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LIFE AFTER "RATIONAL EXPECTATIONS"?

Imperfect Knowledge, Behavioral Insights and the Social Context

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The arguments presented in this paper are extensively developed in our forthcoming book, tentatively entitled ***Illusions of Stability: Financial Markets, the State, and the Future of Capitalism***, which will be published by Princeton University Press in 2010.

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Many people regard the recent financial crisis as a painful addition to an already massive body of evidence that demonstrates the inadequacy of today's economic models of "rational" markets. According to these models, so long as financial markets are populated by "rational" participants, excessive upswings in asset prices, such as those in housing and equity markets in the run-up to the crisis, should not occur. The sudden reversals of these upswings are often pointed to as the proximate cause of the crisis.

But very few have interpreted the inability of "rational" market models to account for such swings as a potentially decisive indication that economists' approach to modeling rational decision-making is irreparably flawed. The debate triggered by the crisis, summarized by *The Economist* in two articles addressing "[w]hat went wrong with economics [a]nd how the discipline should change to avoid the mistakes of the past," has largely overlooked the key problem: the impossibility of establishing a standard approach to modeling how a rational individual makes decisions in *every* situation.[1]

Precisely the presumption that economists' *have* found such a standard has come to underpin models of rational decision-making in a wide variety of contexts – diverse economies, markets, and even fields of inquiry, such as political science and law. In order to arrive at such a universal approach, economists' standard of rationality must abstract as much as possible from differences in individuals' interpretations of the social context, including the process driving market outcomes, history, norms and conventions, and public policies and institutions. For the last three decades, the vast majority of economists, including those following the behavioral approach, have considered the "Rational Expectations Hypothesis" (REH) to be the cornerstone of this standard.

In this paper we sketch the emergence of REH and how it evolved to become the centerpiece of contemporary macroeconomics and finance. We focus on major arguments advanced by the promoters of the hypothesis that seemed to have contributed to its rapid and broad acceptance. We argue that REH models are fundamentally flawed on epistemological and empirical grounds and thus cannot serve as a foundation for thinking about markets and public policy.

Consequently, we urge economists to jettison REH. We have recently proposed an alternative approach, called Imperfect Knowledge Economics (IKE), that could replace

[1] For example, the possibility that the contemporary approach to modeling rational decision-making in financial markets may be woefully inadequate plays no role in Fox's (2009) widely praised insightful discussion of the views of prominent economists concerning the implications of the financial crisis for the relevance and "reform" of finance models.

”rational expectations” in formulating the micro-foundations of models of aggregate outcomes.[2]

In contrast to contemporary models, IKE recognizes the inherent limits to economists' knowledge, as well as the imperfection of knowledge on the part of market participants and policy officials.[3] We argue that adequate accounts of decision-making that ignore imperfect knowledge, regardless of whether they appeal to some notion of "rational" behavior or are based on empirical observations of supposedly "irrational" behavior, are beyond the scope of economic analysis. However, psychological findings, as well as observations concerning the context within which participants make decisions – including historical market outcomes, past policies, norms, and conventions – play a key role in formalizing the foundations of IKE models.

Rationality and the Social Context

According to the *Oxford English Dictionary*, a "rational" individual chooses among alternatives on the basis of "reason or logic." This definition reflects what we intuitively mean when we say that someone makes decisions in a rational manner. However, this common-sense association of "rationality" with reason and logic does not carry over to economists' standard of rationality.

For economists, "a decision-maker is rational if [she] makes decisions consistently in pursuit of [her] own objectives" (Myerson, 1991, p. 2). Economists typically suppose that individuals are motivated by self-interest, and thus that in making decisions they attempt to maximize their *own* well-being. Because selfishness is widely considered to be an innate trait, using self-interest to stand for decision-makers' objectives is compatible with economists' belief that their approach to rational decision-making is universally applicable.

The problem is that what constitutes self-interested decision-making depends on the context within which it occurs.[4] Aiming to define rationality in a way that does not require looking "inside [decision-makers] heads" (Hicks 1956, p. 6), economists have attempted to define consistency of individual choices in terms of purely *a priori* conditions. These conditions treat preference rankings as *purely logical* statements, "which can contradict, or be consistent with each other." (Sen 1993, pp. 498-499). But

[2] For more than 20 years, George Soros has also urged economists to move toward an approach that places individuals' imperfect understanding of processes driving market outcomes at the center of analysis. See Soros (1987, 2008, 2009).

[3] See Frydman and Goldberg (2007, 2008).

[4] For a seminal analysis of this point see Sen (1971, 1993, 1994).

determining whether or not they are consistent often depends on understanding the social context.

As Sen (1993, p. 501) has argued,

> "[S]uppose the person faces a choice at a dinner table between having the last remaining apple in the fruit basket (option B) or leaving the apple for someone else to take and forgoing the opportunity of eating the nice-looking apple (option A). She decides to behave decently and picks nothing (option A), rather than one apple (option B). If, instead, the basket had contained two apples, and she had encountered the choice between having nothing (A), having one nice apple (B), [or having two nice apples] (option C), she could reasonably enough choose one (B), without violating any rule of good behavior."[5]

In checking whether these choices are *internally* consistent, economists would consider them on their *own*, without any reference to an individual's values or the context within which she makes decisions. To be sure, if her sense of decency or some other reason were not behind her apparent preference for A in the first case and for B in the second, such choices would undeniably be inconsistent on purely logical grounds. But, as Sen (1993, p. 501) emphasizes, although this combination of choices would violate the standard consistency conditions, "[t]he presence of another apple (C) makes one of the two apples decently choosable. [T]here is nothing particularly 'inconsistent' in this pair of choices (given her values and scruples)." Indeed, as this example shows, "There is no such thing as internal consistency of choice" (Sen, 1993, p. 499).

Of course, were an economist to take into account the fact that, beyond the anticipated pleasure from eating an apple, the individual is also concerned about the "decency" of her choice, he could have rationalized her choices as being consistent after all. Consequently, once we enlarge the set of factors that an individual considers important for her well-being to include "decency," her choices can be seen to be consistent with self-interest, broadly understood.

Inventing Rational Expectaions

In simple decision problems, as in Sen's apple example, as in the foregoing example, the individual is fairly confident about the consequences of her choices for her own well-being. In such cases, an economist might be able to use his own understanding of the individual's social context to interpret whether she makes consistent choices. However,

[5] This and Sen's other seminal articles (1971, 1994) provide fundamental arguments showing that, even in situations in which the consequences of an individual's choices are known with certainty, there are inherent difficulties in defining rationality in terms of some specific set of *ex ante* logical conditions about the *internal* consistency of her choices.

matters are much more complicated in financial markets, in which the consequences of individuals' choices lie in the future.

Here, an economist must not only model the preferences with which an individual ranks alternative options – for example, in terms of their returns and riskiness – but also how she forecasts these outcomes. Even assuming that all individuals are motivated by self-interest, there is simply no general procedure or model that would pick the precise set of reasons – and the forecasting strategy based on those reasons – that would adequately capture how a *generic* rational individual thinks about the future. But an economist requires precisely such a standard of rational forecasting in order to formulate a set of conditions that would enable him (or anyone else, for that matter) to interpret whether in most situations an individual makes decisions "consistently in pursuit of [her] own objectives."

REH thus instructs an economist to model the way a rational individual forecasts market outcomes with his *own* model of these outcomes. Consequently, in modeling "rational" decision-making, economists largely ignore the diversity of "reasons" upon which individuals in real-world contexts might base their decisions.

Fully Predetermined Rationality

For a contemporary economist a model is not just a mathematical account of market outcomes, Over the last four decades, economists have come to believe that, to be worthy of scientific status, their models should generate "sharp probabilistic predictions" that account for the *full* range of possible market outcomes and their likelihoods.

In order to generate such predictions, economists had to *severely* constrain their accounts of market outcomes to what we refer to as *fully predetermined* probabilistic models. These models *fully* pre-specify how an individual alters the way she makes decisions and the aggregate outcomes unfold over time.[6] By fully predetermining their models, economists disregard the key feature of societal development, particularly in capitalist economies: change is to a significant extent non-routine, for it cannot be adequately captured in advance with mechanical rules and procedures.

As with all contemporary models, every REH model is fully predetermined. REH implies, therefore, an *overarching* forecasting strategy for the market and its participants: it specifies just *one* interpretation of the process driving market outcomes, which, up to a random error term, relates these outcomes exactly to a set causal variables at every

[6] For an early comprehensive treatment of the concept of a sharp probabilistic prediction in modern macroeconomics, see Sargent (1987). For a simple algebraic demonstration that an economist must fully pre-specify change in his models in order to generate sharp predictions, see Frydman and Goldberg (2007, chapters 3 and 4).

point in time, past, present and future. Thus, by using REH to model *individual* forecasting, an economist *must* ignore the diversity of "reasons" upon which individuals in real-world contexts might base their forecasts of the future. Moreover, because each REH model *by design* disregards presumes that participants act *as if* nothing genuinely new would ever happen that would lead them to change the way they think about the future.

Behavioral economists and non-academic commentators often criticize economists' standard of rationality as implying that rational individuals make decisions *as if* they had superhuman abilities to understand the future – that they can compute correctly the consequences for their well-being of alternative options available to them. The raison d'être of behavioral economics has been that most people lack these abilities which supposedly explains why they do not make decisions consistent with economists' standard of rationality.

But REH presumes no such thing. Contrary to the belief that it imputes to individuals superhuman cognitive abilities, REH in fact presumes that market participants forgo using whatever cognitive abilities they *do* have in thinking about the future and making their decisions.

Instead, REH supposes that individuals adhere steadfastly to a single mechanical forecasting strategy. Indeed, economists' characterizations of rational forecasting would appear to any reasonable person, let alone a profit-seeking participant in financial markets, to be obviously *irrational*.

After all, a profit-seeking individual understands that the world around her will change in non-routine ways. She simply cannot afford to believe that she has found an overarching forecasting strategy and, thus, she will look for new ways to forecast, which cannot be fully foreseen. Thus, REH imagines a place devoid of the crucial features that characterize, even in the most rudimentary abstract way, how individuals forecast in real-world markets. [7]

Economists, particularly macroeconomists and finance theorists, often view REH as a "useful abstraction." But the necessity to abstract, intrinsic to all science, cannot render coherent, let alone justify, imputing to individuals demonstrably unreasonable beliefs and then claiming that these individuals are rational.

Unsurprisingly, REH models turned out to be woefully inadequate as characterizations of how profit-seeking individuals make decisions, particularly when it comes to selecting

[7] As one of the most successful participants in financial markets put it, "I went into the financial markets in order to make money, and to do that I did not need to know…the theory of rational expectations." (Soros, 2009).

and revising forecasting strategies.[8] In real-world markets – in which there is diversity and an ever-present possibility that non-routine change will alter the process driving market outcomes – REH models have no connection to what participants would consider "logical and reasonable." Indeed, if individuals really are self-interested, these models portray them as o*bviously irrational*, in the sense that their trading decisions forgo profit opportunities.

REH-based models have played a key role in providing supposedly scientific underpinning strong claims concerning the efficiency of markets, effectiveness of fiscal and monetary policies, as well as the scope and efficacy of financial regulations. Moreover, the widely held belief among economists and non-academic commentators alike that REH portrays adequately how rational individuals think about the future has shaped the public debate on the relative roles of market and the state in capitalist economies.

Emerging Alternative?

REH models have encountered tremendous difficulties in accounting for even the most basic features of aggregate outcomes. Nowhere is this more apparent than in financial markets, where participants' forecasting behavior, for which REH was supposed to be *the model,* is the key factor driving asset prices and risk. Even prior to the recent financial crisis, the "sharp predictions" of REH-based models have time and again turned out to be grossly inconsistent with actual movements of asset prices and risk premia. Elsewhere, we provide an overview of more than 100 studies – *many carried out by REH economists* – that document empirical failures in the currency markets alone.[9] Indeed, studies of other markets, such as those for equities, have also uncovered gross empirical failures.[10]

After considering many empirical studies, Maurice Obstfeld and Kenneth Rogoff concluded in their magisterial book on international macroeconomics that,

> the undeniable difficulties that international economists encounter in empirically explaining nominal exchange rate movements are an embarrassment, but one shared with virtually any other field that attempts to explain asset price data (Obstfeld and Rogoff, 1996, p. 625).

[8] For an early arguments that REH is fundamentally flawed, see Frydman (1982, 1983), Frydman and Phelps (1983), and Phelps (1983).

[9] Frydman and Goldberg (2007, chapters 7 and 8).

[10] In a path-breaking paper, Shiller (1979) showed that conventional models of stock prices are grossly inconsistent with their actual movement. Mehra and Prescott (1985) provided a seminal analysis of the conventional models' failure to account for equity risk premia.

Behavioral economists, for their part, uncovered massive evidence that conventional models – those based on REH – are grossly inconsistent with empirical evidence.[11] Their research has been fundamentally important in opening up economics to alternative explanations of individual decision-making and market outcomes, and has led to new models in which some or all of the *a priori* conventional assumptions have been replaced with formalizations of empirical findings. Many economists have found behavioral insights persuasive, and behavioral economists' relatively quick success in eroding the near monopoly of REH-based modeling is remarkable.

Several factors may explain this development. Arguably, the most important is that "behavioral finance" theorists have embraced the core assumption of the contemporary approach. Thus, they formalize their empirical findings about how individuals act with fully predetermined models.[12] Behavioral economists – the "reformers" – "built on the premise that mainstream economic *methods* are great, [and] so too are mainstream economic *assumptions*." (Rabin, 2002, p., emphasis in the original)

Indeed, when behavioral economists interpreted their important empirical findings that individuals in real-world settings act in ways that are inconsistent with the conventional standard of rationality, they did not conclude that fully predetermined models of rationality fail to capture adequately how self-interested, rational individuals make decisions. Rather, they concluded that market participants are "irrational." Given this interpretation, and their adherence to the conventional approach's conception of science, behavioral economists ended up embracing mechanical models of the "irrational" decision-making that they supposedly observed in markets.[13]

To be sure, not all behavioral economists have embraced fully predetermined models. Indeed, some of the leaders of behavioral finance and macroeconomics have continued to rely on a largely narrative mode of analysis, enabling richer descriptions of fluctuations and risk in asset markets than fully predetermined models of "rational" and

[11] Barberis and Thaler (2003).

[12] For a survey of behavioral finance models, see Shleifer (2000).

[13] Despite their empirical findings, some seminal behavioral models continue to use the *a priori* REH assumptions in modeling forecasting behavior (DeLong et al.,1990a, 1990b). In these models, there is a subset of market participants who are "uninformed" and base their forecasts on erroneous considerations. The "smart" or rational individuals are assumed to have a full understanding of how the uninformed participants forecast. As we discuss in Frydman and Goldberg (2010, chapter 6), this mixing of "rational" and "irrational" particpants is even more problemmmatic than REH. For a recent example of the use of REH in modeling rational forecasting in a widely cited behavioral finance model, see Barberis *et al* (2001).

"irrational" behavior can deliver.[14] But even they have mostly interpreted their findings as indicating irrationality on the part of market participants.

There is, of course, an alternative interpretation of the failure of REH models: purposeful decision-making in capitalist economies, particularly individual forecasting, cannot be adequately portrayed with an economist's fully pre-specified mechanical rules. We urge conventional and behavioral economists to consider this interpretation and abandon REH as a standard of rational forecasting.

Like the contemprary approach to formulating the micro-foundations of aggregate models, the IKE approach that we propose bases its models of aggregate outcomes on mathematical representations of individual behavior. But, unlike contemporary models, IKE attempts to come to terms with early modern economists' justified modesty about how exact their representations of individual behavior could be. As with any scientific theory, IKE must presume that purposeful behavior exhibits regularities, even if these regularities are context-dependent and the moments in time when they become and cease to be relevant cannot be fully pre-specified in advance. However, IKE explores the possibility that these regularities – the ways in which market participants make and alter their decisions – may be formalized with *qualitative* conditions.

Beyond psychology, which behavioral economists emphasize, IKE incorporates observations concerning the social context within which individuals make decisions, including the historical record and conventions among market participants, in formulating qualitative conditions that enter IKE models. While IKE models, *by design*, do not imply sharp predictions of change, they do generate *qualitative* predictions that enable an economist to distinguish empirically among alternative explanations of economic phenomena.[15]

From John Muth to Robert Lucas

Prior to REH, economists portrayed market participants' forecasting with mechanical rules that made no explicit reference to how they reason about the way the economy works or how the causal process underpinning outcomes might change over time. These models portrayed an individual's forecast with a fixed rule that related market prices, or any other outcome, to the historical price record and past forecasts. These models also disregarded the diversity of market participants' forecasting strategies: the

[14] Shiller's (2000) book on "irrational exuberance" in stock prices has become a classic work of this kind. For a recent narrative account of behavioral macroeconomics, see Akerlof and Shiller (2009).

[15] See Johansen *et al* (2010) for econometric methodology. Frydman *et al* (2010) provides a theoretical comparison of REH and IKE explanations of long swings in currency markets and applies the new methodology to test these sharply competing explanations.

forecasts of a single “representative” individual were presumed to capture adequately the aggregate forecast of “the market.”[16]

One such rule that was widely used in the 1960’s portrayed how forecasting behavior would respond to forecasting errors. Suppose that a year ago an individual forecast that the price of wheat today would be $5 a bushel. But, in fact, the price turned out to be $7 a bushel. In forming today’s forecast of next year’s price, an individual was assumed to adjust last year’s forecast by a fixed fraction, say, one half, of the discrepancy between that forecast and today’s price. This “adaptive-expectations” rule implies that she sets her forecast of next year’s price at $6. In most models at the time, this increase in the forecast was assumed to have a positive feedback on price, implying that the individual would continually under-predict the inflation rate.

A profit-seeking individual would, of course, see that, despite her fixed adjustment to forecast errors, her errors kept growing over time. She would likely suspect that there had been a change in the structure of the market or the economy, as well as an upward shift in the overall rate of inflation, and she would attempt to incorporate this reasoning into revisions of her forecast.

REH as a Mechanical Forecasting Rule

John Muth proposed REH as a way to incorporate such considerations into models of forecasting. In criticizing pre-REH forecasting rules, he argued that

> “the character of dynamic processes is typically very sensitive to the way expectations are influenced by the actual course of events. Furthermore, it is often necessary to make sensible predictions about the way expectations would change when either the amount of available information or the structure of the system is changed.” (Muth, 1961 pp. 315-316)

Muth’s idea was that by relating participants’ forecasting strategies to an economic model that purportedly captured the structure of the economy, economists would be able to make such “sensible predictions” over time. Consequently, he formulated REH as a hypothesis that market participants’ forecasts “are essentially the same as the predictions of the relevant economic theory.”

Muth was well aware of the danger that the term “rational expectations” might suggest some notion of rationality. Indeed, he pointed out that REH should *not* be viewed as a normative hypothesis about how rational individuals should forecast the future. As he put it, “At the risk of confusing this *purely descriptive* hypothesis with a pronouncement

[16] For early examples of such expectations rules, see Cagan (1956), Friedman (1956), and Nerlove (1958).

as to what firms *ought to do*, we call such expectations 'rational.'" (Muth, 1961, p. 316, emphasis added)

However, even viewed as a "purely descriptive hypothesis," it is far from clear how REH should be used to describe market participants' forecasting strategies. In order to implement REH, economists had to take a stand on the question of "the relevant economic theory" to which the hypothesis refers.

Muth did not discuss the difficulties inherent in selecting *the* relevant theory that should be used in implementing REH. In a fateful decision that triggered the REH revolution in macroeconomics and finance roughly a decade later, he embedded REH in a simple model of the agricultural market with a production lag. The model portrayed the price of produce at each point in time, *t,* as being dependent on farmers' expectations formed at some earlier time, *t-1,* when they had to decide what crop size to aim for. The implementation of REH in this model is particularly straightforward: farmers' expectations regarding the market price at *t* are set equal to the prediction of that price, implied by an economist's model, at *t-1.*

By using his own model as "the relevant economic theory," Muth in effect ignored the fact that there are many potentially "relevant" theories on offer. Indeed, not only do market participants have diverse views, but economists themselves are notorious for their disagreement about what underpins outcomes, particularly in financial markets and the macro-economy. Thus, even if "the relevant theory" means a model based on economic theory, which is how economists have interpreted REH, each of their many extant models, as well as any combination of them, is *in principle* available to individuals in forming their forecasts about the future. Moreover, as time passes, profit-seeking individuals and career-minded economists discover inadequacies in old models and attempt to formulate new ones, thereby expanding or contracting the set of relevant theories that market participants might use when forecasting the future.

Muth's idea that market participants pay attention to changes in the structure of the economy in forming their forecasts is compelling. However, the hypothesis that the relevant theory that captures how they use this information to think about the future is a *particular* economist's model is far-fetched. Nevertheless, economists have used REH in exactly the way that Muth did: whenever an economist devises a model that relates market outcomes to participants' forecasts of these outcomes, he implements REH by equating these forecasts with the predictions generated by his own model.

In viewing REH as a description of how market participants forecast, disregarding the plurality of extant economic models and forecasting strategies is not the only serious shortcoming. An even more fundamental problem is that for contemporary economists *the* relevant theory is a fully predetermined model. Indeed, the agricultural market model

that Muth used to introduce REH was fully predetermined. Thus, like the pre-REH forecasting rules, REH excludes, by design, the possibility that individuals revise their forecasting strategies in non-routine ways. Because a fully predetermined model implies a *single* overarching forecasting strategy, REH amounts to assuming that one strategy specified in advance adequately characterizes how market participants will think about the future at every point in time.[17]

By maintaining the contemporary insistence on fully predetermined models, Muth subverted his own insight. His idea that changes in the structure of the economy would generally lead market participants to alter their forecasting strategies merely morphed into another mechanical rule that presumed that participants' never revise their forecasting strategies in a way that they, or an economist's REH model, had not foreseen in advance.[18]

Early criticism of REH focused on its epistemological flaws as a model of rational forecasting, and also pointed out its behavioral implausibility as the "purely descriptive hypothesis" that Muth envisaged. Thomas Sargent, one of the most forceful early advocates of REH, acknowledged these critical arguments and recognized that treating REH as a plausible description of how market participants forecast the future is "misleading." As he put it,

> The idea of rational expectations is sometimes explained informally by saying that it reflects a process in which individuals are inspecting and altering their forecasting records....It is also sometimes said that [REH embodies] the idea that economists and the agents they are modeling should be placed on equal footing: the agents in the model should be able to forecast and profit-maximize and utility-maximize as well as...the econometrician who constructed the model. (Sargent 1993, p.21)

He then pointed out that

[17] Economists capture this strategy with a single probability distribution. Frydman and Goldberg (2007, chapter 6) show rigorously that even if an economist allows for changes in forecasting strategies, as Hamilton (1988) does, he fully pre-specifies such revisions, and thus in effect portrays forecasting with a *single* overarching strategy – a single probability distribution – that characterizes forecasting at all points in time, past, present, and future.

[18] For an alternative way to formalize the idea that economists' models might be useful in modeling market participants' forecasting, see the Theories Consistent Expectations Hypothesis (TCEH) in Frydman and Phelps (1990). Frydman and Goldberg (2007, chapters 10 and 15) show how TCEH can be used to examine empirically the movements of exchange rates using models that place imperfect knowledge at the center of the analysis.

> [T]hese ways of explaining things are *suggestive, but misleading*, because they make [REH] sound less restrictive and more behavioral than it really is. (Sargent 1993, p.21, emphasis added)

REH's implausibility as a descriptive hypothesis undermines Muth's hope that it would enable economists "to make sensible predictions about the way expectations would change" in response to changes in policy or any other change in the social context.[19] However, somewhat paradoxically, the implausibility of REH as a description of forecasting in real-world markets is entirely consistent with his warning that it should *not* be viewed as a hypothesis "as to what firms ought to do."

From Inadequate Description to "Gold" Standard of Rationality

Muth's view that REH should be regarded as a "purely descriptive" empirical hypothesis underscored his skepticism that it could play a central role in macroeconomic theory. Indeed, for almost a decade after Muth proposed REH, macroeconomic modelers largely ignored it. Remarkably, when Phelps organized a milestone conference in 1969 on the role of expectations in modeling the micro-level foundations of macroeconomic theories, the papers collected in the conference volume (Phelps, 1970) made no use of REH, and it is not even listed in the index.

Ignoring Muth's warning, Lucas set out to justify the use of REH as *the* way to portray "rational" forecasting on the part of a "representative agent," whose preferences, information, and forecasting strategy stand for an "average" of these aspects of decision-making across all market participants.[20] His "justification" was based on the core belief that underpins the contemporary approach to macroeconomic theory and finance: fully predetermined models can provide adequate accounts of market outcomes. Lucas observed that whenever an economist formulates *his* theoretical account of market prices, he, like every scientist, hypothesizes that his account adequately portrays how these outcomes unfold over time. Were an economist to impute to a representative agent forecasts that differed from the predictions of his own model, he would be assuming, in effect, that "she" is obviously irrational: she steadfastly adheres to the forecasting rule that generates forecasts that, *ex hypothesi,* systematically differ from "actual" market prices.

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[19] Central banks around the world, spurred by widespread acceptance of Lucas's (1976) arguments that REH models, unlike traditional Keynesian econometric models, offer the means to examine the effects of changes in economic policy on market participants' forecasting strategies, adopted the idea that REH models provide an adequate description of forecasting behavior.

[20] Lucas (1995, 2001) provides a fascinating account of the way he arrived at this "justification" and its importance for subsequent developments in macroeconomics and policymaking.

In a leap of faith that would change the course of macroeconomics and finance for generations, Lucas presumed that REH is the *only* way to purge such irrationality from macroeconomic models, because, in a fully predetermined model, the only forecasting strategy that would *not* generate systematic forecasting errors is that implied by REH. Combining an uncontroversial observation concerning scientific practice with an unfounded belief in the possibility of an overarching account of market outcomes, Lucas concluded that the exact consistency between the individual and aggregate levels imposed by REH provided the standard of rationality that could finally turn economics into an exact science.

To an economist who did not question the prevailing faith in fully predetermined models, REH did indeed look like such a standard. Because it can be applied in *every* fully predetermined model, every economist could use REH in the context of his own model to represent how a representative agent – the market – *should* forecast the future. Lucas's presumption that this *model consistency* ensures a representative individual's rationality in forecasting quickly became the standard in modeling "micro-foundations" of macroeconomic and finance models. It was quickly embraced by a vast majority of economists, Chicago-school free-marketeers or MIT neo-Keynesians.[21]

Moreover, because REH supposedly determines the market's forecast, the model-consistency that it imposes has morphed into a presumption in economists' discourse that the market is "rational." Over time, economists' belief in the scientific underpinnings of the rational market entered the public debate, with grave consequences for public policy.

But what the public could not easily see in economists' formal arguments is that the use of model-consistency to analyze outcomes in real-world markets or to design government policies involves building proverbial castles in the air. Their foundation is the weightless belief that every time an economist devises an REH model, he has discovered *the* way to capture, in an *exact* representation, what Hayek (1945) referred to as "the use of knowledge in society" and how its division unfolds over time.

Pseudo-Diversity in the "Rational Market"

In real-world markets, participants must rely on their own imperfect understanding of which variables are important for forecasting and how those variables are related to future outcomes. No participant, let alone an economist, knows in advance how she will revise her forecasting strategies, or how the social context will change as the future unfolds. Myriad possible changes may lead to a rise or decline in an asset price. At

[21] This "consensus" concerning the applicability of REH emerged in the early 1970's and has survived for more than three decades. For a recent account of this consensus by two leading "neo-Keynesisn" macroeconomists, see Blanchard (2008) and Woodford (2008).

each point in time, it is reasonable for some participants to expect the price to rise, and for others to expect that it will fall. It may even be reasonable for some individuals to remain consistently bullish or bearish during a period of time in which the asset price moves steadily against them. Indeed, an individual might reasonably decide to increase the size of her long or short position precisely *because* the price has moved further away from her expected level.

Although Muth, in proposing REH, sidestepped this diversity and focused instead on an aggregation of market participants' forecasting strategies – "the market's" forecasting strategy – he did claim that REH is compatible with it: REH "does not assert that the scratch work of entrepreneurs resembles the system of equations [in an economist's model] in any way" (p. 317). This claim seems to underpin a widely held belief: REH is an "approximation" that enables economists to capture in a parsimonious way the complexities posed for understanding outcomes by diversity and revisions of market participants' forecasting strategies.[22]

What Muth and others have overlooked, however, is that REH requires that the micro-level diversity – the proportions of participants' holding particular views of the future and their forecasting strategies – *must* unfold over time in a fully predetermined way. The same mechanical rules are presumed to characterize this pseudo-diversity of participants' forecasting strategies at all points in time, past, present, and future. Indeed, any change in the proportion of bulls and bears in the market or revisions in their views must be tied to each other mechanically in order to ensure that, in the aggregate, individuals' expectations remain "essentially the same as the predictions" of an economist's fully predetermined model.[23]

By focusing on the market, REH does, indeed, abstract from differences between bulls and bears' forecasting strategies. But, by hypothesizing that an economist' fully predetermined model adequately approximates the predictions of the aggregate forecast, REH does *not* "approximate" the diversity underpinning outcomes in real-world markets, as is commonly believed; it accomplishes this only in economists' imagined

[22] Despite the importance that macroeconomists ascribe to basing accounts of market outcomes on individual foundations and the central role that REH plays in modeling these "micro-foundations," there has been surprisingly little discussion in macroeconomics about viewing REH as being applicable only to the market. By contrast, microeconomists and game theorists, who primarily model individual behavior or interactions among a few individuals, had no choice but to dissect economists' notion of rationality. This research points to several fundamental problems that are analogous to those that plague attempts to rationalize REH. For seminal work on these questions, see Bernheim (1984) and Pearce (1984). For a closely related critical discussion of the Bayesian approach to rationality, see Gilboa, *et al* (2008) and Binmore (2009). Frydman and Goldberg (2007, chapter 3) analyze rigorously an inherent conflict between contemporary economists' program of relating market outcomes to individual foundations and their insistence on modeling these foundations in fully predetermined ways.

[23] For further discussion and rigorous demonstration of this and other claims concerning the flaws of REH summarized here, see Frydman and Goldberg (2010, chapters 3 and 4).

"rational market." In this fanciful place, abstraction is built upon abstraction: each REH model "abstracts" from an already constructed diversity that has no connection to the differences of views among individuals in the real world and how this diversity unfolds over time.

The Incoherence of the "Rational Market"

Beyond its inherent incompatibility with how participants revise their diverse forecasting strategies in real-world markets, the widespread belief that REH "approximates" this micro-level diversity renders incoherent the very notion of the "rational market." If the "rational market" were populated by participants who made use of different forecasting strategies, every one of them would be obviously *irrational*, in the sense that they would ignore systematic forecast errors and thereby forgo obvious profit opportunities *endlessly*.

This incoherence points to the fundamental problem with Lucas's argument that REH enables an economist to rid his model of irrationality. Lucas (2001) considered a simple model of a market that attributes to firms in each period the forecast that a given market price will remain constant at its current level, while such forecasting results in a market price that nonetheless rises period after period. According to Lucas,

> In such a model, you could *see* profit opportunities that firms were passing up. Why couldn't they see these opportunities, too? But if they did, the model couldn't be right. If your theory reveals profit opportunities, you have the wrong theory (Lucas, 2001, p.13).

For Lucas, the supposed "profit opportunities" implied by his simple model were symptomatic of the fundamental flaw in pre-REH attempts to base models of aggregate outcomes on explicit micro-foundations. As he recounted in his Nobel lecture,

> The prevailing strategy for macroeconomic modeling in the early 1960's held that the individual or sectoral models…could…simply be combined in a single [macroeconomic] model. But models of individual decisions over time necessarily involve expected future prices…. However, … [aggregate] models assembled from such individual components implied behavior of *actual* prices… that bore no relation to, and were in general *grossly inconsistent* with, the price expectations that the theory imputed to individual agents (Lucas, 1995, pp. 254-255, emphasis added).

Modeling participants' forecasts with REH was for Lucas the "right theory": the consistency between firms' forecasts and the predictions of the economist's model seemed like *the* way to eliminate "profit opportunities" from his models. As he put it,

“John Muth's [REH] focused on this inconsistency… and showed how it can be removed” (Lucas, 1995).

Although Muth stressed that model consistency should not be confused with “a pronouncement of what firms ought to do,” economists embraced Lucas’s radical reinterpretation of REH as *the* way to model how rational individuals forecast the future. What Lucas and his followers have overlooked is that if REH does *not* assert “that predictions of firms are perfect or that their expectations are all the same**”** (Muth, 1961, p. 317), models that employ this hypothesis imply grossly irrational forecasting on the part of market participants. Thus, Lucas’s claim that REH enables an economist to remove irrationality from his model is simply false.

To illustrate this, suppose that after imposing consistency, Lucas’s simple model predicts that the price will rise by five percentage points per year. By design, REH presumes that firms’ forecasts are consistent with this prediction – on average, they, too, expect the price to rise by five percentage points per year. To allow for some minimal degree of diversity, suppose that there are two different groups of firms of roughly equal size: one forecasts an annual price rise of six percentage points, while the other forecasts a rise of four percentage points. The average forecast is five percentage points, vindicating this REH model’s claim to portray the market’s forecast. But each group’s forecast is obviously and systematically biased. Thus, according to Lucas’ own argument, the REH model “reveals profit opportunities, [and thus is] the wrong theory.”

Recognizing diversity reveals that even if REH models were to apply only to the market, they could hardly be considered a statement about its rationality. On the contrary, REH’s so-called “rational markets” are populated by irrational individuals.

In order to avoid this incoherence, economists would have to discard the belief that REH is compatible with diversity of forecasting startegy on the micro-level. Once diversity is replaced by thought uniformity, each participant thinks alike and forecasting by one of them – a representative agent – captures *both* forecasting on the individual and aggregate levels.

The Irrationality of the “Rational Market”

Even if one views REH as a hypothesis about a representative agent who thinks like all others and *is* “the market,” her “rationality” in REH World has absolutely no connection to the way real-world markets work. Indeed, in the real world, economists’ figment of the “rational market” would imply that market participants, individually and in aggregate terms, forgo obvious profit opportunities endlessly.

Although economists presume that non-routine change is unimportant, profit-seeking individuals cannot afford to do so. They understand that change in markets and the

economy cannot be boiled down to a model that connects the future mechanically to the past. Nonetheless, fully predetermined accounts of aggregate outcomes might be useful in attempts to understand limited periods of time. Indeed, with insightful selection of the causal variables and a bit of luck, these models might adequately capture – according to statistical or other, less stringent criteria – the past relationship between causal variables and aggregate outcomes in a selected historical period.[24]

As time passes, market participants eventually revise their forecasting strategies, and the social context changes in ways that cannot be fully foreseen by anyone. The collapse of the hedge fund Long Term Capital Management in 1998, and the failure of ratings agencies to provide adequate risk assessments in the run-up to the financial crisis of 2007-09, shows that models that assume that the future follows mechanically from the past eventually become inadequate. After all, trading in financial markets cannot be reduced to mere "financial engineering," even if it is based on the most recent advances in contemporary finance theory.

REH models are not only fully predetermined, but constitute a particularly restrictive version of fully predetermined models: they purport to account for the effect of expectations on outcomes exactly.[25] Even if one were to maintain that an REH model adequately described outcomes – produced adequate forecasts on average – before non-routine change occurred, it would cease to do so afterward. Imputing to the market a forecast based on a model that *by design* ignored non-routine change would imply that participants on average gave up obvious profit opportunities.

Thus, contrary to economists' claim that REH provides the only way to model forecasting at all future periods, in fact it presumes that eventually the market – *all* of its participants – will become obviously irrational.

The Fatal Conceit of REH

Unsurprisingly, imposing consistency within economic models did not deliver a simple solution to the daunting problem of modeling how rational individuals think about the future. Instead, it constrained economists to search for explanations of market outcomes that assume that market participants' forecasting does not play an

[24] Fully predetermined models imply that, conditional on a set of causal variables, market outcomes can be adequately portrayed with a standard probability distribution. Savage's (1951) notion of "subjective probability" is often invoked to justify such representations of uncertainty in forecasting and decision-making. But, as Binmore (2009, p. 117) points out, Savage restricted the "application of his theory to what he called *small worlds*" that pertain to probabilities extending over very short time horizons.

[25] Beyond implying a set of causal factors, they require the weights on those factors to satisfy stringent constraints that have been rejected repeatedly on the basis of time-series data. Although fully predetermined models that do not impose such constraints – for example, the traditional Keynesian models – may be useful, this is unlikely to be true of REH models, even over limited periods of time.

autonomous role in driving these outcomes. Once an economist decides how to model market participants' preferences and the context within which they make decisions at all times, past, present, and future, he no longer needs to worry about how they interpret the process driving outcomes and forecast the future. His model tells him how they think: "In rational expectations models, people's beliefs are among the outcomes of our theorizing. They are not inputs."[26]

This lack of an autonomous role for market participants' forecasting in REH models has been viewed as their principal virtue, because it disciplines economic analysis in a way that was absent in previous models. Indeed, Lucas' stricture, "beware of theorists bearing free parameters [and causal factors arising from autonomous forecasting]"[27] had a profound impact on the evolution of economics. Until the recent emergence of behavioral models, explanations of outcomes that violated Lucas' stricture were all but barred from professional journals, public policy discussions, and debate. But, as we have pointed out, economists and the public alike should *beware of REH models:* they have absolutely no connection to real-world forecasting and thus cannot serve as a foundation for thinking about markets and public policy.

In capitalist economies, market participants, individually or in the aggregate, are not constrained to follow economists' "reasons" in thinking that nothing genuinely new can ever happen, even if REH presupposes that it is rational for them to do so. Indeed, precisely because they seek profits, market participants reject the notion that nothing genuinely new can ever happen, and instead engage in an intensive search for change in the process driving outcomes. Capitalist economies' key feature is that profit-seeking individuals search for new ways to deploy their resources and thinking about the future. This underpins an incessant effort not merely to identify change, but to engender it – an effort in which markets play an essential role.

In an interview with Thomas Sargent, one of the pioneers of REH, George Evans and Seppo Honkapohja (2005) asked**:** "Do you think differences among people's models are important aspects of macroeconomic policy debates?" Sargent replied: "The fact is that you simply cannot talk about those differences within the typical rational expectations model. There is a communism of models. All agents inside the model, the econometrician, and God share the same model. The powerful and *useful* empirical implications of rational expectations…derive from that communism of models (emphasis added)."

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[26] Thomas J. Sargent, in an interview with Evans and Honkaponhja (2005, p. 566). All further quotes that appear in this chapter without explicit citation are taken from this interview.

[27] Attributed to Lucas by Sargent (1999, p. 73).

But the reason that markets play an essential role in modern economies is precisely that non-routine change is important and knowledge is imperfect, giving rise to diverse views. Thus, any societal design or scientific program based on a “communism” of ideas – such that everyone believes in the same view of the future, or that market participants, economists, social planners, or policy officials can fully foresee or fully predetermine the future – cannot *in principle* deliver what it promises.

Because REH’s fundamental flaws will continue to impede economists’ search for useful accounts of market outcomes, it is time to consider jettisoning it. Its implications concerning the role of markets, and its assessments of the consequences of various government policies, have no scientific underpinning. As history has shown, such fundamentally flawed theories, when implemented in practice, are likely to produce economically disastrous – and socially dangerous – consequences.

Imperfect Knowledge Economics

IKE resumes the modern research program in macroeconomics, which was interrupted by the REH revolution. The giants of early modern economics (Knight, 1921; Keynes, 1921, 1936; Hayek, 1945, 1948) and the originators of the modern micro-based approach to macroeconomics (Phelps, 1968, 1970) emphasized the importance of forecasting for understanding market outcomes. However, they also argued that the key feature of capitalist market economies is that they engender change that cannot be pre-specified with mechanical rules. At the time Phelps pioneered modern macroeconomics, it was not apparent how to leave mathematical models open to autonomous, non-fully pre-specified revisions of forecasting strategies while still representing individual decision-making mathematically. We propose IKE as such an approach.

Like contemporary models, IKE models consist of representations of an individual's preferences, the constraints that she faces, her forecasts of the future outcomes that are relevant to her well-being, and a decision rule that selects her preferred deployment of resources. However, IKE recognizes that knowledge is inherently imperfect: no one has access to a fully predetermined model that adequately represents, as judged by whatever criteria one chooses, the causal mechanism that underpins outcomes in all time periods, past and future. Consequently, IKE does not fully pre-specify which causal variables may be relevant, or when and how these variables may enter an economist's representation of forecasting behavior. In this way, IKE models remain open to changes in the ways individuals in real-world markets forecast the future – ways that they themselves, let alone economists, cannot specify in advance.

Although IKE jettisons sharp predictions, it aims to explain aggregate outcomes on the basis of mathematical representations of individual decision making. To this end, IKE explores the possibility that revisions of forecasting strategies, though diverse and

context-dependent, might exhibit qualitative regularities that can be formalized with mathematical conditions. An aggregate model based on such microfoundations generates only qualitative predictions of market outcomes.

Non-Standard Use of Probabilistic Formalism

Contemporary models represent outcomes at each point in time -- and thus how they unfold over time -- with a single "overarching" conditional probability distribution.[28] The relationships between the moments of this distribution and the set of causal variables constitute the model's empirical content that can be confronted with the time-series data.

By contrast, early modern economists argued that standard probabilistic representations cannot adequately represent change. Indeed, both Knight and Keynes emphasized that economic decisions and institutional and policy changes are fraught with radical uncertainty; the complete set of outcomes and their associated probabilities can neither be inferred from past data nor known in advance.

Radical uncertainty is often thought of as a situation in which no economic theory is possible: economic decisions stem from “animal spirits.” Although animal spirts may play a role, IKE explores the possibility that individual decision-making displays some qualitative regularity that can be represented with a mathematical model. Consequently, IKE adopts an intermediate position between radical uncertainty and the contemporary presumption that models that fully pre-specify change are not only within reach of economic analysis, but anything less is not worthy of scientific status.

Departing from the position of Knight and Keynes, IKE makes use of the probabilistic formalism. This facilitates the formalization of conditions that specify the microfoundations of IKE models and the mathematical derivation of their qualitative implications. However, IKE recognizes the importance of early modern arguments that market participants, let alone economists, have access to only imperfect knowledge of which causal factors may be useful for understanding outcomes and how they influence those outcomes.

Like extant approaches, IKE represents revisions of market participants' forecasting strategies, and more broadly change in how individuals make decisions, with transitions across probability distributions. However, IKE constrains these revisions with only qualitative conditions. Consequently, it does not follow extant approaches in presuming that individual decision making and market outcomes can be adequately represented with a single overarching probability distribution. At the same time, IKE does not adopt the other extreme position that uncertainty is so radical as to preclude economists from

[28] See Frydman and Goldberg (2007, chapter 6).

saying anything useful and empirically relevant about how market outcomes unfold over time.

Because its restrictions on change are qualitative, IKE models represent outcomes at every point in time with myriad probability distributions. Nevertheless, the qualitative restrictions of IKE models constrain all transitions across probability distributions to share one or more qualitative features. These common features, which are embodied in what we call partially predetermined probability distributions, enable economists to model mathematically some aspects of the causal mechanism that underpin individual decision making and market outcomes.[29]

Such probabilistic representations constitute the empirical content of IKE models. Although IKE acknowledges the limits to knowledge, it constrains its models sufficiently to distinguish empirically among alternative explanations of aggregate outcomes. Jettisoning sharp predictions may appear to lower the "scientific standard" that economists have self-imposed on their models. However, as Hayek anticipated, replacing the "pretense of exact knowledge" with imperfect knowledge as the foundation for economic analysis is crucial for understanding markets.

Combining Insights from Economics and Other Disciplines[30]

The premise of IKE that individual decision making cannot be adequetely characterized with *a priori* assumptions. In modeling individual behavior, therefore, economists must make use of empirical findings about how individuals actually behave. This necessity undermines the common belief among economists, that contemporary economics can rigorously explain the findings of other "soft" social sciences. IKE models require an economist to adopt the opposite view: in order to represent purposeful individual decision-making, economists must draw on the findings of other social scientists. IKE makes use of these findings in specifying the microfoundations of its models.

Preferences

Many studies have found that conventional representations of preferences, which usually involve expected utility theory and the assumption of risk aversion, are grossly inconsistent with the way individuals actually behave. Much of the evidence concerning how individuals make choices is based on laboratory experiments in which the structure of payoffs from various gambles is predetermined by the experimenter. This common experimental design allows the investigator to examine the nature of an individual's preferences without the confounding problem of having to represent her forecasts of the

[29] For some simple examples of partially predetermined probability distributions, see Frydman and Goldberg (2007, chapter 3).

[30] The examples in this section draw from Frydman and Goldberg (2007).

potential payoffs from gambling. The seminal formulation of prospect theory by Kahneman and Tversky (1979) and Tversky and Kahneman (1992), including loss aversion, make use of such a experimental setup.

Although laboratory experiments have been the key to uncovering new ways to model preferences, their typical design effectively limits the economist's view of an individual's decision-making; the economist is able to observe only the subject's responses to an experimenter's stimuli. This basic framework, which is used extensively in psychological research, sidesteps a key problem: participants in real-world markets forecast payoffs---the experimenter's "stimuli"---on the basis of imperfect knowledge. Moreover, these forecasts depend not only on the subject's creativity, her analytical abilities, and other personal characteristics, but also on the unfolding social context.[31] As a result, the basic type of model used in these psychological experiments is grossly insufficient as a foundation for representing economic behavior.

In specifying the microfoundations of our IKE models of asset markets, we extend Kahneman and Tversky's original formulation of prospect theory to recognize the importance of imperfect knowledge.[32] Our formulation, which we call *endogenous prospect theory,* is motivated by the experimental evidence. It assumes that an individual's degree of loss aversion increases as her forecast of the size of potential losses increases. Because we represent forecasting with qualitative conditions, the way in which an individual's degree of loss aversion changes between any two points in time is only partially predetermined in our models.

Forecasting Behavior

IKE replaces REH and other fully predetermined forecasting rules with qualitative conditions characterizing how an individual revises her forecasting strategy. In formalizing such revisions we make use of behavioral observations. For example, researchers have uncovered much evidence that individuals are moderate in how they revise their beliefs in the face of new evidence.[33] In our model of exchange rate swings, we formulate this finding in terms of partially predetermining restrictions that limit the change in a market participant's forecast that arises from the change in her forecasting strategy.

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[31] Kahneman and Tversky (1979) recognized that laboratory experiments, while useful in uncovering the properties of the utility function over single outcomes, may be much less informative about an individual's choices over gambles with two or more uncertain outcomes in real-world markets.

[32] See Frydman and Goldberg (2007, chapter 9).

[33] See Edwards (1968) and Shleifer (2000).

However, the importance of the social context for an individual's decision-making implies that, in searching for empirical regularities that might be useful in modeling an individual's decisions, economists will need to look beyond laboratory experiments and insights from psychology. For example, we make use of Keynes's (1936) insight that conventions among market participants play an important role in individual decision-making. We also draw on our understanding of the qualitative regularities that have characterized aggregate outcomes; we suppose that market participants must also be aware of these regularities when they form their forecasts. For example, the tendency of exchange rates to undergo long swings away from historical benchmark levels and then to exhibit sustained counter-movements plays a key role in our model of the premium on foreign exchange.

IKE as the Boundary of What Macroeconomic Theory Can Deliver

In Frydman and Goldberg (2007), we show how IKE models shed new light on the salient features of the empirical record on exchange rates, which have confounded international macroeconomists for decades. Although these results are promising, it is much too early to claim broader usefulness for IKE in macroeconomic and policy modeling.

In contrast to the conventional approach, which seeks to understand economic decisions with fully predetermined rules, the constraints of IKE models are qualitative and context-dependent. If qualitative regularities can be established in contexts other than asset markets, IKE can show how they can be incorporated into mathematical models. However, in contexts in which revisions of forecasting strategies cannot be adequately characterized with qualitative conditions, empirically relevant models of the observed time-series may be beyond the reach of economic analysis. In this sense, IKE provides the boundary to what modern macroeconomic theory – which aims to explain empirical regularities in aggregate outcomes with models that are based on mathematical micro-foundations – can deliver.

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