This model requires the use of simplifying assumptions such removing sequential build-out timing considerations and uncertain variable stochasticity. It uses non-linear programming to perform sensitivity analysis on key system variables to identify optimal designs for each set of variables. Once optimal designs have been selected, they are compared with each other to find the real options (flexibilities) that are common to and beneficial for all sets. Like Cardin’s model, optimal value creation, but not necessarily optimization, is the goal.

### *8.3.3. Layer Two – The High-Fidelity Simulation Model*

The next layer is a high-fidelity simulation model, by which selected design sets are analyzed using technical and economic uncertainties that were not considered in Layer One. This model adds back uncertain variable stochasticity but does not consider timing issues. It tests for the robustness, reliability, and benefits of the design sets and provides information by which they can be refined.

#### 8.3.4. Layer Three – The Option Valuation Model

Using the results of Layer Two, an option valuation model is run on the final design contenders. This model now includes timing and strategic considerations in the analysis by

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 ...

[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.

To assist those readers who do not have an expertise in the kinds of programming used in his 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, pp. 39–42)

Wang notes a deficiency of stochastic mixed-integer programming – it is difficult to tell if the result is a global or a local optimum. However, he maintains that even if the optimums provided by his methodology are local rather than a global, the overall results are superior to those available through traditional methodologies or human intuition.

#### 8.3.5. Conclusion

Wang’s methodology can be executed easily and rapidly on an ordinary laptop computer once a problem has been programmed. I suggest that, in spite of its computational complexity, its application to economic systems should be further explored.

## 9. APPLICATIONS OF REAL OPTIONS “IN” ECONOMIC SYSTEMS

Just as engineering systems design, implementation, and valuation can no longer be properly captured using traditional linear deterministic methodologies, so we face the same barriers for the design, implementation, and valuation of the economic system of the firm. Both the Cardin and Wang models may provide a means by which to address these challenges effectively. To support this concept, I will consider the two examples of complex valuation problems discussed in [Section 6](#) and one additional example from the work of Joseph Schumpeter that could be analyzed and resolved using the proposed models.

### *9.1. Designing and Valuing Complex Capital Structures*

As stated in [Sections 5.2 and 6.1](#), complex capital structures arise from mergers and acquisitions, deal financing, and other equally dynamic scenarios. These scenarios are mismatched with the valuation theory and models currently in use. The real options models discussed in [Section 8](#) are ideally suited for transaction design (pre-acquisition) and for post-acquisition valuation purposes because they are able to actually explore the range of real options/flexibility available “in” possible or actual deal and capital structures. If deal structures and post-acquisition valuations included non-linearities and path dependencies as part of the strategic option set, not only would management and investors gain a clear picture of the uncertainty and flexibility available in the system and be able to negotiate better deals, but the future success of the combined entity might be less at risk.

### *9.2. Designing and Valuing Complex Tax Attributes*

The complexity and range of the tax attributes of firms is enormous as firms continuously seek to minimize the effect of taxes on corporate and investor wealth. As stated in [Section 6.1](#), once we begin to take tax attributes into account for one design element of the firm (here, its legal structure), would it not be useful to also consider the effect of taxation on other value-creating or value-destroying design elements?

For example, the valuation of intangible assets under SFAS 141(R) includes quantification of the future tax benefits attributable to the

amortization of such assets. Yet, using common linear models, we cannot discuss and quantify a realistic picture of the expected future benefits of these assets. Thus, we may be overvaluing them.

In another example, when valuing privately held companies by using public company benchmarks, we are forced to ignore the tax attributes of the benchmarks because they vary so widely and, in fact, may not be available to “outsiders.” Yet, these tax attributes may be significantly different from those of the subject privately held company and from the default attributes we use in our cash flow models. Again, this has the potential to skew the valuation of the subject company.

Both proposed engineering systems design models could be used to explore taxation real options “in” the firm and provide assistance to financial managers and others who perform various aspects of transaction and organizational design and to accountants and valuation analysts who need to quantify tax effects and put them into financial statements. While considering the effects of taxation on every aspect of the firm seems both unnecessary and burdensome, the proposed design models could narrow the taxation design space for a particular firm and reduce the number of options for consideration. Once the most beneficial configuration of tax model design was established for a particular firm, it could be revisited and updated over time to take into consideration changing conditions. This process would enable the firm to design and pursue a rigorous, consistent tax policy and track the effects of its taxation decisions on profitability and firm health.

### *9.3. Capturing Creative Destruction and Other Attributes of Economic System Life Cycles*

Of the capitalist economic system and its sub-systems, Joseph Schumpeter wrote,

Capitalism ... is by nature a form or method of economic change and not only never is but never can be stationary. And this evolutionary character of the capitalist process is not merely due to the fact that economic life goes on in a social and natural environment which changes and by its change alters the data of economic action; this fact is important and these changes (wars, revolutions and so on) often condition industrial change, but they are not its prime movers. Nor is this evolutionary character due to a quasi-automatic increase in population and capital or to the vagaries of monetary systems of which exactly the same thing holds true. The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumer goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates ... [This is a] process of

industrial mutation – if I may use that biological term – that incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism. (Schumpeter, 1942, pp. 82–83)

The Austrian School economists also recognize such dynamism and disequilibrium in system life cycles by including explicit consideration of *time* as a critical component of economic system structure.

Time manifests itself at least four different ways in the structure of economics. A world of disappointment and surprise is one of *disequilibrium* and *discoordination*. The plans of market participants are continually being disordinated by the imperfect fulfillment of expectations. Disequilibrium implies that opportunities for mutually advantageous exchange exist, and that those who possess superior information will reap a kind of arbitrage *profit* by seizing these opportunities ... [T]he contrast between [the Austrians generally] and the neoclassical theory of value ... cannot be stressed too much. It is essentially the distinction between a world in which time plays a vital role, and one in which the passing of time may be ignored. (Rizzo, 1979, pp. 1–2, 38)

Without solutions such as the proposed “real options ‘in’ systems” methods, we cannot map the process of creative destruction in the life cycles of firms or economies. We have limited, impoverished ways by which to discuss and quantify the effects of time. I suggest the proposed models might allow us to create richer and more realistic design space, generate new insights about firm value creation/destruction and long-term sustainability, and open new avenues for investigation and innovation in finance and economics.

#### 9.4. *The Obstacle of Computational Complexity*

While a somewhat lesser concern in Cardin’s methodology, computational complexity is a very real obstacle to the further exploration and utilization of Wang’s model for economic system design and valuation.

The question we must ask ourselves at this juncture is whether it is preferable to make increasingly complex, sequential, and subjective adjustments to various traditional model variables to attempt to capture 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 “firm as economic system” we are valuing. 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 speculation.

Simple, deterministic calculations 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.

## **10. AVENUES FOR FUTURE RESEARCH AND WHY IT MATTERS**

Clearly, further research must be performed to understand if the “real options ‘in’ systems” models can be utilized in the manner proposed herein, within the time and resource constraints of normal firm and consulting environments. Then the challenges of operationalizing the models must be addressed. If these challenges could be successfully addressed and the resulting models made readily available to the finance and valuation communities, at reasonable cost, only our imaginations would be the limit to the further applications of these concepts.

Why does this matter? We have offered many examples already. Accounting regulators want accounting to function like finance, leading to the corruption of financial statements and market data and the effective disaggregation of the firm into a collection of resources and claims against them. But traditional finance and valuation do not currently have the tools or concepts to solve this problem. Both disciplines are being required to do what neither can. Economic system participants at all levels make choices within a dynamic, high-risk environment while using static, linear, deterministic models that cause them to ignore, misunderstand, or mis-measure the effects of uncertainty and flexibility on the system. Firms make material decisions on a daily basis, using tools and concepts that fail to identify, consider, or quantify critical optionalities that could change firm destiny. Can we afford to continue in this manner?

We believe that the real options “in” economic systems might provide an answer.

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