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Securities Price Risks and Financial Derivative Markets

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Abstract: The financial and popular media report almost daily on the volatility of securities market prices. Yet, many people continue to buy securities to hedge against or speculate on certain risks. People can also buy or sell derivatives to hedge against or speculate on fluctuations in securities prices. This Article discusses three regulatory policy implications of utilizing derivatives markets to reallocate the bearing of securities price risks. First, if there are too few non-redundant derivative markets, a competitive market equilibrium allocation of securities price risks is typically constrained Pareto inefficient. This financial economic result means that for typical economies, a regulator can in principle improve social welfare by financial market interventions. Second, introducing some but not enough non-redundant derivatives markets has indeterminate normative consequences for the allocation of securities price risks. This financial economic result means that for typical economies, introducing a new derivative market can improve, worsen, or have no effect on the welfare of consumers and investors. Finally, government regulation might not improve the social allocation of securities price risks because of informational or political economy obstacles. This financial economic result means that for typical economies, the ability of regulatory intervention may be constrained by limited knowledge.

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I. INTRODUCTION

The 21st century ushers in a new millennium with the promise of great changes and novel opportunities for societies in general and for their derivatives and securities markets in particular. But, as is true with many opportunities, there is also the potential for corresponding dangers.[1] Repeated recent declines in financial market prices across the globe remind us once again that derivative and securities markets are not only volatile, but also increasingly global in the sense of being linked across national boundaries. In fact, "[t]here are only a few things in daily life which are regarded as a better synonym for uncertainty than security prices."[2] An increasing number of people monitor in real-time the performance of asset markets in general and their portfolios in particular. This trend is reflected by the advent of people that only day trade for their living; the rise and success of financial news channels on television; and the plethora of real-time financial market quotations on the Internet. Financial markets offer the appeal of freedom, gambling, education, investing, power, security, spectator or participatory sports, and vicarious or actual pleasure.[3]

International financial markets challenge our current and historical system of jurisdictional and national-based regulation.[4] A related but distinct question is whether the Securities and Exchange Commission ("SEC") can keep up with advances in information technologies.[5] The twin forces of globalization and technological progress mean that derivative and securities markets today face risks of tumultuous changes. The precise nature of the risks that participants in and regulators of these financial markets face in such a world is the subject of this Article.

Financial markets would be superfluous in a world that did not unfold over time.[6] In a multi-period world of certainty, investors can shift income over time by trading in riskless bond markets. This reallocation of wealth is possible because in such a counterfactual world in which there is no risk of

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[1] The Chinese characters for danger and opportunity form the Chinese word for crisis.

[2] Ralf Korn & Elke Korn, OPTION PRICING AND PORTFOLIO OPTIMIZATON: MODERN METHODS OF FINANCIAL MATHEMATICS, ix (2000).

[3] *See, e.g.,* Adrian Furnham & Michael Arqyle, THE PSYCHOLOGY OF MONEY 136-43 (1998) (describing the emotional underpinnings of money).

[4] Richard Dale, RISK AND REGULATION IN GLOBAL SECURITIES MARKETS (1996) (arguing that coordination of international securities regulation will become increasingly crucial); Joseph A. Grundfest, *Internationalization and Regulation of the World's Securities Markets, in* REGULATING INTERNATIONAL FINANCIAL MARKETS: ISSUES AND POLICIES 123, 125 (Franklin R. Edwards & Hugh T. Patrick, eds.) (1992).

[5] Joseph A. Grundfest, *The Future of United States Securities Regulation in an Age of Technological Uncertainty,* STANFORD LAW AND ECONOMICS OLIN WORKING PAPER NO. 210 (Dec. 2000), *at* http://papers.ssrn.com/ paper.taf?abstract_id=253763.

[6] Chi-fu Huang, *Time and Uncertainty,* presented at the General Equilibrium Theory 40th Anniversary Conference at CORE, Louvain-la-Neuve, Belgium (June 1993) (on file with the author) (making this observation).

any sort, riskless bond markets would suffice for all payoff-relevant investment purposes. The term risk denotes a situation in which a decision-maker actually knows or believes that she knows the probability distribution of the randomness about which she cares. The view that people not only can, but also do quantify the randomness they face is exemplified by modern statistical decision theory.[7] A different viewpoint is that people do not know the probability distribution of the randomness they encounter. This alternative formulation of randomness is known as Knightian uncertainty and is named after the famous economist, Frank Knight.[8] Ardent supporters of the uncertainty approach to randomness include another famous economist, John Maynard Keynes.[9] This Article considers randomness in the form of both risky and uncertain securities prices.

In the real world, there are risks of many sorts. Investors can trade in securities markets to reallocate their wealth across certain types of these risks. In a classic seven-page tour-de-force article, the 1972 Nobel Laureate in economics, Kenneth J. Arrow, clarified the precise nature of the risks that investors can reallocate by trading in securities markets.[10] While risks are ubiquitous in life in general and in financial settings in particular, risks can be classified into at least two categories, namely exogenous risks and endogenous risks.[11]

Exogenous risks are ones that an individual or a society believes lie beyond its control. Neoclassical economic models consider exogenous risks to be data or primitive variables that are taken as given. Economists believe that exogenous risks lie outside the scope of economic systems and

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[7] *See*, e.g. Leonard Savage, THE FOUNDATIONS OF STATISTICS (1954) (providing an overview of modern statistical decision theory).

[8] Frank Knight, RISK, UNCERTAINTY, AND PROFIT 233 (1921) (differentiating between risk and uncertainty).

[9] John Maynard Keynes, A TREATISE ON PROBABILITY (1921) (advocating the view that most forms of economic randomness are difficult to quantify precisely); John Maynard Keynes, THE GENERAL THEORY OF EMPLOYMENT, INTEREST, AND MONEY 149-52 (1936) (stating that long-term investments expectations are not so much rationally formed, but instead based on rather precarious conventions).

[10] Kenneth J. Arrow, *The Role of Securities in the Optimal Allocation of Risk Bearing*, 31 REV. ECON. STUD. 91 (1964).

[11] *See, e.g.*, Peter J. Hammond, *Uncertainty*, in THE NEW PALGRAVE: A DICTIONARY OF ECONOMICS, UTILITY AND PROBABILITY 280, 281 (John Eatwell, et al., eds., 1990) (distinguishing between exogenous and endogenous uncertainty); Mordecai Kurz, *The Kesten-Stigum Model and the Treatment of Uncertainty in Equilibrium Theory*, in ESSAYS ON ECONOMIC BEHAVIOR UNDER UNCERTAINTY 389, 393-97 (Michael S. Balch, et al., eds., 1974) (introducing the distinction between exogenous uncertainty and endogenous uncertainty); MORDECAI KURZ, ENDOGENOUS ECONOMIC FLUCTUATIONS: STUDIES IN THE THEORY OF RATIONAL BELIEFS (Mordecai Kurz, ed., 1997) (collecting papers on a positive theory of endogenous uncertainty); Mordecai Kurz & Maurizo Motolese, *Endogenous Uncertainty and Market Volatility* (May 5, 1999), *at* http://papers.ssrn.com/sol3/papers.cfm?cfid=226302&cftoken=28406860&abstract_id=159608.

the predictive and explanatory realm of economic models. Thus, economists treat exogenous risks as fixed and given. Exogenous risks include variations in consumer tastes and production technologies. Natural weather is the prototypical type of an exogenous risk in the form of such natural disasters as earthquakes, drought, floods, hurricanes, tidal waves, tornadoes, tropical storms, and tsunamis.

Endogenous risks are ones that result from the interaction of individual choices made by consumers, firms, governments, and organizations. Neoclassical applied economists believe that they can forecast or predict endogenous risks. Economists view endogenous risks as the subject of their inquiry and possibly control. Thus, endogenous risks are the subject of economic models and are within the predictive and explanatory purview of economic models. Examples of endogenous risks include the volume of trade and the degree of liquidity of markets. Market prices are the prototypical type of endogenous risk. Other endogenous risks include those variables whose values are determined in part by the functioning of markets. Examples of such variables include product quality, product variety, and the scope of the market. Endogenous price risks correspond to market volatility that is propagated internally by the functioning of markets themselves.

The decision as to whether one classifies a particular risk as exogenous or endogenous depends to a large degree on the scope of a particular model and the level of its analysis. The same risk could be viewed as exogenous for the purpose of one model, but viewed as endogenous for the purpose of another model. For example, a model of the U.S. economy may treat foreign interest rates as exogenous risks. But, a model of the global economy may treat all interest rates as endogenous risks. A classical economic model of domestic environmental policy may treat global warming or the destruction of the ozone layer as exogenous catastrophic risks. However, a more recent economic model of international environmental strategic policy may treat global climate and atmospheric changes as endogenous catastrophic risks that are induced by the industrial emissions of carbon dioxide, the burning of fossil fuels to produce energy, and the global use of chlorofluorocarbons for industrial production.[12]

In addition to the above noted flexibility in the classification of exogenous versus endogenous risks, many, if not most, risks contain both exogenous and endogenous components. An example of such a bundled risk is the harmful effects of cigarette smoking that are due to exogenous genetic dispositions for the harmful effects of smoking and endogenous choices to smoke cigarettes. A ubiquitous example of an economic risk that has exogenous and endogenous aspects is that caused by asymmetric or differen-

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[12] Graciela Chichilnisky & Geoffrey M. Heal, *Global Environmental Risks*, 7 J. ECON. PERSP. 65 (1993) (describing the role that financial markets play in hedging weather risks).

tial information between economic agents. Often, the same underlying economic phenomenon involves moral hazard in the sense of hidden risk attribute or type and adverse selection in the sense of unobservable risk choice or decision.[13] Thus, in the context of health insurance, for example, a policyholder may have different actuarial risk probabilities or pre-existing conditions in addition to making different choices about levels of precaution or amounts of care in terms of exercise or diet.

Exogenous and endogenous risks may differ not only in their sources, but also in the ability of people to accurately forecast them. Exogenous risks by definition exist regardless of human efforts in prediction. Exogenous risks have been around as long as nature has and exogenous risks have not increased in their volatility recently. Finally, human experience over time has resulted in greater accuracy in predicting exogenous risks than in the past. We have a large historical sample of data upon which to base the forecasting of exogenous risks.

Endogenous risks are caused by human choices that in part are the result of human efforts to forecast other humans' choices.[14] Endogenous risks have only been around as long as we have. Endogenous securities price risks have increased in their volatility in recent years. Moreover, humans appear to be no better now at forecasting endogenous price risks than before. A type of quantum uncertainty principle may apply to forecasting market prices in the sense that a residual amount of endogenous risk will always remain in markets.[15]

The conceptual distinction between exogenous and endogenous risks is analogous to that between an individual's type and that individual's choices in multi-person interactive decision theory, also known more commonly as game theory.

> The fundamental problem of game theory (for players and game theorists alike) is to predict how players will behave. Thus players face uncertainty over the endogenous decisions of other players. Incomplete information games are converted into complete, but imperfect information games by introducing the notion of players' types. Thus, strategic uncertainty over endogenous decisions can often be replaced

[13] *See generally,* Jean-Jacques Laffont, THE ECONOMICS OF UNCERTAINTY AND INFORMATION 153-98 (1989) (providing a survey of adverse selection and moral hazard); Ines Macho-Stadler & David Perez-Castrillo, AN INTRODUCTION TO THE ECONOMICS OF INFORMATION 37-182 (1997) (same).

[14] Robert K. Merton, *The Self-Fulfilling Prophecy,* ANTIOCH REV. 193 (1948) (introducing the notion of self-fulfilling prophecies to describe human forecasts of human behavior that are true because or despite those forecasts becoming known).

[15] Werner Heisenberg, 43 ZEITSCHRIFT FUR PHYSIK 172 (1927), *translated in* QUANTUM THEORY AND MEASUREMENT 62 (John Archibald Wheeler & Hubert Zurek, eds.) (1983) (stating the famous uncertainty principle).

by structural uncertainty over exogenous parameters describing a game.[16]

A natural question is thus whether endogenous securities prices can be reduced to exogenous risks in a similar manner. The rest of this Article addresses this fundamental question.

II. REDUCING ENDOGENOUS SECURITIES PRICE RISKS TO EXOGENOUS RISKS

Obviously, exogenous risk can be a source for endogenous securities price risk. For example, the equilibrium stock price of a company that produces, markets, and sells orange juice depends on weather, among other things. Most neoclassical economic models implicitly view exogenous risk as the only source of endogenous securities price risk. In other words, endogenous securities price risks are completely resolved once exogenous risks are completely resolved. In our weather example, once somebody is able to predict weather and other exogenous risks perfectly, that person will also be able to perfectly forecast endogenous securities prices. In order for endogenous securities price risks to be reducible to exogenous risks, investors must be able to compute the competitive market equilibrium values of securities prices upon knowing the values of all exogenous variables. Such amazing computational feats require not only that people know the actual structural equations that describe their economy and can solve for the competitive market equilibrium values of commodity and securities prices, but also that there is a unique vector of such equilibrium prices.

Arrow's pioneering model of the role that securities markets play in allocating risks involved a number of strong assumptions. First, Arrow assumed that investors face only exogenous risks. Second, Arrow assumed that a complete set of competitive securities markets exists, where securities market completeness means that any possible payoff pattern over time and under alternative future risk scenarios can be achieved by trading in active securities markets. Third, Arrow hypothesized that each investor maximizes her expected utility where her subjective probability beliefs are represented by a single individual probability measure.[17] Fourth, Arrow postulated that all investors shared common expectations over exogenous risks and have perfect foresight about spot commodity market prices.[18]

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[16] Peter H. Huang & Ho-Mou Wu, *Market Equilibrium with Endogenous Price Uncertainty and Options*, *in* MARKETS, INFORMATION, AND UNCERTAINTY: ESSAYS IN ECONOMIC THEORY IN HONOR OF KENNETH J. ARROW 100 (Graciela Chichilnisky, ed., 1999).

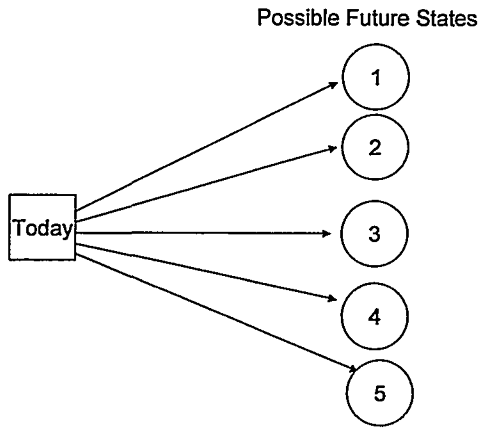
[17] In addition to Knightian uncertainty discussed earlier, there are theoretical and empirical challenges to expected utility theory. *See, e.g.* CHOICES, VALUES, AND FRAMES (Daniel Kahneman & Amos Tversky eds., 2000) (providing classic articles on prospect theory).

[18] A formulation of endogenous uncertainty considers heterogeneous expectations, some of which are mistaken. *See* Kurz (1997), *supra* note 11.

Fifth, Arrow supposed that all investors process information in the same manner.[19]

Each of these assumptions greatly simplified Arrow's analysis thus permitting for a rich, powerful, and tractable model. Arrow formally proved a result that illustrates how securities markets can economize on the number of markets that are required to ensure a Pareto efficient allocation of exogenous risks. Arrow introduced a seminal idea to capture all exogenous risks, namely that of a set of states of the world, also known as states of the environment, or states of nature. A state of the world is a comprehensive notion that "is a description which is complete for all relevant purposes ... about conditions of production or tastes or anything else, which if known, would affect individuals' desires to trade" and "completely specifies demand and supply conditions."[20] "[A] state of the world is a description so complete that, if known to be true, would completely define all endowments and production possibilities."[21] A natural question is whether equilibrium prices are or can be part of a state of the world.[22] The neoclassical formulation of states of the world is depicted in figure 1.

Figure 1: Exogenous Uncertainty



Arrow showed that a complete set of state-contingent securities markets allows investors to achieve the Pareto efficient outcome that would prevail under a complete set of contingent commodity markets. Suppose

[19] *See, e.g.*, Ariel Rubinstein, MODELING BOUNDED RATIONALITY 41-62 (1998) (surveying alternative models of information processing).

[20] Kenneth J. Arrow, THE LIMITS OF ORGANIZATION 34 (1974).

[21] Kenneth J. Arrow & Frank H. Hahn, GENERAL COMPETITIVE ANALYSIS 122 (1971).

[22] Jacques H. Dreze, *The Formulation of Uncertainty: Pricės and States*, *in* MARKETS, INFORMATION, AND UNCERTAINTY: ESSAYS IN ECONOMIC THEORY IN HONOR OF KENNETH J. ARROW, 45, 46, 48 (Graciela Chichilnisky ed., 1999) (asking that question and noting difficulties with answering it coherently).

that a particular economy has C physically differentiated commodities and S states of the world. Arrow asked whether an economy is able to achieve the Pareto efficient outcome that is attainable from S times C contingent commodity markets with less than that many markets. Arrow mathematically demonstrated that an economy can do so by utilizing only S securities markets today and C spot commodity markets in the future. Decreasing the number of required markets from S x C markets to S + C markets is apparently a drastic reduction in the number of markets. Such an economizing on the number of markets lowers the fixed costs of setting up markets and the ongoing transaction costs of running active markets. But Arrow's theorem requires that all of the above five hypotheses are true. In particular, Arrow's theorem assumed that all investors possess rational expectations over the prices that will prevail in a complete system of spot commodity markets for any particular state.

The progeny of Arrow's approach to exogenous risk include the major successes of neoclassical financial economics, namely models that explain how investors can utilize securities markets to reduce if not eliminate some of the financial risks that everyone faces.[23] These models include modern portfolio theory,[24] the capital asset pricing model,[25] the random walk theory of stock prices,[26] the arbitrage pricing theory,[27] and option pricing theory.[28] All of these models explicitly or implicitly assume that securities markets are complete and that endogenous financial risks are solely the result of exogenous risks. Nevertheless, unfortunately and ultimately, both of these are strong and untenable assumptions.

A moment of introspection reveals that although there are many securities markets, there are far fewer securities than there are conceivable states of the world. It is possible for securities markets to be dynamically complete in the sense that repeated trading of a fixed set of multi-period securi-

[23] Melvin W. Reder, ECONOMICS: THE CULTURE OF A CONTROVERSIAL SCIENCE 197-203 (1999) (discussing the success of financial asset pricing models).

[24] Harry M. Markovitz, *Portfolio Selection*, 7 J. FIN. 77 (1952) (modeling the choice of an optimal portfolio for an individual investor).

[25] William F. Sharpe, *Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk*, 19 J. FIN. 425 (1964); John Lintner, *The Valuation of Risk Assets and the Selection of Risky Investment in Stock Portfolios and Capital Budgets*, 47 REV. ECON. & STAT. 13 (1965); Jan Mossin, *Equilibrium in Capital Asset Markets*, 34 ECONOMETRICA 768 (1966); and Jack L. Treynor, Towards a Theory of Market Value of Risky Assets (unpublished manuscript) (1961) (modeling equilibrium stock market prices).

[26] Burton G. Malkiel, *Efficient Markets Hypothesis*, *in* 2 THE NEW PALGRAVE: A DICTIONARY OF ECONOMICS 322 (John Eatwell, et al., eds.) (1987) (describing the random walk theory of securities prices).

[27] Stephen A. Ross, *The Arbitrage Theory of Capital Asset Pricing*, 13 J. ECON. THEORY 341 (1976) (using arbitrage principles to model asset prices).

[28] Fisher Black & Myron Scholes, *The Pricing of Options and Corporate Liabilities*, 81 J. POL. ECON. 637 (1973); Robert C. Merton, *Theory of Rational Option Pricing*, 4 BELL J. ECON. & MGMT. SCI. 141 (1973) (providing models of pricing options).

ties generates any set of payoffs across the underlying states.[29] However, such a theoretical possibility assumes the very strong hypothesis that investors possess rational expectations over the stochastic process that prices of multi-period securities will follow. In fact, substituting the reconvening of multi-period securities markets for the number of those markets requires demanding assumptions on the degree of rationality of expectations over prices that investors possess. Many investors, especially institutional ones, exhibit much higher levels of rationality than are true of the apocryphal widows and orphans that SEC regulations and rules are purportedly designed to protect. Institutional investors can increasingly make their financial decisions with the aid of artificial intelligence, nonlinear chaotic models, genetic algorithms, neural network time series forecasting, and sophisticated quantitative computer valuation models.[30] But, even these very sophisticated investors will have difficulty forming rational expectations over multi-period stochastic price processes as the number of periods increase. Most investors do not understand or even know the structural equations describing their economy. Even were financial institutions given this information, they may be unable to compute the values of equilibrium prices once they correctly deduce the actual state. Instead of being omniscient and unboundedly rational, financial institutions utilize statistical methods to make the best estimates of their idiosyncratic models of securities prices. The prevalence of unforeseen contingencies is a major reason why investors will not be able to have perfect foresight. Unforeseen contingencies also explain why real world securities markets are incomplete.[31]

The assumption that securities markets are complete, dynamically or statically, is thus a counterfactual one. There is a recent literature about incomplete securities markets in the presence of exogenous risks. This financial economic theory is known as the general equilibrium theory of incomplete securities markets.[32] It is abbreviated by the acronym of GEI. The normative implications of GEI theory are threefold.[33] First, if a suffi-

[29] Darrell Duffie & Chi-Fu Huang, *Implementing Arrow-Debreu Equilibria by Continuous Trading of Few Long-Lived Securities*, 53 ECONOMETRICA 1337 (1985) (demonstrating the possibility of dynamically complete securities markets).

[30] *See, e.g.*, Paul Wilmott, PAUL WILMOTT ON QUANTITATIVE FINANCE, VOL. 1 & 2 (2000).

[31] David M. Kreps, *Static Choice in the Presence of Unforeseen Contingencies*, *in* ECONOMIC ANALYSIS OF MARKETS AND GAMES: ESSAYS IN HONOR OF FRANK HAHN 258 (Partha Dasgupta, et al. eds., 1992).

[32] *See, e.g.*, Darrell Duffie, *The Nature of Incomplete Security Markets*, *in* 2 ADVANCES IN ECONOMIC THEORY 214 (1992) (presenting a synopsis of the basic GEI models); John D. Geanakoplos, *An Introduction to General Equilibrium with Incomplete Asset Markets*, 19 J. MATH. ECON. 1 (1990) (providing another perspective on GEI); Michael Magill & Martine Quinzii, THEORY OF INCOMPLETE MARKETS (1996) (offering yet another exposition of GEI).

[33] Peter H. Huang, *A Normative Analysis of New Financially Engineered Derivatives*, 73 S. CAL. L. REV. 471, 473-74 (2000) (explaining these three policy implications).

cient number of securities markets are missing, then a GEI is typically associated with a constrained Pareto inefficient allocation of exogenous risks. Second, introducing some, but not enough distinct securities markets, has indeterminate normative consequences for the allocation of exogenous risks. Finally, government regulation might not improve the social allocation of exogenous risks because of informational or political economy obstacles.

Recent advances in theoretical financial economics and the modeling of bounded rationality extend the neoclassical financial economics paradigm in various directions. This Article considers the policy implications for the regulation of derivative and securities markets of some of the recent extensions in financial economic theory involving the phenomenon of endogenous securities price risks and incomplete derivative and securities markets in the face of such risks. In doing so, this Article parallels a previous article of the author's that provided a detailed exposition of the GEI literature and its regulatory policy implications regarding financial engineering in the face of exogenous risks. This Article provides an explanation of the differences and similarities between the ability of securities markets versus derivative markets to reallocate respectively exogenous risks versus endogenous securities price risks.

III. IRREDUCIBLE ENDOGENOUS SECURITIES PRICE RISKS

A leading economic theorist stated in her essay that extends the canonical model of neoclassical economics to incorporate endogenous price risks, "Kenneth Arrow once said that uncertainty about prices may be the most important form of economic uncertainty. Yet the treatment of uncertainty in Arrow-Debreu markets reflects only nature's moves. It therefore neglects price uncertainty, because prices depend on human behavior."[34] The phrase Arrow-Debreu markets refers to a canonical model of a competitive market economy due to a pair of economics Nobel Laureates, Kenneth J. Arrow (a 1972 recipient) and Gerard Debreu (a 1983 recipient).[35] This model has become the standard benchmark among economic theorists of what constitutes an excellent model. As another leading economic theorist stated in the introduction to a graduate industrial organization text which is a standard in that field, "[t]he best-developed and most aesthetically pleasing model in the field of economics is the competitive-equilibrium paradigm of Arrow and Debreu."[36]

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[34] Graciela Chichilnisky, *Existence and Optimality of General Equilibrium with Endogenous Uncertainty*, *in* MARKETS, INFORMATION, AND UNCERTAINTY: ESSAYS IN ECONOMIC THEORY IN HONOR OF KENNETH J. ARROW 72 (1999).

[35] Kenneth J. Arrow & Gerard Debreu, *Existence of an Equilibrium for a Competitive Economy*, 22 ECONOMETRICA 265 (1954) (proving that a competitive equilibrium exists and is Pareto efficient in a model of a complete system of goods markets under certainty).

[36] Jean Tirole, THE THEORY OF INDUSTRIAL ORGANIZATION 6 (1988).

The Arrow and Debreu paradigm captures the intuition that in a complex economy, everything may depend on everything else.[37] The focus of the Arrow-Debreu model is on demonstrating that a competitive economy has a general equilibrium vector of market-clearing prices. The phrase general equilibrium ("GE") distinguishes the Arrow-Debreu model from the partial equilibrium approach that is most often associated with the University of Chicago School of Economics. A GE model consists of a system of simultaneous equations representing equality of demand and supply for every market in an economy. A partial equilibrium approach to an issue just looks at one single market in isolation. The difference between general versus partial equilibrium analysis is that the former is more complex, while the latter sometimes might suffice for the purpose of policy formulation. Nonetheless, in many situations, including the international context, partial equilibrium approaches will be insufficient, if not misleading for making policy recommendations. GE theoretical and computational models are the appropriate tools for understanding markets that are linked across national boundaries.

The Arrow-Debreu model under uncertainty envisions an economy in which there is a complete system of contingent goods markets indexed by time periods and states of the world. Such a model is not now, nor was it ever, intended to be a realistic description of any economy. Rather, the Arrow-Debreu model is a normative ideal because Arrow and Debreu mathematically demonstrated that under certain technical conditions, a competitive market economy has a GE and that every such GE is Pareto efficient. This result is known as the first fundamental theorem of welfare economics.[38] It formalizes the intuition captured in the metaphor, due to Adam Smith, of an economy whose inhabitants are motivated not by altruism, but as if they were guided by the invisible hand of self-interest to reach a Pareto efficient allocation.[39]

As this Article pointed out earlier, the formulation of a state of the world introduced by Arrow is able to capture the phenomena of exogenous risks, but not endogenous securities price risks. Fortunately, several recent models in theoretical financial economics deal with endogenous price risks. One approach to endogenous price risks is based upon the simple, but far-reaching observation that competitive market economies typically have a

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[37] Marilu Hurt McMarty, THE NOBEL LAUREATES: HOW THE WORLD'S GREATEST ECONOMIC MINDS SHAPED MODERN THOUGHT 171-74 (2001) (describing general equilibrium models and explaining their significance).

[38] *See, e.g.* David M. Kreps, A COURSE IN MICROECONOMIC THEORY 199 (1990); Andreu MasColell, et al., MICROECONOMIC THEORY 549 (1995); Hal R. Varian, INTERMEDIATE MICROECONOMICS: A MODERN APPROACH 522 (5th ed., 1999) (stating and proving alternative formulations of the first fundamental theorem of welfare economics).

[39] ADAM SMITH, AN INQUIRY INTO THE NATURE AND CAUSES THE WEALTH OF NATIONS 423 (Edwin Cannan ed., reprint, Modern Library 1937) (1776) (stating the metaphor of an invisible hand).

multiplicity of GE. Even in the absence of any sort of exogenous risk, a typical economy will have multiple GE.[40] More precisely, economies that possess a unique GE are rare in two related but distinct senses. First, randomly perturbing the parameters describing any economy that has just one GE results in parameters describing another economy with multiple GE. The standard parameters that describe an economy are the goods and skills that people are initially endowed with, the tastes that individuals have in their roles as consumers, and the alternative technologies that producers can utilize in supplying markets. Second, the parameters that correspond to any economy with multiple GE have around them an entire neighborhood of nearby parameter values that also describe other economies with multiple GE. A property P is said to be true generically if the set of parameters describing an economy for which P is true has the above two properties. Thus, non-uniqueness of GE is true generically. The intuition for the generic multiplicity of GE is that uniqueness of GE requires very stringent conditions to be true. An example of such a condition is the gross substitutability property for the aggregate excess demand function.[41] Another example is assuming that the aggregate excess demand function satisfies the weak axiom of revealed preference.[42]

The multiplicity of GE for typical economies means that even were people to know and understand the structural equations describing their economy, they cannot predict which of the multiple GE will come to prevail. In other words, even assuming an amazing degree of rationality, knowledge, and computational abilities, the non-uniqueness of GE means that equilibrium securities prices are sources of endogenous risks. Indeterminacy of GE means that it is impossible to reduce all endogenous securities price risks into exogenous risks because even after the state of the world is known, there remains multiplicity of GE.

The difference between these alternative views of endogenous securities price risks is captured visually by figures 2 and 3. In figure 2, there are several exogenous states of the world. But, once the state is known or correctly deduced, economic actors are assumed to be able to compute the unique GE price vector that corresponds to that particular state of the world. In symbols, s denotes the alternative states of the world. Thus, s lives in the set S, which consists of all of the mutually exclusive and exhaustive de-

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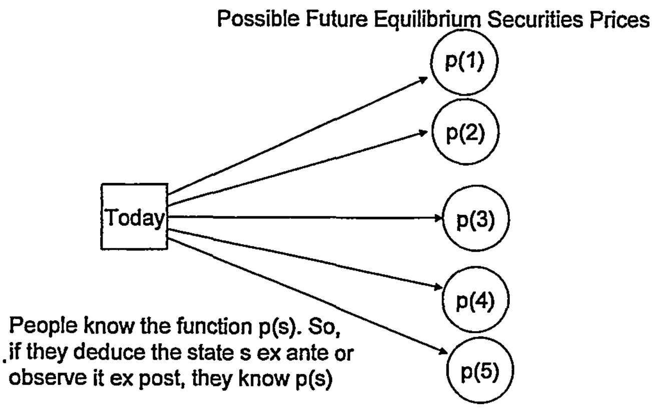
[40] Gerard Debreu, *Economies with a Finite Set of Equilibria*, 38 ECONOMETRICA 387 (1970) (proving that most economies have multiple competitive equilibria).

[41] Timothy J. Kehoe, *Uniqueness and Stability*, *in* ELEMENTS OF GENERAL EQUILIBRIUM ANALYSIS 38, 43-44, 83 (Alan Kirman, ed.) (1998) (noting the restrictive nature of conditions that guarantee uniqueness of GE and explaining the role of the condition of gross substitutes in obtaining uniqueness of GE).

[42] MAS-COLELL, *supra* note 38, at 606-14 (1995) (observing that uniqueness of GE can be guaranteed only in special cases and explaining how the weak axiom of revealed preference and gross substitutes assumption each imply uniqueness of GE).

scriptions of payoff relevant exogenous risks.[43] This formulation means that just one value of s will come to pass. Risk in this world means not knowing ex ante which s will be the one that is realized ex post because the inhabitants of these models know or can solve for the function that maps exogenous states of the world into equilibrium price vectors. Let p(s) denote this function. To say that p(s) is a function assumes that there is a unique GE for every possible state of the world. Thus, the reduction of endogenous securities price risk to exogenous state risk can only occur at the expense of assuming not only hyper-rationality by investors, but also the strong conditions that are required to ensure the uniqueness of GE.

Figure 2: Reducible Endogenous Securities Price Risk



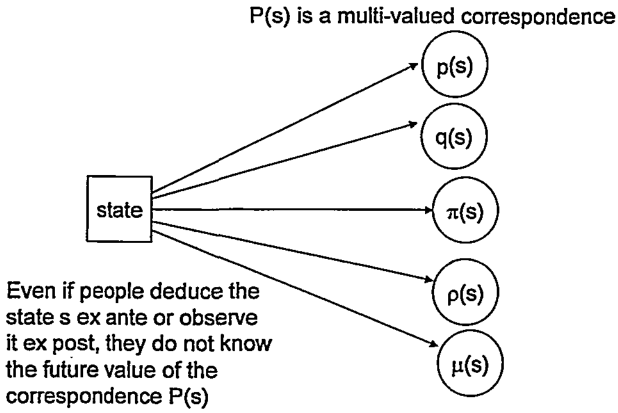
In figure 3, the later heroic uniqueness assumptions are dropped. In other words, figure 3 maintains the assumption that investors of this fictional world know or can solve for what is known as the equilibrium correspondence P(s) because they know the structural equations of their economy.[44] Once again, P(s) maps exogenous states of the world into equilibrium securities price vectors. The difference between figure 2 and figure 3 is that investors now realize the mapping P(s) is for typical economies a genuine multi-valued correspondence and not a single-valued function p(s). Although both figures 2 and 3 involve endogenous securities price risks, the difference between them resides in the source of those risks. In figure 2, the source of endogenous securities price risks is risk over which of the several exogenous states of the world is likely to materialize. In figure 3, the source of endogenous securities price risks is risk over multiple GE even after some particular exogenous state of the world materializes. The endoge-

[43] The cardinality of S is often assumed to be a finite set for mathematical simplicity, although there are models with a continuum of states of the world.

[44] *See e.g.*, Yves Balasko, FOUNDATIONS OF THE THEORY OF GENERAL EQUILIBRIUM 14 (1988).

nous securities price risk in figure 2 completely disappears once investors can deduce the actual state of the world ex ante or after they observe the actual state of the world ex post. The endogenous securities price risk in figure 3 persists even if investors can deduce the actual state of the world ex ante or after they observe the actual state of the world ex post.

Figure 3: Irreducible Endogenous Securities Price Risk



A recent financial economic model investigates the role of derivative markets in the optimal allocation of endogenous securities price risks.[45] In particular, that model demonstrated that a complete set of competitive European option markets permits a Pareto-efficient allocation of endogenous securities price risks.[46] Such a comforting theoretical result provides a normative benchmark supporting a laissez-faire regulatory stance towards an economy with a complete set of European options markets.[47] Interestingly, while European options may appear to be redundant assets because there will be a unique spot market equilibrium, the presence of a set of complete European options markets is crucial to guard against non-equilibrium expectations about endogenous securities spot market prices.[48] Thus, European options play a slightly different role in helping investors cope with endogenous securities price risks than they do in helping investors deal with exogenous risks.

[45] Huang & Wu, *supra*, note 16, at 97 (Graciela Chichilnisky, ed.) (1999) (providing such a model of endogenous securities price risks).

[46] *Id.* at 109-111: Propositions 3 and 4 (proving that a complete set of European options markets eliminates endogenous price risk. A European as opposed to American option provides its owner with the right to buy or sell an underlying security at some fixed price on some date as opposed to anytime before that date also.).

[47] For a discussion of the notion of completeness when there is endogenous risk, *see id.* at 108.

[48] *Id.* at 111 (discussing this phenomenon).

However, if as is likely the case, European option markets are incomplete, their role must be modified. An economy with incomplete European option markets will not generate competitive equilibrium allocations that are Pareto-efficient allocations of endogenous securities price risks.[49] Thus, a model of incomplete European option markets provides a framework to study the normative properties of financial innovation and financial engineering to manage endogenous securities price risks. In fact, the GEI of economies involving endogenous securities price risks have normative consequences that differ from those in the complete markets case.[50] As was true for exogenous risks, GEI are not only Pareto-inefficient, but also constrained Pareto-inefficient.[51] In addition, as was true in the case of exogenous risks, adding European options markets without completing asset markets has indeterminate normative consequences. Finally as was true in the case of exogenous risks, the possibility that government intervention can improve social welfare for typical economies depends on regulators being benevolent and sufficiently knowledgeable.

The notion of endogenous price risks is causing a fundamental rethinking among economists of the neoclassical theoretical financial economic models that were premised on exogenous risks.[52] This rethinking has the potential for very far-reaching paradigm-shifting consequences within many fields of economics, including financial economics and macroeconomics. Two of the most important endogenous price risks that ordinary people must cope with are those of inflation and recession.[53] Both of these risks affect an individual's consumption, investment, and retirement. A similar rethinking of legal attitudes towards financial innovation and financial engineering involving derivative markets is required because after all a promise of derivative instruments is their potential to hedge against endogenous price risks of the underlying cash instruments that derivatives are written upon.

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[49] *Id.* at 113 (discussing inefficiency of equilibrium allocations).

[50] *Id.* at 111-16 (assessing the current state of models involving endogenous securities price risk for economies with incomplete European options markets).

[51] An allocation of commodities and securities is Pareto inefficient if there is a reallocation of commodities and securities that makes at least one person better off without making any other person worse off. An allocation of commodities and securities is constrained Pareto inefficient if there is a reallocation of securities alone that makes at least one person better off without making any other person worse off.

[52] Huang & Wu, *supra* note 16, at 99-102, and the references that are cited therein.

[53] Robert J. Shiller, MACROMARKETS: CREATING INSTITUTIONS FOR MANAGING SOCIETY'S LARGEST ECONOMIC RISKS 52, 94 (1993) (documenting the lack of much insurance against recession and inflation).

IV. CONCLUSIONS

In the presence of endogenous securities price risks, as was true in the case of exogenous risks, for typical economies, there are new issues raised by multiplicity of equilibrium prices for underlying spot commodity and securities markets. As with the case for exogenous risks, how effectively households can utilize competitive European option markets to hedge irreducible underlying endogenous securities price risks depends on whether such European option markets are complete. With complete European option markets, European options fully insure against underlying price risks. But, with incomplete European option markets, European options do not fully insure against underlying price risks and so, they are not redundant assets and cannot be priced by arbitrage.

This article has only scratched the surface in terms of the new concepts, ideas and normative results that endogenous securities price risks offer legal scholars concerned about derivatives.[54] Hopefully this article, by drawing attention to the notion of endogenous securities price risks, will inspire other legal scholars to join in considering the implications of endogenous securities price risks on regulating derivative and securities markets. Increasingly, the dual forces of globalization and technological change affect financial markets. These developments can result in higher volatility and greater interdependency of underlying capital markets. That increased endogenous securities price risk in turn means that derivative markets have a larger potential role to play in hedging against or speculating upon such risks.[55] Whether that potential is realized depends on whether the regulation of derivative markets is informed by the new advances in financial economic understanding of endogenous securities price risks.

Hopefully, over time legal scholars, judges, and regulators will incorporate the lessons of recent financial models of endogenous securities price risks and endogenous non-price risks that extend the well-known models of exogenous risks from the golden age of neoclassical finance. Although this article focused on the role of derivatives in hedging against endogenous securities price risks, there are financial economic theoretical models on the role of securities markets in hedging against endogenous non-price risks.[56]

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[54] *Id.* at 113-16 (discussing a model of endogenous price risks when investors do not have full structural knowledge of their economy).

[55] Alessandro Citanna, *Financial Innovation and Price Volatility* (Mar. 21, 2000), *at* http://papers2.ssrn.com/paper.taf?ABSTRACT_ID=260912 (proving that for sufficiently incomplete securities markets, generically financial innovation can decrease, increase, or have no effect on price volatility).

[56] *See, e.g.*, Graciela Chichilnisky & Geoffrey M. Heal, *Catastrophe Futures: Financial Markets for Unknown Risks*, in MARKETS, INFORMATION AND, UNCERTAINTY: ESSAYS IN ECONOMIC THEORY IN HONOR OF KENNETH J. ARROW 120 (Graciela Chichilnisky, ed.) (1999) (providing a model of the role of securities markets in the optimal allocation of endogenous non-price risks).

In addition, the Chicago Board of Trade introduced in 1994 the trading of catastrophe futures, whose payoffs depend on the values of annual indices of insurance claims against such natural disasters as hurricanes or tropical storms in the United States, as measured by the Insurance Service Organization.[57] Catastrophe futures can be combined with contingent insurance or mutual contracts to form what are known as catastrophe bundles.[58]

In conclusion, the normative analysis of derivatives when endogenous securities price risks are irreducible to exogenous risks parallels the normative analysis of derivatives when endogenous securities price risks are reducible to exogenous risks. There are, however, theoretical questions that remain open when option markets are incomplete for endogenous securities price risks that are irreducible to exogenous risks.[59] In particular, the incompleteness of European option markets raises the possibility that people will face uncertainty in the Knightian sense instead of risk over endogenous securities prices.[60]

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[57] Chichilnisky, *supra* note 12, at 72.

[58] *See, e.g.*, Graciela Chichilnisky, *Catastrophe Bundles Can Deal with Unknown Risk*, 1 BEST'S REV. (Feb. 1996) (describing catastrophe bundles from an industry perspective).

[59] Huang & Wu, *supra* note 16, at 116 (discussing open theoretical questions in the case of incomplete European option markets).

[60] *Id.*