A Methodological Study of Economic Uncertainty

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Abstract

Economists have long considered uncertainty an important variable in determining how decision-makers operate in the economy. Despite its importance, the New Classical school of macroeconomics has relegated the topic to the field's periphery. Post Keynesian researchers have criticized New Classical assumptions that oversimplify an uncertain world. This thesis applies a Kuhnian framework to understand the importance of uncertainty in the field. Drawing upon Post Keynesian criticisms and recent financial crises, this thesis explores the effect of conflating risk with uncertainty. We find that some patterns within economic research suggest uncertainty could serve as a point of revolution given the right circumstances.

1 Introduction

What probability could we assign to the occurrence of a European war 30 years in the future? What about a prediction of the price of copper over the same period? John Maynard Keynes proposed these questions to illustrate situations where uncertainty obscures a calculable future outcome. In the words of Keynes, there are times when "we simply do not know" (Keynes, 1937). Assumptions about decision-making tendencies occupy an important piece of the foundation for micro and macroeconomic models. Economic uncertainty arises out of this study of decisions and future expectations. From the works of Keynes to that of Frank Knight toward the beginning of the 20th century, uncertainty has become a subject at the periphery of economic modeling with the arrival of the New Neoclassical Synthesis. The rise of concepts like the rational expectations hypothesis has emphasized the ability of quantifiable risk to encapsulate uncertainty while leaving ontological concerns unresolved.

This thesis will introduce a methodological framework to understand the importance of uncertainty in the field of economics. Thomas Kuhn's concept of paradigms provides a solution for understanding the consistent dissonance between economists when considering uncertainty and risk. Although Kuhn's

work arose through an analysis of the natural sciences, the evolution of economic thought fits a similar pattern. Previous authors have applied this framework to economics[1] to different ends. This thesis will take advantage of Kuhn's work as well as previous applications of paradigms within economics to help frame the development of risk and uncertainty throughout the history of the subject.

This thesis will chart the study of uncertainty and outline the two major schools of thought on the subject as well as their development throughout time. The analysis of Keynes and Knight preceded the development of subjective expected utility theory. Despite the work of Keynes and Knight, risk replaced uncertainty at the center of economic orthodoxy. The application of probabilistic statistics to decision-making provided a basis for more mathematical applications within economics. Economic modeling evolves again with the rational expectations hypothesis which consolidates modeling assumptions across economic and financial analysis. Consistent economic growth from the 1980s onward in many Western economies reinforced the emerging techniques despite warning signs from the Long-Term Capital Management crisis during the 1990s. In the wake of the financial crisis and the end of the great moderation, some economists identified key flaws in established economic theory. Yet the textbook study of economics remains the same. Uncertainty remains a problem in the field as a subject that gains importance during times of crisis. In the wake of the subprime crisis, economists have attempted to address this problem in new ways that warrant analysis within the Kuhnian framework. Using the subprime crisis and the downfall of Long-Term Capital Management as case studies, this thesis will explore the role of uncertainty in facilitating major changes in the field looking into the future.

2 Methodological Framework

Thomas Kuhn's *Structure of Scientific Revolutions* provides a useful lens through which this thesis will review economic uncertainty. In the book, Kuhn pushed against the cumulative theory of scientific progress as described by Popper (1963). Kuhn described a non-monotonic method for evolution involving what he calls scientific paradigms. After a period without a solid foundation, a field comes to maturity by adopting a dominant paradigm that sets the theoretical basis for research. Any paradigm provides the basic standards for the science; also, according to Kuhn, the paradigm must attract a sufficient following while also providing questions for further research (1970, pg. 10). Periods without a dominant paradigm are marked by "deep debates over legitimate methods,

[1] Kuhn's ideas have also had an impact in the field of sociology, notably David Bloor and the Edinburgh school. We provide Barnes *et al.* (1996) to interested readers.

problems, and standards of solution" which inhibits much actual scientific experiment (Kuhn, 1970, pg. 48). A paradigm provides stability to a field through consistency of practice.

Paradigms need not explain every phenomenon in a field to become dominant. There may exist some specific problems within a field deemed valuable by scientists, whose solutions become more important. The problems deemed the most important by scientists in the field become the questions that the paradigm must solve to become dominant. The dominant paradigms answer a small subset of important questions that serve as a foundation for the further articulation of the field. This focuses research efforts on specific fields while leaving many phenomena unexplained. The goal of the scientists within an established paradigm becomes the articulation of those fundamental theories. Kuhn compared the work of scientists to puzzle-solving. Some scientific problems have anticipated outcomes based on theory, but the method for reaching the outcome remains unknown Kuhn (1970). The paradigm provides the tools for scientists to use in innovative ways to solve problems that may have an anticipated solution derived from underlying theory. The paradigm grows as scientists solve the puzzles.

However, these paradigms have disincentives for scientific discoveries that upset expectations. Violating the predictions of a paradigm would suggest an error or new dynamic that disrupts the underpinnings of the field. The establishment of a paradigm leads to a certain complexity or "professionalization" of the field that fosters "considerable resistance to paradigm change" (Kuhn, 1970, pg. 64). Paradigms provide stability which allows further articulation of a field; maturity increases precision in the field which leads to the discovery of anomalies that upset the field's foundations. Anomalies arise when researchers discover a problem without a reachable solution given the tools of the paradigm.

While a paradigm sets the stage for the discovery of anomalies, the presence of these problems alone does not ignite scientific revolution or change in paradigms. The transition between two different paradigms requires the construction of new theories and the destruction of insulated theories. The shift from Ptolemaic to Copernican astronomy provides one such revolution that illustrates the crisis necessary for a change. In this case, the convergence of a "technical crisis" with social pressures proved a strong enough problem for Copernicus to explore an alternative theory (Kuhn, 1970, pg. 69). The crisis arrived as the culmination of failed attempts to resolve problems that have existed within the field years before. New theories emerge as a "direct response to crisis" (Kuhn, 1970, pg. 75).

Crises emerging from unique anomalies create ambiguities within the practice of normal research. Boundaries become blurred as scientists search for ways to resolve the major problem. Although the crisis can subside within the ex-

isting paradigm, the transition to a new paradigm proves most interesting and relevant within this context. The rejection of one paradigm means the acceptance of another. Crises increase the number of discoveries as scientists test the boundaries of their current paradigm; a competing school of thought may also grow in popularity as a potential new paradigm. Scientists decide between the current and new paradigms by seeing which puzzles each provides and which problems each addresses. Comparing different paradigms becomes challenging as the language of one school differs from that of another; incommensurability refers to a situation when an idea or phrase in one paradigm has no meaning in another. Without a shared language, competing paradigms cannot logically argue about their worth to the other. If another candidate paradigm arises as the result of a crisis, debates begin in the scientific community. No historic pattern has emerged among the paradigms which overthrew their predecessors, but the ability to explain major shortcomings of the previous paradigm and the promise of future research are two important traits. Despite the tenacity of some scientists within older paradigms, newer generations eventually usher in a new era for the field.

2.1 Application to economics

Kuhn treats social sciences as separate from the natural sciences. It remains a question as to the validity of its application to the field of economics. Economics during the 20th century seemed to follow a path of paradigmatic revolutions. Keynesian economics supplanted the Neoclassical school following the Great Depression. The existence of systematic unemployment proved unsolvable under the previous regime; the combination of a technical flaw with social pressures led to a revolution. The period of elevated inflation and unemployment during the 1970s and 1980s served as the crisis that started the movement from Keynesian economics to the New Classical model which dominates today. These developments[2] strike a similar pattern to the paradigmatic revolutions described by Kuhn.

Additionally, economists have endeavored to formalize the field throughout the 20th century with the use of mathematical proofs to support economic theory. Subjective expected utility theory is one example of this trend, but a major part of this shift involved developments within econometrics. Haavelmo (1944) presented an early example in his argument to model the economy with a set of equations leading to a probability distribution of potential outcomes. Continued iterations upon this idea lead to the dynamic stochastic general equilibrium

[2] Mankiw (1990) provides a broad view of macroeconomic developments during the 1970s and 1980s which captured a major transition in the paradigmatic evolution of economics.

models which dominate macro econometrics today. Methods for approaching the randomness of human behavior in the economy and the mathematization of financial economics have set a standard of formalization across the field.

These methods have their limits which set economics steps away from the natural sciences. Velic (2008) assessed the validity of treating economics as a science. Experimental conditions for economic tests fluctuate more than those of hard sciences[3]. However, economists, like other natural scientists, cannot hold every exogenous variable constant (Velic, 2008). The distinctions between econometrics and work in other hard sciences indicate shortcomings for work in economics. Econometric predictions often rely more heavily on the stability of certain conditions leading to weaker results (Velic, 2008). Econometricians also have the choice of which models to apply to given data. Different methods may give different results, and the econometrician may present the lone model among many attempts that provided the result corresponding with their pre-established theory (Velic, 2008). Consistent practices within the field and greater access to data on human behavior could solve some of these problems. Current practices within econometrics, like relying upon narrow conditions or tinkering with models until one fits given data, suggest that the field remains distinct from other hard sciences.

Despite falling into a different category for Kuhn, the field of economics has still received analysis within the Kuhnian framework due to its similar developmental pattern. McCombie and Pike (2013) considered the staying power of the New Neoclassical Synthesis in the wake of the 2008 financial crisis, exploring the paths to communication between two competing paradigms. The two authors also analyzed the unique challenges that economics poses as a field within the paradigmatic structure; due to the limitations of economics as compared to other sciences, economic paradigms lack an "objective or logical" basis for their sustenance (McCombie and Pike, 2013, pg. 505). Jalladeau and Kuhn (1978) viewed the transition into neoclassical economics at the start of the 20th century through the lenses of a Kuhnian and Lakatosian framework. The Lakatosian theory, although related to Kuhn, relies less on the psychology present in Kuhn's theory and more on the Popperian tradition with more rationality in the development of a science. The authors concluded that the ideological shift in question follows the Kuhnian structure of scientific revolutions more closely than the theory outlined by Lakatos. Fischer (1993) used a Lakatosian framework to explain

[3] The nonstationarity of many economic situations poses a problem to econometricians, but the allowance for time variance within models helps resolve the issue from a wider perspective. However, certain assumptions about how people act within models generally rely upon stationary probability distributions from which representative agents make decisions. Nonstationarity remains a unique problem regarding the formulation of decision-makers within these models.

the persistence of an "equilibrium paradigm" in economics.

Lakatosian research programs warrant a short departure as they differ from Kuhnian paradigms. Two key pieces make a research program as defined by Lakatos, a collection of fundamental ideas creating the "hard core" surrounded by a "protective belt" of additional theories that can more often change (Jalladeau and Kuhn, 1978, pg. 585). The core provides stability so that scientists can test hypotheses within the outer layers and adjust the belt if necessary. The research program then provides scientists with a double heuristic guiding their studies; the program provides avenues for scientists to complete their research while also forbidding any questions pointed toward the core. Additionally, Lakatos drew upon the Popperian tradition to classify research programs as either "progressive" or "degenerating" based on the ability of a research program to add knowledge (Jalladeau and Kuhn, 1978, pg. 587). Unlike Kuhn, Lakatos saw periods of normal science as avoidable and championed academic pluralism. Lakatos supported a linear progression in the production of knowledge, based in rationality as emphasized in Jalladeau and Kuhn (1978). Lakatos's account did not resolve the problem of incommensurability between competing programs which leaves a gap in his Popperian approach. Kuhn provided an account of scientific development that incorporates subjectivity and psychology in a way that is more appealing when reviewing the history of economics as a field.

Returning to Kuhn, McCombie and Pike (2013) highlighted the incommensurability of language between competing paradigms. Two paradigms with differing foundations may not share the same vocabulary; an argument on behalf of one paradigm will communicate using a language potentially indecipherable from the perspective of another paradigm. McCombie and Pike (2013) distinguished between strong and weak incommensurability; the strong form indicates examples of terms that have no meaning in alternative paradigms while the weak form references situations of shared terms with differing interpretations. Post Keynesians include uncertainty as a key topic for their analysis, but the subject is weakly incommensurable with economic orthodoxy. Within the mainstream, assumptions like the rational expectations hypothesis preclude the analysis of unquantifiable uncertainty. McCombie and Pike (2013) emphasized the importance of rhetorical persuasion and the research of Deirdre McCloskey[4] for the scientific revolutions of economics.

Most often, the use of a Kuhnian or related framework criticizes or warns about the dangers of certain implications of a dominant paradigm. Rousseas (1973) feared the permanency of normal science and pushed back against the formalization of the field and the cementing of a dominant paradigm. Walker (2010) argued for academic pluralism within the field of international relations

[4] See McCloskey and McCloskey (1994) for further discussion.

and believed that paradigmatic research restricted scientific development. Heise (2014) took a Lakatosian perspective in the aftermath of the 2008 crisis to predict future developments in the paradigmatic structure of the field. Without predicting a scientific revolution, the author pointed to the subfields of behavioral economics and behavioral finance as those that stood to grow during the 21st century.

Even though economics fails to fit the formal definition of natural science, many authors have applied a Kuhnian (or related) framework to the field. This thesis differentiates from others with the analysis of the risk/uncertainty dichotomy through this lens. This problem remains crucial for the formalization of the field, and using this framework will elucidate the position of uncertainty as a pressure point for the practice of economics.

3 Risk and Uncertainy in Economics

3.1 Foundations

Different definitions of uncertainty have emerged throughout time. Keynes provided an early and oft-cited version of uncertainty in a 1937 article titled "The General Theory of Employment". Within this article, he described the nature of uncertain knowledge as predicting the "prospect of European war" or "the price of copper and the rate of interest twenty years hence" (Keynes, 1937, pg. 214). However, this quote in isolation misrepresents the development of his point of view in the context of his prior works. Keynes (1936), his hallmark work, approached the subject when discussing long-term expectations as a factor in the return on an investment. Keynes recognized the importance of available knowledge in macroeconomic processes, but his study of uncertainty extends further back in time. As a student of mathematics before economics, Keynes began by describing the decision-making process using probability as a key measure in the determination of outcomes. Probability for Keynes represented "the degree to which a person can rationally believe a conclusion" based on initial conditions (Rotheim, 1988, pg. 83). Each decision maker starts with a set of premises from which they can take logical steps to reach some conclusion; probability replaces complete certainty for the inductive process (Carvalho, 1988). Problems arise when the interactions between premises become too complex to comprehend.

In cases of incomplete knowledge, the decision maker must fill the gaps with "imagined premises" with varying levels of accuracy (Carvalho, 1988, pg. 74). Uncertainty within this context refers to the availability of information for the decision maker at the time of a decision. However, the uncertainty can reference information unknown but knowable, information that is completely unknowable,

or situations with known premises but unknown interactions[5]. Rotheim (1988) put more emphasis on the shift from rational induction to the understanding of interactions between premises. The initial decision-making framework produced by Keynes assumed a fixed understanding of independent premises and the conclusions leading from them in an atomistic system (Rotheim, 1988). An atomistic system suggests the independence of fixed parts allowing for the deduction of their consequences. In "organic conditions," this assumption of independent premises fails to describe a complex reality that characterizes most real decisions. This switch to a more realistic worldview led to the distinction made by Keynes in his 1937 article. He explained this distinction as a reaction to mainstream long-run equilibrium analysis which takes known conditions as an assumption. He noted roulette as an example of something with calculable outcomes unlike that of war (Keynes, 1937). Keynesian uncertainty appeared here to be defined in an ontological way; the conditions of reality obscure the predictability of future outcomes.

Keynes's liquidity preference followed from this distinction as money provides a store of wealth under unclear business conditions. Liquidity preference emerged as one clear innovation in the Keynesian method that relates to uncertainty. Runde (1994) provided a concise analysis of the topic and its relation to uncertainty. For Keynes, there were three motives for holding money: transactional, speculative, and precautionary. It is the latter of these motives that draws the closest link to uncertainty as defined above. While speculative motivation indicates some sort of confidence in the future, the precautionary motive originates from uncertainty about potential future opportunities unknown at the present. The Keynesian asset choice framework introduced a liquidity premium term to reflect the availability of the given asset. If decision-makers lack a complete basis of information, then people will desire flexibility to alter previous decisions or a liquidity preference for asset choice.

Keynes's theory became further developed with the arrival of the IS-LM model[6] created by John Hicks. However, Hicks's later reflections suggested some dissatisfaction that prefaced the development of Post Keynesians on uncertainty. Hicks (1980), a radical departure from his previous interpretation of Keynes's General Theory, specified two points of criticism with the modeling strategy: price flexibility and time differences. In his analysis of the IS-LM model understood over the period of a year as initially intended by Keynes, Hicks identified the necessity for an economy to be in equilibrium for the year

[5] Knowing the probabilities or dispositions of other decision-makers becomes a problem encapsulated within Keynes's description of uncertainty, exemplified by the newspaper beauty contest example in Chapter 12 of Keynes (1936).

[6] See Hicks (1937) for full development of the model which had great significance in the development of macroeconomic theory.

analyzed. The investment and demand sides must maintain an equilibrium to accurately represent reality (Hicks, 1980). This equilibrium then implies consistent expectations which require correct predictions throughout the year. Hicks noted that this would remove the liquidity dimension from the framework since expectations over the period become certain. Hicks (1936) emphasized the methodological importance of expectations as a factor for investment and savings. For Hicks, the use of expectations allowed for the analysis of alternative situations of "disequilibrium" with greater modeling flexibility (1936, pg. 240). The overall importance of expectations emerging from Hicks's analysis became obscured by the IS-LM tool he produced. However, the emphasis on economic actors' understanding of future scenarios became more significant with more recent Post Keynesian analyses.

Packard *et al.* (2021) provided an alternative view of Keynesian uncertainty that framed his viewpoint on the subject within his ideological history. The authors applied a "socialist worldview underpinned by a rational immoralist ethic"[7] to Keynes's writing to come to a different conclusion where uncertainty is entirely epistemic and not ontological (Packard *et al.*, 2021, pg. 11). They argued that Keynes believed in the expression of any decision as a combination of probabilities; uncertainty exists insomuch as the decision maker cannot have the necessary information to know the probabilities. It may be impossible to assign a probability to an outcome, but rational behavior requires a judgment based on some numeric determination (Packard *et al.*, 2021, pg. 13). Keynes never provided an explicit definition of uncertainty, and thus there remains disagreement over his viewpoint as one of the first major economists to table the subject.

Knight provided a clearer distinction between risk and uncertainty through his book *Risk, Uncertainty, and Profit*. He outlined the "theoretical method" as the search for general principles that set the groundwork for further analysis; however, these first steps build upon assumptions about the system that require consideration (Knight, 1921). Knight wanted to identify the limitations of the field of economics by reviewing this foundation. He acknowledged the challenges of economics as a social science attempting to imitate a more exact study and hoped to explore the concept of profit as a factor in equilibrium modeling. He wanted to determine the roots of the difference between perfect competition, without profit, and reality characterized by profit. It is to this problem that Knight distinguished between risk and uncertainty that set the foundation for any future analysis of the subject. Risk refers to situations where there are measurable probabilities while "true uncertainty" references cases "not susceptible

[7] The authors contextualized Keynes's view of uncertainty within the context of his political and ethical perspective emerging from his works.

to measurement and hence to elimination" (Knight, 1921, pg. 232).

Knight's work has been the subject of misinterpretation as the result of applying a "subjective probability framework" of later thinkers to his thoughts (Packard *et al.*, 2021, pg. 14). For the sake of mathematical analysis, the theoretical distinction between risk and uncertainty becomes less important. Many applications of econometrics reduce uncertainty and risk to just risk for the sake of the analysis. However, the Packard *et al.* (2021) contextualization of Knight within his philosophy pointed to an irreducible, ontological uncertainty. Additional texts from Knight indicated that he believed in a non-deterministic world whose future evolves throughout time; thus, the "realm of social sciences" is characterized by "incessant uncertainty" (Packard *et al.*, 2021, pg. 19). Based on his perception of the world and the original text, Knightian uncertainty seems to reference situations where decision-makers cannot assign a probability to the occurrence of outcomes[8].

Despite the differing interpretations of both Knight and Keynes, a dichotomy of definitions emerge as follows: an objective, unquantifiable uncertainty, and some quantifiable risk in the words of Knight. Dequech (2000) recognized the confusion attributed to the interpretations of Knight and Keynes, suggesting an alternate vocabulary to clarify uncertainty. In his essay, Dequech defined ambiguity as "uncertainty about probability... due to lack of information" (2000, pg. 45). There exists a necessary limit on ambiguity since the concept suggests the existence of all relevant information thus implying future outcomes could be determined if only the information was known. Ambiguity in this definition appears synonymous with epistemological uncertainty. Fundamental uncertainty refers to situations of greater "indeterminacy" that Dequech associated with the "possibility of creativity and structural change" (2000, pg. 48). This type of uncertainty involves the complete lack of knowledge at the time of decision. This falls in line with the ontological version of uncertainty that Knight and Keynes developed earlier. We can distinguish between epistemological and ontological uncertainty; the former refers to events where there is a gap in available information to create probabilities while the latter refers to situations where no such additional information exists[9]. These concepts become the center of different schools throughout the second half of the 20th century.

[8] Davidson (1996) emphasizes Knight's belief in a deterministic system where the uncertainty arises out of the fact that humans lack the ability to comprehend each moving part. This interpretation parallels the application of chaos theory to economics; there is some system of equations that describe the world, but humans lack the ability to know the parameters.

[9] Allington *et al.* (2012) associates epistemological uncertainty with Knight and ontological uncertainty with Keynes. The two ideas remain the same, but the interpretations of other texts differ from here.

3.2 Subjective Expected Utility Theory

The modern treatment of quantifying risk with probabilities originates in the early work of subjective expected utility theorists. Utilitarian philosophy existed before the mid-1900s as has the idea that individuals pursue options to maximize their utility. Additionally, the true roots of macroeconomics lie far before the developments of the 20th century[10]. However, the evolution of economics reached a turning point[11] with John von Neumann's and Oskar Morgenstern's 1944 book *Theory of Games and Economic Behavior*. In the book, the two authors attempted to apply principles of mathematics with the goal of developing a formal theory of human behavior (von Neumann and Morgenstern, 1944). The two approached the topic at a time when little mathematics had reached the world of economic analysis. The authors endeavored to push economics toward a formal science in a trend that continues later in the 20th century. The two authors provided a proof for the treatment of utility, arriving at some axiomatic assumptions about how actors discern between choices. These axioms proved key for future economic analysis. Bell and Farquhar (1986) provided a clearer version of the axioms as follows:

1. The completeness axiom outlines that for any two choices p and q, only one of the following can be true: $p = q, p > q$, or $p < q$.

2. The transitivity axiom states that for options p, q, and r, it is true that $p > q$ and $q > r$ imply $p > r$.

3. Two additional axioms on independence and continuity[12].

It is immediately plausible some ways in which rational actors could violate these axioms[13]. Bell and Farquhar (1986) summarized empirical studies of decisions as leading to two points of contention with the axioms. They saw that decision-makers often act in a way that violates the axioms. More problematic, these decision-makers continue to violate these axioms after learning that their behavior violates these rational rules (Bell and Farquhar, 1986). Daniel Ellsberg considered how decision-makers may operate differently than defined by the axioms under conditions of uncertainty. In Ellsberg (1961), the author began by

[10] See Murphy (2009) for additional background on the origins of macroeconomics starting before the 1900s.

[11] The developments described here underlined a greater development of econometrics as a method for modeling a dynamic, economic system using probability distributions as explained in greater detail in Haavelmo (1944).

[12] See Chapter 3 of von Neumann and Morgenstern (1944) and Bell and Farquhar (1986) for both proofs and greater mathematical context for the axioms.

[13] Arrow's Impossibility Theorem, presents another criticism. If Actor 1 prefers A to B and B to C but Actor 2 prefers C to B and B to A, then the axioms do not provide a way of determining the socially preferable outcome (Morreau, 2019).

recognizing the Knightian distinction between uncertainty and risk before proceeding with an analysis that concerned risk and epistemological uncertainty. He then provided various situations that seem to violate the axioms, the first of which is the simplest. He started with two urns, both of which contain red and black balls; the first urn contains an unknown ratio of 100 red and black balls while the second contains 50 of each (Ellsberg, 1961). He then defined four bets as follows: betting that a ball selected from the first urn will be red or black and betting that a ball drawn from the second urn will be red or black.

Ellsberg noted that the majority preferred to place bets on the draws from the second urn with a known ratio. When given the option, a majority of people stated a preference to bet on a red ball from the second urn over a bet on a red from the first and a bet on a black ball from the second urn over a black from the first. Preferring to bet on the red ball from the second urn implies the ratio of red balls in the first urn is lower than in the second. The ratio of black balls then must be higher in the first which would lead to people choosing to bet on black from the first urn. Thus, the choice to make two bets on the second urn violates axiomatic behavior (Ellsberg, 1961). He followed with some additional examples before proposing a possible framework for understanding the consistent violations of the axioms. Ellsberg suggested an alternative decision-making method that involved combining the expected utility with the minimum possible outcome based on the decision (1961). With this method, it is possible to explain how additional information and diminishing ambiguity can shift one's preference; as the decision-maker becomes more confident with the expected outcome of the decision, they can weigh the minimum outcome by a lesser amount. With greater confidence in the possible outcomes, the decision-maker will behave more in line with the axioms (Ellsberg, 1961). This analysis notably considered a case of epistemological uncertainty and not ontological uncertainty as suggested by earlier economists.

Despite the flaws in these axioms, they provided a mathematical basis for analyzing decisions which opened the door for further exploration. The bones of a scientific paradigm began to emerge with formalization like that of the axioms. These assumptions lead to the conclusion by Kenneth Arrow that "there is a method of assigning utilities to the individual outcomes so that the utility assigned to any probability distribution is the expected value under that distribution of the utility of the outcome" (Arrow, 1951, pg. 425). A decision can rely on both the utility of possible consequences and their subjective probabilities as assigned by the actor. The application of probability within this decision-making process represents a departure from previous frequentist approaches. There are limits to using frequentist approaches, those that take past repeated events to determine future likelihood, in the application to economic decisions.

Leonard Savage's *Foundation of Statistics* provided a useful follow-up to von Neumann and Morgenstern by highlighting the difference in probability used in utility theory. Savage followed his peers with additional mathematical postulates concerning the ordering of decisions. However, the overarching points of theory derive greater importance here. In the book, he described this new way of viewing probability as "personalistic" where a probability measures the certainty or confidence of some outcome (Savage, 1972, pg. 3). Savage also recognized the "vagueness" of situations with difficulty in assigning exact probabilities, and he claimed that this would be the basis for future work (1972, pg. 59). Savage arrived at the same utility function as his predecessors, cementing subjective expected utility theory as the groundwork for future decision-making analysis.

In the works of Arrow and Savage, the authors levied critiques toward the approaches of Knight and Keynes. Arrow's criticism of Knight's analysis pointed toward paradigmatic problems between concepts of risk and uncertainty. The more theoretical exploration by Knight clashed with the more formal analyses that Arrow targeted in his exploration of decisions; per Arrow, Knight's description of unmeasurable uncertainties reflected that of probabilities used to measure confidence (1951). Decision-makers could still assign probabilities in uncertain scenarios, and Arrow believed the distinction between risk and unmeasurable uncertainty to be unnecessary. The Keynesian idea of "weight" as correlating with the availability of evidence for a given choice fell outside the orthodox Arrow focused on throughout his survey of choice theory. Savage had some points of contention with Keynes as well, stemming from what he termed a "necessary" view of probability which Savage believed indefensible (1972, pg. 3,79). In Savage's view, Keynes's probability reflected an extension of human logic, separate from opinion; this idea clashed with the more personalistic views of the subjective expected utility theorists (1972). Despite differing levels of incompatibility, a clear dichotomy emerges between risk and uncertainty among economic theorists.

3.3 Macroeconomic Shift and Expectations

From the 1960s onward, the study of macroeconomics shifted its focus toward the microeconomic foundations for models. Subjective expected utility theorists made way for research on the formation of expectations in orthodox economics. This development strengthened the divide in perspectives of uncertainty and risk. Robert Lucas's famous paper criticized econometric models for failing to consider the interactions between economic policy effects and model parameters (1976). Along with other work, he helped establish a "new classical ap-

proach" that maintained "a strong emphasis on underpinning macroeconomic theorizing with neo-classical choice-theoretic microfoundations" (2005, pg. 223). Economists wanted to base macroeconomic theories on an understanding of how individual people act within the economy. Developing a theory for expectations, something Keynes had kept exogenous, became a topic of utmost importance.

Keynesian macroeconomics dominated in the post-war era until the combination of elevated unemployment and high inflation induced critiques. Milton Friedman first rethought the importance of monetary policy; however, he also contributed to theories of expectation formation. He introduced a theory of adaptive expectations in his modification of the Phillips Curve. In the previous tradition, Keynesians had claimed that it would be possible to induce lower employment through monetary or fiscal policy while suffering a reasonable level of inflation; Friedman posed that workers would update their wage expectations based on the inflation they experience (Birol, 2013)[14]. Thus, any attempt to lower unemployment below some "natural rate" would fail as workers would demand higher wages based on the new rate of inflation (Snowdon and Vane, 2005). This theory of expectation formation underlying the analysis held more importance within the context of understanding uncertainty. Under this idea of adaptive expectations, economic actors change their expectations based on past results and errors; this notably allows a gap in time between the original and updated expectations where the rate of unemployment could fall below the natural rate (Snowdon and Vane, 2005). The sole use of past data to set expectations for the future allows for consistent errors in predictions. This idea of expectation formation supported early criticisms of Keynesian macroeconomics but made way for a new theory in the coming years.

The rational expectations hypothesis (REH), originally the work of John Muth but established more clearly by Lucas, overtook the adaptive expectations framework to become the key paradigmatic assumption for future econometric work. Under this new hypothesis, Muth stated that expectations can be treated as if they are "the same as the predictions of relevant economic theory" (1961, pg. 316)[15]. Snowdon and Vane (2005) noted the importance of distinguishing between the weak and strong versions of the hypothesis where the former only suggests the use of all information by actors to make decisions while the latter suggests subjective probabilities of actors will equal the real distribution of that variable. Like the hypothesis of adaptive expectations, ra-

[14] Some Keynesians have argued these positions, blaming the stagflation period during the 1970s on trade unions and a wage spiral following the rise in oil prices. Friedman's blanket assumption that Keynesians believed in inflation only through the mechanism of excess demand thus partially misunderstood the position of all Keynesians.

[15] The REH assumes the accuracy of the "relevant" model, but some critics may note that this model could be wrong. The exploration of Shackle later will expand upon the potential of an incorrect underlying model of the economy.

tional actors learn from previous mistakes, but the REH assumes the eventual elimination of systematic error (Snowdon and Vane, 2005). The formation of rational expectations, however, requires an understanding of the economic model that describes reality which leads to the question of how people acquire that knowledge. Snowdon and Vane posed one possible rebuttal that the strong form of the REH does not require the correct model, only that the expectations will resemble those that would be formed with the knowledge of the model[16] (2005, pg. 228). Despite the acceptance in orthodox economics of the REH, the Post Keynesian school has emerged as the main opponent of the theory regarding its relation to uncertainty. The Post Keynesians, as the name suggests, emerged from the Keynesian tradition but valued the question of uncertainty in a way that distinguished the school from the IS-LM formulation of Keynes's work.

Paul Davidson has long proved to be one of the main critics of the REH and its use within New Classical economics from a Post Keynesian point of view. He elaborated a critique of the REH that explored the applicability of the theory within many economic contexts. Per Davidson, the REH suggested a reality of stochastic processes with established probability distributions of outcomes; Davidson explained it as "nature is conceived of as throwing the die to select the events of the stochastic process" (Davidson, 1982, pg. 184). Accepting the REH requires accepting the fact that the stochastic processes are ergodic, implying "future outcomes are merely the statistical shadow of past and current market signals." (Davidson, 1996, pg. 480). Ergodicity requires an assumption of stationarity or independence to time; the historical time of the event should not influence its outcome. Thus, economists can apply the REH in situations that satisfy this ergodic condition.

If economic conditions change throughout history, then many economic processes become nonergodic[17]. Keynes's distinction of uncertainty suggested the existence of nonergodic situations outside the scope of probability. Past and present information may provide some insights, but the future probability of unprecedented events would remain unknown. Davidson referenced the concept of cruciality as defined by GLS Shackle[18] for making the distinction between ergodic and nonergodic situations. An agent who makes a crucial decision changes the state of the world that existed before the decision. Davidson introduced entrepreneurs, a key concept in the Austrian school, as the key crucial decision makers. The REH would deny the existence of crucial decisions and would restrict decisions to the result of some probability distribution. Accepting the

[16] This argument remains unconvincing for many. Snowdon and Vane (2005), pg. 228 provides additional references for the criticisms of the REH on this point.

[17] Nonstationarity is a sufficient but not necessary condition for nonergodicity.

[18] For those interested in Shackle's original works, we refer readers to Shackle (1938) and Shackle (1949).

fact of unique economic conditions in historical time requires the acceptance of crucial decisions and nonergodic processes. The REH would remain useful for ergodic processes, but it remains unclear whether any economic processes satisfy the ergodic condition.

The position of uncertainty has ontological implications for those who assume ergodicity or nonergodicity. New Classical economics has arrived as the dominant economic paradigm with an equilibrium model based on stochastic processes which consist of random variables describing some model or system (McCombie and Pike, 2013). The REH and assumed ergodicity provide the structure for this development within macroeconomics, but the assumption implies a fixed reality. Davidson classified models of immutable reality into two categories: those that allow short-term knowledge of future outcomes and those that accept incompleteness of knowledge of the future for the short term. For the latter group, short-term errors make way for more accurate predictions that approach reality in the long run. These systems that assume short-term errors in exchange for long-term accuracy involve epistemological uncertainty; a nonlinear and determinate system of equations borrowed from chaos theory proves useful in explaining the knowledge gap. The complexity of available knowledge or relationships inhibits the ability to predict the future. If humans could understand the relationships between every mechanism in the world, this application of chaos theory would confirm our ability to predict the future. Uncertainty as described by Keynes suggested a transmutable reality. The existence of unpredictable future outcomes implies a nonstationary and nonergodic reality. Agents operating within these situations base decisions on probability distributions subject to surprise changes unpredictable by the nature of uncertainty.

Snowdon and Vane (2005) provided a holistic view of the Post Keynesian perspective regarding uncertainty. The current position of orthodox economics combines uncertainty with risk, considering both concepts quantifiable for the sake of analysis. This simplification parallels the development of subjective probabilities as elaborated by von Neumann, Morgenstern, and Savage. Post Keynesians emphasize the importance of true or ontological uncertainty as a preventive factor in using probabilities to make decisions; this belief has led to disagreement with the REH. In this perspective, decisions can fall into one of the three following probabilistic environments: the objective probability environment, the subjective probability environment, and the true uncertainty environment (Snowdon and Vane, 2005, pg. 464). The objective probability environment refers to situations where past information can provide a statistical understanding of the future as assumed by the REH, where the ergodic assumption holds. The subjective probability environment harkens to the work of subjective expected utility theorists where probabilities reflect personal pref-

erence but may contain inaccuracies. True uncertainty becomes a factor when there is no available information about the future so that any probabilities become "not calculable" (Snowdon and Vane, 2005, pg. 464). Davidson's criticism of the REH reflected how the objective environment can become one of true uncertainty. For the subjective probability environment, true uncertainty exists when actors cannot fully order or specify their preferences (Snowdon and Vane, 2005, pg. 467). Depending on one's belief about the ergodicity of various economic processes, true uncertainty can become a factor that dominates economic analysis.

The application of the REH to financial and capital markets has provided a distinct line of study within financial economics titled the efficient markets model or the efficient markets hypothesis (EMH). In a 1970 paper reviewing the research concerning the subject, Eugene Fama outlined different levels of the EMH in a similar way to the REH. Fama started with the fact that an efficient market is one "in which prices always 'fully reflect' available information" (1970, pg. 383). Differing levels of strength of the model adjust the amount of information considered available. The weak form only requires adjustments based on historical prices; the semi-strong form expands to other obvious information like earnings announcements while the strong form includes all information (Fama, 1970). The model suggests that the price of an asset is equal to its expected value based on all available information along with some function of risk. At the time of his review, Fama concluded that "the evidence in support of the efficient markets model is extensive" (1970, pg. 416).

Robert Shiller and his modern review of financial research provided an updated perspective on the behavior of financial markets. In 1981, Shiller posed the possibility of excess volatility in the stock market due to the marked difference in the trend of S&P stock prices and their present value (2003). The variation in stock prices exceeded the variation from the present value of those prices calculated in several different ways. Shiller (2003) explained how the EMH assumes that the variance in the prices of stocks must be less than or equal to the variance of the forecasts for those prices. To test this, Shiller first took the present value of real dividends on the S&P Composite Stock Price Index discounted using a constant discount rate plotted against the path of actual S&P prices; the present value of dividends provided a proxy for price forecasting and thus should vary more than the actual prices based on the EMH. Shiller (2003) showed the opposite where the actual S&P prices fluctuated more than the discounted dividends. Early critics suggested using either interest rates or the marginal rate of substitution for consumption as discount rates instead of a constant rate; Shiller (2003) showed that these two methods also presented forecasts more stable than the actual prices. He concluded that the EMH cannot

hold because of this excess variance.

Failing to find a way to understand this volatility within the EMH, some researchers in the 1990s moved toward psychology in search of a more satisfactory explanation despite resistance from some financial economists. Shiller cited feedback theory as an alternative method for understanding some of the excess noise in stock prices; in some cases, stock prices rise due to the cyclical optimism of investors (Shiller, 2003). This feedback loop can lead to speculative bubbles, a phenomenon present in markets for hundreds of years. From the tulipmania bubble in the Netherlands in the 1630s to the 21st-century stock market, speculative bubbles arise out of expectations for continuous price increases, not out of asset fundamentals. Shiller (2003) cited some studies within finance and psychology that have explored "feedback" theory; one such example involved a representativeness heuristic where actors will predict future patterns that most closely resemble the past without considering the probability of these patterns occurring. This research suggests that some key assumptions in New Classical research fail to include an accurate understanding of human behavior.

Quantifiable risk has come to dominate the risk-uncertainty dichotomy in the current economic mainstream. Ideas like the REH and the EMH have become institutionalized into the current economic paradigm. Unquantifiable uncertainty as championed by the Post Keynesians became quantifiable or nonexistent for orthodox economists.

4 Uncertainty as an Anomaly

Keynes and Knight recognized the importance of the distinction between uncertainty and risk, but that understanding has slowly dissipated. The formalization of the field into more concise and mathematical practices has favored quantifiable risk as a means of accounting for the probabilities of future events. Economists in the New Classical paradigm struggle to capture uncertainty using the present tools, leaving a massive gap in understanding how people approach decisions in the real economy. Uncertainty remains a largely unanswered question in the current economic paradigm, and the consequences of this inattention can prove devastating. Uncertainty has become a Kuhnian anomaly for the field that could lead to a paradigmatic crisis if economists continue to fail in their attempts to capture it using New Classical tools.

The evolution of economics to the New Classical paradigm has gradually marginalized uncertainty in favor of quantifiable risk. The SEU theorists of the mid-20th century built a foundation for modeling the activity of decision-makers with subjective probabilities. The creation of the REH refined a useful theory of expectations for econometric research. These innovations provided the theoret-

ical basis for disregarding situations where uncertainty prevents the assigning of probabilities to possible future outcomes within a quantifiable framework. The creation of subsequent assumptions about the decisions of rational actors has over-simplified economic agents, warranting reformulation within uncertain scenarios. These assumptions have become ingrained in the practices of the current paradigm so orthodox research rarely considers alternative hypotheses. The momentum of the field has proved insulative for the field. The cementing of these assumptions as a general practice leaves uncertainty as an unconquered peripheral challenge.

The increasing connectedness of the global economy and financial markets magnifies the importance of addressing uncertainty. Macroeconomic shocks to Asian countries contributed to the downfall of Long-Term Capital Management, and the subprime crisis exhibited network effects throughout the world. The increasing scale of financial investments and ease of access across continents leads to the inclusion of new actors with different incentives into the global macro economy. The development of new markets in Africa and Asia will create new investment opportunities and increase the connectedness of the global economy. The influence of uncertainty on consumers, investors, and policymakers will continue to be important while also affecting a larger volume of economic activity. Inevitable financial crises that sew uncertainty among economic actors will have more devastating effects on larger groups.

Under conditions of economic stability, few incentives exist within the paradigm structure to answer the question of uncertainty. Calculating risks under certain conditions appears to provide an almost infinite number of possible puzzles to solve. The lack of consistent conditions across periods of economic testing converges with an abundance of mathematical methods to produce a challenging puzzle. Failed models make way for different attempts that increase in complexity as a means of solving the problems of previous iterations. This repetition of model creation exemplifies the non-cumulative dynamic of risk modeling as econometricians design the models with the same goal. Researchers continue to explore different routes to discover risk metrics emphasizing the puzzle-solving nature of quantifiable risk.

Uncertainty then remains in a challenging position given the current paradigm. Researching uncertainty fails to fit the puzzle-solving schema and lacks the safety of researching risk. The tools in the paradigm, established and insulated in graduate school textbooks, do not fit the problem of uncertainty as well as they do the problem of risk quantification. The historic momentum that has culminated with the New Classical paradigm has left uncertainty out of much analysis, but the importance of the topic has resurfaced during periods of instability. Recent financial crises have exposed the weaknesses of modern risk modeling and high-

lighted the problem of conflating risk and uncertainty when considering future outcomes. These failures provide useful cases for understanding the importance of uncertainty within economic analysis. Models built upon data collected from stable conditions fail during crises.

The collapse of the hedge fund Long-Term Capital Management (LTCM) provides a relevant case that preceded the subprime crisis by a decade. LTCM began investing in 1994 with $1.3 billion in equity which eventually rose to $7 billion in 1997 before a precipitous fall to $600 million in the fall of 1998 with the fund closing in 2000 (Allington *et al.*, 2012). Despite its whirlwind existence, LTCM delivered attractive returns early in its life with a 43% return in 1995 (Edwards, 1999). The fund boasted a strong group of partners including Nobel winners Myron Scholes and Robert Merton known for their work in financial economics. This fact helps explain the firm's high incentive fees and its access to leverage (Edwards, 1999). Thus, LTCM represented not a regular hedge fund but one guided by influential figures in financial economics.

LTCM took a "market-neutral arbitrage" strategy where the firm held a long position on high-yield bonds and a short position on low-yield bonds (Edwards, 1999). The firm believed the gap between high-yield and low-yield bonds was too wide and that this gap would narrow as the collapse of Asian markets during the summer of 1997 pushed further into the rearview (Edwards, 1999). The analysts at LTCM built their models using data from the past decade; the models built upon data from a stable period failed during the unpredictable crises that followed. The investors at LTCM thought the risk premia priced into high-yield bonds, like those in emerging markets, remained too high. To enact this strategy, LTCM borrowed over $100 billion and entered derivatives contracts that, at the start of 1998, had a notional value north of $1 trillion (Edwards, 1999). The high-stakes game came crashing down with the aftershocks of the Asian financial crises and a Russian moratorium on some national debt in August of 1998 (Allington *et al.*, 2012). The ensuing panic directed investors toward reliable low-yield bonds while the price of high-yield bonds increased, opposite the bets of LTCM. During the first nine months of 1998, LTCM lost more than $4 billion in the value of its equity (Edwards, 1999). Due to the perceived fragility of financial markets and the systemic risk posed by a formal default of LTCM, the Federal Reserve orchestrated a bailout for the hedge fund to avoid a possible meltdown[19] (Edwards, 1999).

The LTCM tale provided several points of caution, many of which remained unheeded in the wake of the subprime crisis 10 years later. A desire for greater

[19] The implications of this move in increasing moral hazard are important and more information can be found in both Edwards (1999) and Allington *et al.* (2012). The Federal Reserve attempted to limit its connection with the bailout, noting that no taxpayer money was used.

transparency from hedge funds emerged as these unique financial institutions had previously flown under the radar of most regulatory bodies. Hedge funds have since become the subject of greater regulation, but they lack a strong connection to the subprime crisis. The danger of excess leverage, particularly within the derivatives market, presented itself as a key lesson in the aftermath. The problem of systemic risk also emerged as a key point from the collapse. This event also exposed the weakness of risk modeling during times of crisis. Allington *et al.* (2012) noted the consistent understatement of risk for the firm in their disclosures; the paper explained that the firm's models had prescribed a loss of the magnitude LTCM experienced as occurring "once in the life of several universes" (563). The interaction of high leverage and systemic connections magnified the effects of this mispriced risk.

The positive economic performance proved strong enough insulation to stabilize the current economic paradigm despite the abundance of red flags. The collapse of LTCM vaulted the Value at Risk modeling technique to the forefront as the primary method of modeling risk (Allington *et al.*, 2012). Economists perceived the problem as one of risk miscalculation, not of a misunderstanding of fundamental ideas. As the development of new risk models seemed to solve the mistakes of those involved with LTCM, leverage ratios continued to rise with many non-hedge fund financial institutions taking on debt at levels above those taken at LTCM (Allington *et al.*, 2012). The failures of LTCM, rationalized as a one-off incident, did not lead to institutional change but the refinement of prior ideas. Even though bailing out the hedge fund seemed necessary to avoid a market-wide disaster, the LTCM saga failed to induce many fundamental changes in the dominant economic paradigm.

The Post Keynesian criticism of the reaction to LTCM as captured in Allington *et al.* (2012) pointed toward the EMH as the main culprit in the collapse. Although the theory has become less relevant recently, the EMH led the LTCM fund managers to disregard the possibility of a crisis leading to abnormal returns (Allington *et al.*, 2012). Many "black swan" (incredible outlier) events occur much more frequently than the underlying normal distributions would suggest (Allington *et al.*, 2012). In situations of uncertainty, like those times under crisis, probability distributions become much more difficult if not impossible to discern. Allington *et al.* (2012) cited the importance of research in behavioral finance as a potential starting point for better understanding how decision-makers act during these times. Thus, the overreliance on risk modeling as a panacea for the prediction of future events falls significantly short of a paradigmatic assumption. No better environment illustrated how uncertainty can infect financial markets than the subprime crisis a decade later[20].

[20] We refer readers to Lowenstein (2002) for additional exploration of the LTCM crisis.

Following the demise of LTCM, the subprime crisis presented another cautionary tale for the overreliance upon risk models to capture ambiguity within the economy. The billions of dollars of losses on subprime mortgage loans incited a widespread financial crisis with consequences in the United States and abroad (the Eurozone debt crisis being a key aftershock of the earlier recession). Financial deregulation that began in the 1970s but culminated with the repeal of the Glass-Steagall Act in 1999 allowed commercial banks and investment banks to participate in activities previously kept separate. Commercial banks could now participate in security markets and investment banks could accept deposits (Arestis and Karakitsos, 2013). This allowed investment banks to take on an originate-and-distribute model with loans wherein banks could originate loans before bundling and selling the collection of loans as a security (Arestis and Karakitsos, 2013). Financial engineering led to an alphabet soup of new securities including Collateralized Mortgage Obligations (CMOs), Collateralized Loan Obligations (CLOs), and Credit Default Swaps (CDSs) just to name a few (Arestis and Karakitsos, 2013). To reduce the risk of individual subprime mortgages, which made up a large part of the toxic assets, banks would collect many mortgages together and split the cashflows into different tranches. The lower tranches earned higher yields while also serving as the first line of loss in the case of defaults for the loans; higher tranches would take on a much lower share of default risk with a lower yield (Gottesman, 2008).

While Credit Rating Agencies[21] and some human malpractice contributed to the precipitous collapse of primarily the subprime mortgage securities, failed risk models emerged as a major cause of the disaster. Many believed that the securitization of different cash flows would "reduce risk of system-wide failure" by limiting the possibility of failure in a single institution (Gottesman, 2008, pg. 62). Despite investor optimism, including the support of Alan Greenspan as head of the Federal Reserve, the true risk of these assets exceeded expectations. Gottesman (2008) identified two major issues with valuing the securities: the sometimes "unknowable" quality of underlying assets and the reliance on probability estimates of those assets' behaviors (63). For the case of subprime mortgages which were not taken as individual but as part of a group to be bundled, originators of the securities would calculate the default probabilities for the overall group of loans that created the security (Gottesman, 2008). The optimism in housing prices meant that many of the mortgage owners had taken out the loan, not with the plan of repaying but with the hopes of the value increasing before the payments came due. A failure to investigate individual

[21] Coffee Jr (2008) provides a more narrative account of the role of Credit Rating Agencies in the financial collapse that falls outside the bounds of the explanation here. Arestis and Karakitsos (2013) also gives a more holistic account of some major factors in the crisis.

situations led to incredible mispricing in the risk of defaults for many of these loans.

Value at Risk (VaR) models dominated the landscape for valuing these securities. The technique originates in the 1990s from work within JP Morgan; Dennis Weatherstone, chairman at the time, sought a more holistic measure for addressing risk across a diverse portfolio[22] (Nocera, 2009). VaR then grew from an internal solution to a standard measure that the SEC desired from institutions as a true measure of institutional risk (Nocera, 2009). VaR simplified the reporting of risk that became attractive to financial managers; these models allowed analysts to phrase their risk as follows: "We do not expect losses to exceed $1 million on more than 1 out of the next 20 days" (Culp *et al.*, 2008, pg. 163). With a distribution of portfolio movements for some time horizon, a firm could look at the left tail distribution events and set some sort of limit, like 5%, where losses of some magnitude (or greater) would be expected to happen no more than 5% of the time over the set time horizon (Culp *et al.*, 2008). The ease of comprehension and flexibility across assets translated into widescale popularity among financial institutions[23].

The functional and methodological downsides of VaR modeling expose the limits of the technique. Modeling VaR also requires a portfolio to remain the same over the time horizon in question; any changes in assets would create a new underlying probability distribution of returns (Culp *et al.*, 2008). The subsection of VaR models that use a variance-based approach relies upon the assumption of normality on the price changes of the assets in question; the existence of asymmetric or fat-tailed distributions would lead to problems in the prediction (Culp *et al.*, 2008). These models also performed poorly during the financial crisis; a Federal Reserve review of six banks' VaR performances before and during the crisis found that the models performed worse during the crisis (O'Brien and Szerszeń, 2017). The analysis found that the models were too conservative before the crisis but underestimated errors during the crisis (O'Brien and Szerszeń, 2017). The authors provided some additional tweaks to the VaR approach with some better results, but they also note that periods of market instability make the quantification of risk inherently challenging (O'Brien and Szerszeń, 2017).

Nassim Nicholas Taleb has levied additional criticism toward this method of modeling that relates to his concept of black swans, referring to unpredictable events with massive consequences. A VaR model can specify a certain threshold for a loss but cannot quantify the extent of the potential downside (Nocera,

[22] Nocera (2009) notes Weatherstone famously requested daily reports using VaR to evaluate JPMorgan's risks.

[23] Culp *et al.* (2008) provides more context on the specific benefits of VaR in a more optimistic light than described here.

2009). In those 1% or 5% negative scenarios, these models specify very little. Additionally, these models rely upon an assumption of stationarity where future market variations will behave similarly to those identified in the past. This ergodic assumption would become problematic during crises or black swan events where decision-makers face unseen circumstances for the first time; in crises, asset returns may not follow historic distributions. Finally, Taleb cited the repetition of black swan events as proof that these probabilistic measures are flawed (Taleb, 1997). These events, whose predicted likelihood would have been functionally zero, break the model.

In a world marked by the existence of uncertainty, nonergodicity, and black swan events, VaR models fall short. Measuring risk has become more sustainable as a puzzle-solving endeavor due to its ease in formalization. Probabilistic work within econometrics has accumulated a toolbox with which economists can create models like VaR that attempt to quantify future possibilities. Failures of these models lead to refinements or innovations in the mathematical method but not a reconstruction of the ideas of risk and uncertainty. Nelson and Katzenstein (2014) used the subprime crisis as a case for studying the dynamics of uncertainty and risk; they found that the existence of uncertainty would disrupt VaR risk models (Nelson and Katzenstein, 2014). Even after introducing new techniques into their research with the hopes of overcoming this fact, every attempt falls short of the mark. A connection appears between a failure to recognize the importance of uncertainty and the subprime crisis. Risk models that assume away or relegate uncertainty to the periphery of analysis failed to accurately quantify asset fluctuations.

The persistence of these models proves the staying power of New Classical macroeconomics. While some researchers have added more nuance to the study of uncertainty, risk remains the dominant of the binary despite indications from financial crises of their limits. The tradition embedded in the field has survived criticisms after the downfall of many financial institutions in the late 2000s. Uncertainty remains an anomaly that could develop into a paradigmatic crisis given the significant pressures. Evidence continues to arise pushing against some key assumptions that support risk models, but those errors have yet to drive the field into a time of revolution. The economic paradigm is strong enough to support the consistent progression of research but also strong enough to avoid a crisis.

Further development of this paradigmatic practice involves the modeling of systemic risk or connectedness within the economy. The causal relationships between institutions and securities within financial economics have become a major problem following the subprime crisis. Allington *et al.* (2012) cited the reason for the Fed's decision to bail LTCM out as not being too big but be-

ing "too integrated to fail" (577). Tobias and Brunnermeier (2016) provided a new measure for systemic risk named Conditional VaR or CoVaR abbreviated. The authors took an institution's CoVaR as the VaR for the financial system conditional on the institution's stability. The authors then took the difference between the CoVaR based on the median state and the disaster states as a measure of systemic risk; how much does one institution becoming unstable affect the value at risk for the financial system? The authors noted that the change in CoVaR is directional; it is simple to change the conditionality so that the metric could measure the connectedness between institutions without considering the entire system. The authors developed a forward-looking measure using CoVaR that exhibited countercyclical habits which appear useful for preventing the buildup of systemic risk bookended by financial crisis. Diebold and Yılmaz (2015) presented a different attempt to quantify the connectedness between different variables using pairwise variance decompositions. The authors' approach lacks significant assumptions toward the causes of variable connectedness while providing a way of measuring system-wide and pairwise connectedness[24].

These examples along with other attempts at measuring systemic risk illustrate further development within the current risk-centric economic paradigm. This research does not attempt to solve the problem of uncertainty but to further flesh out the field's understanding of quantifiable risk. This is not to say the research will not prove useful in the prevention or management of future crises; each of these examples provides strong arguments for use in identifying systemic issues in ways impossible before. These developments show the positive results of paradigmatic insulation insofar that this research could help avoid future systemic downfalls. However, the actions of agents under conditions of uncertainty remain unaddressed by research here. The historic inevitability of future crises will create uncertainty within the economy. These paradigmatic extensions follow the puzzle-solving pattern from before. Without understanding the effects of uncertainty, these models will likely experience a similar fate to their predecessors during financial disasters.

Economists have developed methods to handle non-normal results. Heterodox commentators have long criticized the Gaussian assumption because of the occurrence of outlier events at a rate higher than predicted using a normal distribution. Fernández-Villaverde and Rubio-Ramírez (2007) provided one example of such research. The authors borrowed the practice of particle filtering, popular in financial econometrics, to better explore non-normal economic models[25]. They then estimated dynamic equilibrium models without requiring the

[24] An exhaustive description of the empirical work falls outside the scope of this thesis.

[25] The technical details of the paper again fall outside the scope of the argument here, but readers are encouraged to read the paper in its entirety if interested.

assumption of normality. This example represents expansion within the current paradigm as methods become more robust to different statistical possibilities. Previously, computational challenges have inhibited the use of non-normal distributions within macroeconomic modeling. With stronger processors and additional empirical development, the assumption of normality becomes less of a crutch for research within the paradigm. Under distributions with fatter tails, events considered extreme outliers under conditions of normality become more frequent. These developments suggest that events like the one that spurred the collapse of LTCM should no longer appear as surprising as before.

Some economists have taken on the challenge of capturing trends in uncertainty as distinct from risk. The work of Lars Peter Hansen and Thomas Sargent represents an orthodox attempt to take the econometric tools of the current paradigm and consider the topic of uncertainty. Hansen's Nobel Prize essay provided a unique point of view that introduced a new conceptualization of uncertainty in economic modeling. He distinguished between two kinds of uncertainty, outside and inside, the latter of which is relevant here[26]. Inside uncertainty refers to the uncertainty faced by decision-makers within an econometric model (Hansen, 2014). The REH allows models to run without further consideration or complications to decision-makers within the model. Hansen entertained the theory of some learning process where actors make changes to their beliefs due to errors in previously believed ideas; he then provided a strategy for quantifying "animal spirits" in a way that applied to empirical research (Hansen, 2014).

Sargent and Hansen have also written about uncertainty as the possibility of model misspecification. Any decision-maker has some set of possible models which could describe the economy. The decision-maker is unsure of which of these models accurately reflects reality. Sargent (2012) described a method of accommodating this uncertainty that involves min-max expected utility across the set of models; since the decision-makers act under uncertainty, they will assign higher probabilities to models with lower bottom-end scenarios to compensate for this missing information. This solution represented a departure from the utility-maximizer assumption within the context of trying to improve upon the REH for in-model behavior. The definitions of uncertainty posed by Sargent and Hansen along with their associated solutions act as responses to the failures of paradigmatic assumptions in the past.

The work of Sargent and Hansen points toward a theme that Kuhn discusses as a field attempts to deal with an anomaly. While an anomaly within a field

[26] Outside uncertainty refers to the uncertainty faced by econometricians when designing their models. He elaborates on possible solutions to this issue in the Noble Prize paper Hansen (2014).

can lead to a crisis and a scientific revolution, the field goes through additional phases before the final step. Assuming uncertainty to be a Kuhnian anomaly for the current economic paradigm, researchers in the field would attempt to find some sort of way of addressing the anomaly with the tools allotted by the paradigm. Attempts at quantifying systemic risk or modifying VaR models illustrate attempts to retreat into the confines of the paradigm but not to address the reality of uncertainty. Although not incorporated into mainstream research, the work of Sargent and Hansen provides one example of an econometric translation of uncertainty.

However, their work could also push the field toward a revolution into a new paradigm. Kuhn noted that when a paradigm enters a crisis, such a condition "loosens the rules of normal puzzle-solving in ways that ultimately permit a new paradigm to emerge" (Kuhn, 1970, pg. 80). The ideas presented here push against key ideas like the REH which supports the current economic paradigm. The restrictions and shortcuts that delimit most orthodox economic research become negotiable in the cases of Sargent and Hansen. Should additional researchers and papers formalize these ideas and theories into quantifiable methods, this line of research could lead to new paradigmatic ideas that better understand uncertainty. The emergence of some tangible new paradigm would require time and acceptance among academic and professional economists. It remains to be seen whether these ideas will lead to a greater change, but they appear emblematic of a paradigm attempting to deal with an anomalous concept.

One Post Keynesian critique emerges as an important factor when considering the validity of uncertainty as conceptualized by Hansen and Sargent. GLS Shackle's analysis fell between the Austrian and Post Keynesian schools, but his ideas on uncertainty have emerged in some Post Keynesian critiques. He considers the possibility that the underlying model of the economy is unknowable because it is constantly changing. Shackle wanted to identify how economic actors would come to make decisions under conditions of uncertainty. He understood ontological uncertainty as a key component for decision-makers as he viewed reality as constantly in flux or "kaleidic" (Rosser Jr, 2001). Latsis (2015) noted that the extremity of his view lay with the fact that Shackle rejected "probabilistic reasoning" when studying decisions and preferred the concept of "potential surprise". Instead of attempting to assign distinct probabilities to outcomes, decision-makers under this model accept the possibility of future surprises[27] (Cantillo, 2010). For Shackle, the underlying model of the economy at

[27] See Cantillo (2010) for a more systematic explanation of Shackle and "potential surprise". Additionally, Rosser Jr (2001), pg. 551 provides some additional sources of formalization derived from Shackle's theory.

any point in the future is impossible to know in the present due to unknowable changes that occur between the points in time.

Charges of nihilism have impeded the inclusion of Shackle in much heterodox criticism. The question arises as to how any analysis of the future can proceed if we accept Shackle's theory. Latsis (2015) explored the consistent presence of these critiques; he finds that nihilistic criticisms of Shackle focus on the fact that his ideas attack some key fundamentals of orthodox theory. Latsis (2015) argued that Shackle pointed to a different type of analysis instead of denying any new theory in a nihilistic fashion. To combat these criticisms, Davidson (1982) drew upon Shackle's idea of crucial decisions which restricts nonergodicity to certain situations. Using crucial decisions to limit the nonergodic criticism to certain situations then reframes the Post Keynesian argument as one that delimits the boundaries for orthodox methods. Shackle's work pushed against some of the foundations of orthodox economics, drawing this nihilistic criticism; the use of crucial decisions as a qualifier or a consideration of alternative analyses assuages the nihilistic concern.

Shackle's claims about potential surprise fall in line with other Post Keynesian criticisms of the inability of orthodox economics to study uncertainty. Sargent and Hansen's idea of uncertainty would fall short under the conditions for reality put forth by Shackle. For Sargent and Hansen, each decision maker has a discrete set of possible economic models where one reflects reality but there is uncertainty as to which one. For Shackle, reality appears so complicated that makes the task of knowing the true economic model challenging. In Shackle's reality, model misspecification would appear a natural trait of economic actors due to the destructive process of crucial decisions. Thus, this Post Keynesian criticism would push the current paradigm beyond this understanding of uncertainty. Sargent and Hansen push the boundaries in search of an answer, but the possibility of reality as described by Shackle suggests the necessity of new methods of analysis for capturing the uncertainty in the real economy.

We see a confluence of factors that suggest the anomalous nature of uncertainty for the field. The conflating of risk with uncertainty falls short during periods of crisis. The failure of risk models to quantify exposures has pushed researchers toward different methods of identifying risk without considering the potential impact of uncertainty on those failures. This resilience represents a symbol of strength for the paradigm, but orthodox research on uncertainty, exemplified by Sargent and Hansen, proves the existence of some concern over the impact of uncertainty on the economy. Despite this work, Shackle's theory of reality would suggest that this orthodox view may not accurately represent the true nature of uncertainty. The failures of risk models combined with the mainstream recognition of the subject point toward uncertainty as a subject that

will warrant future concern. The inability of New Classical macroeconomics to capture uncertainty could prove important in the development of the field.

While quantitative solutions to addressing uncertainty may prove useful in future econometric research sustaining the current paradigm, the qualitative underpinnings of the discipline deserve further understanding. Quantitative models serve an important role for policymakers and economists, but the development of the field to this point has failed to quantify all human behavior. Gathering greater quantities of data will prove useful in the descriptive analysis of decision-making, but the sociological and behavioral pieces of the field need greater attention. The work of behavioral economists to discover trends that buck the assumptions made in empirical research should be heeded as points of departure for further developments in theory[28]. The understanding of uncertainty may require the reconstruction of basic assumptions. The nature of economics keeps it separate from the natural sciences. Economists should reconsider the formalized façade that has insulated the field from fundamental changes as a step toward better-capturing uncertainty as a factor in their analysis.

Accurate theories about how decision-makers operate under uncertain conditions will rely upon more complete data regarding human behavior. When looking toward the development of new theories, Summers (1991) rings important in its criticism of many econometric papers that test developed models with data. The paper instead argued that the most impactful contributions to macroeconomics have arisen out of research identifying empirical trends. Summers saw much of macroeconomic theory as too separated from empirical data; he believed theory should rely upon actual observations. Behavioral research stands to serve an important role in further understanding how decision-makers may behave in different circumstances. Utility maximization and cold rationality may not reflect the actions of real people in cases of instability. Any future paradigm or method of understanding uncertainty as an important factor in economics must look to build strong foundations reliant upon empirical observations.

Within this search for theories that can support the existence of unquantifiable uncertainty, Bausor (1984) presented a heterodox framework for including psychological factors in economic analysis. The model aids in showing one possibility of incorporating behavioral factors into the decision-making schema. Bausor (1984) set out to model the relationships between the four following concepts: actual outcomes, perceptions of that reality, expectations set from the

[28] Smith (2003) and Algan *et al.* (2014) represent two exciting examples of orthodox researchers concerned with the behavior of people within economic models. Smith (2003) considers two formulations of rationality while Algan *et al.* (2014) presents methods for estimating econometric models assuming heterogeneity among economic agents.

perceptions, and strategies for action that result from the expectations. This cyclical model provides four different functions relating to these concepts. Using the notation from Bausor (1984), the function I represents the distribution of information available to decision-makers concerning past outcomes; this can range from fully available information to only private knowledge. The function T signifies how actors take perceptions to create expectations; this function allows for the application of rational expectations or the influence of imagination in the development of expectations. The function D represents the transition from expectations to strategies ranging from utility-maximizing behavior to reliance upon customs and tradition. Finally, the function M indicates how the collective actions of the group translate into outcomes that will be used to set future expectations.

This model allows for irrational behavior. Imagination can exist within this model through the formation of expectations. Utility maximization remains an option, but the model is robust to the inclusion of other choice heuristics as well. As such, consistent observations from behavioral economics could embed themselves in an economic model like this. Instead of assuming utility maximization and the REH *a priori*, the model reconsiders microeconomic behavior. In ergodic situations (assuming some exist), we could plug in the well-developed assumptions that have supported mainstream econometric research. In other cases, we could incorporate different assumptions that may better reflect real processes. The framework developed by Bausor (1984) proves the possibility of incorporating irrational behavior into a consistent method of analysis.

The challenge of incorporating these aspects into economic analysis or developing new models lies within the insulation of the field. The tradition of econometric modeling throughout textbooks and practice remains steady. Uncertainty appears to those researchers that choose to take up the subject as a challenging problem with achievable solutions. The maintenance of economic practices in the wake of the subprime crisis proves the existence of this insulation and the difficulty of reevaluating the foundations of the field. A convincing alternative paradigm, which understands uncertainty in the Post Keynesian interpretation, has yet to challenge as a serious competitor. Thus, the probability of a revolution in the field remains low. The ability of different modeling techniques to fit different economic trends will also mean that future crises will go the way of past black swan events: surprising but explainable in hindsight. It remains to be seen if the employment of current economic tools along with more developed datasets will lead to breakthroughs in the explanation of uncertainty that is theoretically satisfactory and empirically consistent.

5 Conclusion

Economists have yet to provide a model that encapsulates the concept of uncertainty and its effect on human behavior. The problem will continue to emerge during periods of instability where the indeterminacy of the future becomes top of mind. The uncertainty-risk dichotomy has become cemented over time paralleling the ascent of the New Classical economics. Post Keynesian analysis of uncertainty provides a point of departure for understanding the problem as a key factor for the dynamics within the current economic paradigm. The transition to an alternative paradigm remains improbable, but evidence has surfaced of efforts to push the boundaries of the current paradigm in search of a sufficient way of incorporating uncertainty into economic analysis. Resistance to past crises has confirmed the tenacity of the current paradigm; Post Keynesian models provide a glimpse of heterodox possibilities for the field[29].

This thesis has attempted to encapsulate the study of uncertainty using the Kuhnian methodological framework. The framing can help categorize different types of economic research with a greater understanding of how these pieces exist together relating to the dynamics of the field. Economists continue to refine risk modeling techniques in hopes of avoiding a similar disaster to the one in 2008; quantitative techniques have evolved, allowing economists greater robustness with the use of alternative probability distributions[30]. Some mainstream researchers have begun to grapple with the idea of uncertainty with the tools allotted by the New Classical paradigm. Despite this work, convincing Post Keynesian arguments would limit the possibility of understanding uncertainty using current econometric tools. The model from Bausor (1984) provides one heterodox example of systematically incorporating uncertainty into economic models.

If uncertainty is to exist as a Kuhnian anomaly in the field, there must develop a greater recognition of its vitality in the study of economics. The countercyclical nature of uncertainty research works against the topic; researchers recognize the importance of understanding uncertainty only during periods of instability. The rise in the influence of behavioral economics will likely lead to a better understanding of human behavior that could have spillover effects on the topic of uncertainty. This thesis argued for the importance of the subject of uncertainty, but the future of the economic paradigm concerning the idea remains an open question.

[29] Post Keynesians differ from New Classical macroeconomists in other ways, notably assuming that the money supply is endogenous. See Nayan *et al.* (2013) for further exploration of this idea. A shift to Post Keynesian macroeconomics would include more than just a reframing of uncertainty.

[30] The recent problems with Silicon Valley Bank and Credit Suisse seem to expose remaining vulnerabilities in the financial sector.

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