Change and Expectations in Macroeconomic Models: Recognizing the Limits to Knowability[*]

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In modern economies, individuals and companies engage in innovative activities, discovering new ways to use existing physical and human capital, and new technologies in which to invest. The institutional and broader social context within which these activities take place also changes in novel ways. Moreover, market participants search for and occasionally adopt new ways to forecast returns from their activities.[1] Thus, change in capitalist economies is to a significant extent non-routine, for it cannot be adequately represented in advance with mechanical rules and procedures.

Contemporary macroeconomics and finance theory has overlooked the limits to what economists can know – limits that arise from non-routine change. To be sure, economists have developed a variety of models that recognize market participants' need to cope with imperfect knowledge or incomplete and/or distorted information concerning the process driving outcomes. But, notwithstanding their many differences, all of these models assume away the possibility that participants in real-world markets cope with their imperfect knowledge and information in ways that economists cannot fully foresee.

Indeed, the vast majority of contemporary models are *fully predetermined*: conditional on the values of the causal (often-called "informational" variables) in an economist's model at a point in time, they determine *exactly* all potential changes and the probabilities with which they might occur-----in the past, present, and future all at once. Such *overarching* probability distributions represent change as random deviations from a fully predetermined time path and thus assume away non-routine change altogether.

Assuming away non-routine change does not, however, eliminate its importance for understanding outcomes in capitalist economies. Non-routine change alters how market outcomes unfold over time in ways that puts an overarching probabilistic representation of the process driving outcomes out of reach of economic analysis. That is why economists often find gross inconsistencies when they confront their fully predetermined models with time-series data.

In our recent work, (Frydman and Goldberg, 2007, 2011, 2013a), we argue that contemporary models also suffer from insuperable epistemological flaws, and that their empirical and theoretical difficulties – which are particularly apparent in modeling market participants' expectations – can be traced to economists' core premise that fully predetermined accounts of change are possible.

[1] For seminal arguments concerning the complex interactions between market participants' expectations and market outcomes in modern economies, see Keynes (1936), Phelps (1970), and Soros (1987). For recent expositions in the context of modern macroeconomics and finance theory, see Phelps (2007), Frydman and Goldberg (2007, 2011), and Frydman and Phelps (2013).

In the first part of this paper, we sketch how this core premise has derailed the development of macroeconomic analysis for the last four decades.[2] We discuss why portraying outcomes with fully predetermined models lacks any connection – even as a bold abstraction – to how individuals forecast outcomes in real-world markets. Moreover, we explain how ignoring the limits to knowability has underpinned economists' widespread belief that the so-called Rational Expectations Hypothesis (REH) represents how rational individuals forecast the future. That belief, we point out, has obscured our understanding of markets' role in modern economies, and of how, in many markets, their participants' forecasting drives outcomes. It has also led to a false dichotomy: rational decision-making based on fundamental considerations versus irrational behavior driven by psychological factors.

In the second part of the paper, we discuss how Imperfect Knowledge Economics (IKE) jettisons extant models' core premise, and how this helps us to overcome their epistemological flaws. By opening economic models to non-routine change and recognizing imperfect knowledge *on the part of economists,* IKE reflects the fact that, as Popper put it, "Quite apart from the fact that we do not know the future, the future is objectively not fixed. The future is open: *objectively* open" (Popper, 1990, p. 18, emphasis added).

Tony Lawson (1979) forcefully argued that the failures of extant models are largely due to their disregard of the objective openness of the future course of real-world events. But he went further: in Lawson (2001), he suggested that "event regularities of the requisite sort" to represent individual behavior and aggregate outcomes mathematically are "rather rare even in the natural realm," let alone in markets.

While we share Lawson's position concerning the source of fully predetermined models' empirical failure, we argue that opening models to non-routine change does not *necessarily* mark the end of formal economic theory. IKE holds out the possibility that individual behavior and market outcomes exhibit regularities, which makes economic theory possible, though we cannot expect these regularities to conform to mechanical rules. At best, these regularities can be portrayed with qualitative conditions that begin and cease to be relevant at moments that no one can fully foresee.

Moreover, such qualitative and contingent regularities are context-dependent. In this sense, IKE picks up where Keynes left off. As Dow (2013) points out, Keynes believed that long-standing

[2] For a rigorous demonstration of the main claims discussed in this paper, see Frydman and Goldberg (2013a).

conventions imparted some regularities to individual behavior. Thus, she argues for the possibility of formal economic theory for an "open system," which "is not the opposite of a closed system, since there is a range of possibilities for openness, depending on which conditions are not met and to what degree….Deviating from a closed system does not mean abandoning theory or formal models."

We discuss how IKE recognizes that the future is "objectively open" and yet can represent individual decision-making and aggregate outcomes with a mathematical model. We show that opening a mathematical model to non-routine change and imperfect knowledge on the part of economists enables us to incorporate both fundamental variables (such as earnings and interest rates), on which REH theorists focus, and the psychological and social considerations that behavioral economists emphasize without presuming obvious irrationality on the part of market participants.

Although respecting the limits to knowability does entail abandoning the contemporary search for overarching probabilistic accounts of outcomes, as Popper (1957) argued, it does not necessarily mark the end of formal economic theory that can be confronted with empirical evidence.

Although IKE models do not represent outcomes in standard probabilistic terms, they generate qualitative and contingent predictions that can be confronted with empirical evidence. In a companion paper prepared for this conference (Frydman and Goldberg, 2012a), in a recent paper co-authored with Soren Johansen and Katarina Juselius (Frydman *et al.*, 2012b), we show how implications for time-series data can be derived from an IKE model of fluctuations in currency markets. We show that an IKE model provides a significantly better account of these fluctuations than its fully predetermined "rational" counterparts. This finding suggests that recognizing the inescapable limits to our knowledge that arise from non-routine change may be the key to bringing macroeconomic and finance models closer to reality.

Assuming Away Non-Routine Change

In modeling an individual's decision-making – in an asset market, for example – economists typically specify her preferences, forecasting strategy, the constraints that she faces, and a decision rule governing how she selects among the available options. This representation relates the outcomes of her choices – her supply or demand of an asset – to the variables and parameters appearing in each of these components.

Economists typically regard the market price as the value that balances the total demand and supply, which results from aggregating individuals' supplies and demands. Doing so relates prices at *a point in time* to a set of causal factors. The functional form of such a relationship, its parameters, and the properties of the causal factors constitute the causal structure of the model. That much is common to the way in which macroeconomists and finance theorists represent the relationship between individual behavior and aggregate outcomes, regardless of whether they rely on REH, behavioral considerations, or IKE.

At any given point in time, the causal structure of models based on these alternative approaches differs in a number of important respects, particularly in representing the diversity of market participants' forecasting strategies. However, the soundness of a model's epistemological foundations, and its ability to explain movements in market outcomes, hinges primarily on assumptions that characterize change in its structure *over time*. Herein lies the key difference between IKE models, which are open to non-routine change, and their REH and behavioral counterparts, which assume it away completely.

As time passes, individuals find new ways to interpret current and past information to forecast the future. Economic policies, institutions, the state of technology, and other features of the social context also change in novel ways. Thus, to account for time-series data on economic outcomes, an economist will need different causal structures at different points in time.

However, the vast majority of economists construct models that use the same causal structure to represent individual behavior and aggregate outcomes at every point in time. These time-invariant models presume both that individuals never alter the ways in which they forecast market outcomes, and that the social context remains unchanged.

In representing market outcomes in standard probabilistic terms, an economist specifies the causal variables, such as interest rates and other policy-influenced variables, with stochastic processes. His time-invariant model then represents market prices at every point in time with the exact same probability distribution, conditional on "current" and past information on the causal factors.

Economists sometimes recognize that participants do indeed revise their forecasting strategies over time, and that the social context and the process characterizing causal variables change over time. A particularly influential class of such models uses one of several pre-set structures to characterize forecasting strategies and causal variables during each time period, and represents change with a probabilistic Markov rule that governs switches between the assumed structures,

or "regimes."[3] But, because these models fully pre-specify both the process governing change and the post-change representation of outcomes, they share a key property with their time-invariant counterparts: they describe change with an overarching probability distribution in which the set of outcomes and their associated probabilities are fully predetermined in all time periods – past, present, and future.

An overarching distribution implied by a fully predetermined model ignores the unavoidable limits of what anyone can know about change. Instead, change is described as a random "shock" – a deviation – from the model's fully predetermined causal structure, and is supposed to characterize the model builder's uncertainty about how outcomes will unfold over time. However, by representing these deviations with a standard probability distribution, an economist in effect presumes that he can fully characterize *all* potential deviations of outcomes from his model's fully predetermined path, as well as the probabilities of their occurrence.

Over the last four decades, economists have come to agree that *only* models that generate such "sharp" probabilistic predictions of change are worthy of scientific status. It is this conception of economic science that continues to underpin widespread belief that the Rational Expectations Hypothesis provides *the* solution to the daunting problem of modeling how rational, profit-seeking market participants forecast the future. Economists' embrace of REH has profoundly altered the development of macroeconomics and finance theory and their applications by market participants and policymakers.

"Rational Expectations" as an Artifact of Fully Predetermined Models

Even cursory observation indicates that how market participants think about the future and revise their forecasts is one of the crucial factors driving outcomes in many markets. In discussing his vision for the micro-foundations approach to macroeconomic analysis, Phelps (1970, p. 22) underscored the fundamental difficulty in portraying individuals' expectations: "isolated and apprehensive, these Pinteresque figures construct expectations of the state of the economy...and maximize relative to that imagined world."

Early models of expectations did not attempt to formalize market participants' "imagined world." Instead, they often portrayed the forecasting process as an automatic response to forecast errors: participants were assumed to revise up or down their one-period-ahead forecast of inflation, for example, by a fixed proportion of the error between current-period inflation and the previous period's forecast.[4]

[3] For a seminal exposition, see Hamilton (1988).

[4] This rule, called "adaptive expectations," was originally formulated by Cagan (1956), and Nerlove (1958).

John Muth (1961) criticized such error-correcting rules. He argued that they assume away an important consideration: in forming expectations, market participants take into account their understanding of the causal process driving the outcomes that they are attempting to forecast. In an attempt to incorporate such considerations into representations of forecasting, Muth proposed the Rational Expectations Hypothesis: market participants' forecasts "are essentially the same as the predictions of the relevant economic theory" (Muth, 1961, p. 316).[5]

Rationality as Consistency in a Fully Predetermined Model

In order to implement REH, economists had to take a stand on the question of "the relevant economic theory" to which the hypothesis refers. By the 1980s, the vast majority of the economics profession embraced the belief that any fully predetermined model could serve as "the relevant economic theory": in order to represent how rational market participants forecast the future, an economist had only to impose consistency between his model's predictions on the individual and aggregate levels.

This belief seems puzzling: why would the predictions of any fully predetermined model represent how profit-seeking participants forecast outcomes in real-world markets?

Why a group of thinkers or scientists comes to embrace a common belief is a complex issue. But such coalescence of views around a controlling idea – in this case, the idea that economic analysis can provide a universal procedure for representing how rational individuals forecast the future – often involves tacit acceptance of one or more false premise. In Frydman and Goldberg (2011, 2013), we trace the profession's belief in REH representations' efficacy in this regard to the core premise of extant models: economists can discover a fully predetermined account of change in capitalist economies.

In his professional memoir, Robert Lucas (2001) recounted how this premise led to him to the belief that, by imposing consistency on his model, an economist can adequately capture how rational market participants understand the economy. His argument has been invoked time and again as the conceptual underpinning for REH models.

[5] Muth was well aware that the term "rational expectations" suggests some notion of rationality. Indeed, he explicitly warned 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 as to what firms ought to do, we call such expectations 'rational'" (Muth, p. 316, emphasis added). For early arguments that REH should be viewed neither as a normative nor as a descriptive hypothesis, see Frydman (1982, 1983), Frydman and Phelps (1983), and Phelps (1983).

According to Lucas's REH narrative, whenever an economist formulates a fully predetermined model of market prices, he supposes that the probability distribution that it implies provides an adequate account of real-world outcomes, and that, if it did, profit-seeking market participants would discern what the economist already knew. It then follows that in the context of his fully predetermined model, non-REH forecasting rules generate systematic forecast errors, which were presumed to point to obvious, yet unrealized, profit opportunities in *real-world markets*. As Lucas later emphatically put it, "if your theory reveals profit opportunities, you have the wrong theory" (Lucas, 2001, p. 13) of how "actual prices" unfold over a longer run.[6]
In a leap of faith that transformed macroeconomics and finance for generations, the REH theorists of the 1970s presumed that the right theory of capitalist economies, which arguably thrive on non-routine change, is a fully predetermined model that assumes such change away completely. But, once that leap was taken, it was a small step to argue that representing rational forecasting in real-world markets required an economist to remove systematic forecast errors – supposedly unrealized "profit opportunities" – from his model by imposing consistency between its individual and aggregate levels.

From the early 1970s on, this REH narrative gained wide acceptance among macroeconomists and finance theorists, spanning all major schools of thought. Chicago free-market adherents, MIT New Keynesians, asymmetric-information theorists, and behavioral-finance theorists have all portrayed "rational" forecasting by imposing consistency within their fully predetermined models.

Derailing Macroeconomic Research

What has been largely overlooked is that, by embracing the REH narrative, the economics profession embarked on a research program that has obscured, rather than illuminated, the crucial role that participants' expectations play in how outcomes in many markets unfold over time. The pre-REH formal macroeconomic models, such as those in the path-breaking volume of Phelps *et al* (1970), portrayed market participants' expectations as one of the key *autonomous* factors driving market outcomes. However, because they relied on a time-invariant structure to represent market outcomes, their non-REH error-correcting representations presumed that market participants do not change how they forecast, even in the face of easily detectable forecast errors.

[6] Lucas (1986) did acknowledge that non-REH "adaptive theory" might be useful in accounting for shorter-run behavior in some contexts. In Lucas (2004), he acknowledged that REH does not "let us think about the US experience in the 1930s or about financial crises and their consequences….We may be disillusioned with the Keynesian apparatus for thinking about these things, but it doesn't mean that this replacement [REH] apparatus can do either. It can't."

As such, these fully predetermined models presumed that market participants are obviously irrational.

This was the state of economic model-building at the time. An approach that would rid economic models of such obvious irrationality and yet preserve an autonomous role for market participants' expectations had to await further development of the theory and better empirical knowledge of how participants form forecasts in real-world markets.

However, Lucas's REH narrative suggested a different direction for further development. Because most economists did not question the premise that fully predetermined accounts of outcomes are within reach of economic analysis, inconsistent models – those that made use of non-REH representations of expectations – became "the wrong theory," and were jettisoned. Moreover, the vast majority of economists, adopting Lucas's narrative, embraced REH as the right theory.

Banning Autonomous Expectations from Macroeconomic Models

The belief in REH has made efforts to obtain empirical evidence concerning how actual individuals form and revise their forecasting strategies in real-world markets seem unnecessary. Once an REH theorist decides how to model market participants' preferences and the context within which they make decisions at all times, 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" (Sargent, 2005, p. 566).

In REH models, the causal variables that enter a market participant's forecasting strategy are those that an economist chooses to represent her preferences and constraints. Moreover, to render identical the model's predictions on the aggregate and individual levels – an economist must relate the weights attached to the causal variables in his portrayal of forecasting behavior exactly to the parameters of the model's other components. In this way, REH bars an economist from exploring explanations of forecasting that consider factors and parameters other than those appearing in his specifications of the other non-expectational components of his model.

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's dictum, "[B]eware of theorists bearing free

parameters [and causal factors arising from autonomous forecasting],"[7] had a profound impact on the evolution of macroeconomics and finance theory. From the Phelps volume in 1970 until the emergence of the behavioral approach, nearly all macroeconomists and finance theorists devoted much of their research efforts to searching for accounts of market outcomes that insisted that market participants' expectations need not be accorded an autonomous role.

The Troubled Return of Autonomous Expectations

The search for REH-based accounts of market outcomes has resulted in serious empirical difficulties, despite decades of "fine-tuning." As Phelps (2007, p. xv) recently commented, "[t]he stampede toward 'rational expectations,' widely called a 'revolution,' though it was only a generalization of the neoclassical idea of equilibrium…has not illuminated how the world economy works."

Nowhere have REH's empirical disappointments been more apparent than in efforts to model financial-market outcomes, which are largely driven by participants' expectations. Beginning with Robert Shiller's (1981) path-breaking paper, research has shown that REH models are unable to explain the basic features of fluctuations and risk in stock markets.[8] Likewise, in their magisterial work on the current state of international macroeconomics, Maurice Obstfeld and Kenneth Rogoff (1996, p. 625) concluded 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."

Not surprisingly, empirical studies pointed to one of the most important sources of these failures: REH's inconsistency with how real-world market participants form and revise forecasts. In view of such findings, economists began to return to the pre-REH practice of modeling market participants' expectations as an autonomous component – an input rather than an output – of models of aggregate outcomes.

Drawing on their experimental and psychological studies, behavioral economists offered alternatives to REH models that formalized their empirical findings about how individuals "actually" forecast outcomes. Because these portrayals are based on context-specific, empirical evidence, behavioral models represent a significant advance over REH's reliance on *a priori,* supposedly universal, constraints on how market participants should behave.

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[7] Attributed to Lucas by Sargent (2001, p. 73)

[8] For a review of the empirical record, see Campbell et al. (1997).

However, despite justifying their alternative representations by appealing to their "psychological realism," behavioral-finance theorists have continued to maintain the core premise of contemporary models, and have represented individual forecasting and other aspects of market participants' behavior with fully predetermined probabilistic rules.[9] Moreover, although behavioral economists helped to uncover much of the evidence that REH is inconsistent with how market participants *actually* forecast outcomes, they did not conclude that REH fails to account for forecasting behavior in real-world markets. Instead, because they relied on fully predetermined models, they embraced the belief that REH represents how rational market participants *should* forecast the future, and interpreted REH models' empirical failures as a symptom of market participants' irrationality.[10]

Of course, behavioral economists' use of fully predetermined models to formalize their empirical findings means that their representations of forecasting behavior imply systematic, easily detectable forecast errors. Such forecast errors in the real world would indeed be a symptom of gross irrationality, and, as Lucas argued, models that imply them are "the wrong theory" of longer-term regularities in how market outcomes unfold over time.

To be sure, Lucas would not deny that an inconsistent behavioral-finance model might adequately represent the relationship between the causal variables and aggregate outcomes in a certain historical period. All that was needed was insightful selection of the causal variables, based on empirical evidence and a stretch of time that did not involve much change. Indeed, in his widely cited critique of policy analysis based on non-REH models, Lucas (1976) acknowledged the good short-term forecasting performance of the so-called "Keynesian" econometric models that were developed in the 1960s. But he argued that "'the long-run' implications of…[these] models are without content."

The reason for this striking claim is rooted in his REH narrative: as time passes, profit-seeking market participants would begin to see their forecasting errors, and thus alter the non-REH forecasting rules that were attributed to them by a behavioral economist. Such revisions of forecasting strategies would render the structure of the behavioral model inadequate as a representation of both individual decision-making and market outcomes over the longer term.

[9] Many behavioral economists have emphasized the importance of preserving the core premise in the development of their approach. See, for example, Camerer *et al*. (2004, p. 3). Seminal behavioral models include Frankel and Froot (1987) and DeLong *et al* (1990). For more recent examples, see Shleifer (2000), Abreu and Brunnemaier (2003), and De Grauwe and Grimaldi (2006), and references therein.

[10] Not all behavioral economists have embraced fully predetermined models. Indeed, some leading exponents of the approach continue to rely on a largely narrative mode of analysis to explore the implications of behavioral findings. However, attesting to the influence of the Lucas narrative, they, too, have referred to departures from REH as "irrationality." For a recent example, see Akerlof and Shiller (2009).

REH as a Model of Stasis and Thought Uniformity

This argument underpinned Lucas's (1976) widely influential critique of policy analysis based on Keynesian econometric models, which ignored model instability arising from participants' forecasting revisions. He claimed that REH would not only address this problem, but would also be able to represent how rational individuals would respond to macroeconomic-policy changes.

Lucas's claim that inconsistent fully predetermined models are "the wrong theory" seems uncontroversial. But what he and much of the economics profession missed is that fully predetermined models that impose consistency are also "the wrong theory." After all, self-interested, rational individuals would collectively adhere to one forecasting strategy in perpetuity only in a fanciful world in which non-routine change in technology and other aspects of the social context ceased to be economically important, and all market participants converged on the true overarching model of market outcomes.[11]

In this fanciful REH World, the economist, too, would have found the same overarching model of outcomes. Indeed, as one of the pioneers of the REH approach strikingly put it**: "**The fact is that [one] simply cannot talk about differences [among people's models] 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. Useful empirical implications of rational expectations…derive from that communism of models" (Sargent, 2005, p. 566-67).

Rediscovering Markets' Essential Role

Acknowledging that the empirical "usefulness" of REH models derives from their assumed "communism of models" highlights the striking disconnection between these models and what real-world markets actually do – and thus why modern economies rely upon them.[12] In his prescient argument that central planning is impossible *in principle*, Friedrich Hayek pointed out that the diversity of market participants' views is the key to understanding why an individual, whether an economist or a central planner, could not adequately mimic how the market allocates society's resources or replicate how market outcomes unfold over time. As he put it,

> The economic problem of society is . . . not merely a problem of how to allocate "given" resources—if "given" is taken to mean given to *a single mind* which deliberately solves

[11] See Frydman (1982) for a demonstration that such convergence is, in general, inconsistent with the assumption that individuals are profit-seeking. For a recent discussion and further references, see Guesnerie (2013).
[12] Relying on this "communism of models" and the tight connection between random shocks and outcomes that it implies, Sargent (2011) argues in his Nobel lecture that "rational expectations acquires empirical power to sort through cause and effect" in the macroeconomy.

> the [resource-allocation] problem. . . . It is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know. Or, to put it briefly, it is a problem of the utilization of knowledge which is *not given to anyone in its totality*. [Hayek, 1945, p. 519–20, emphasis added]

The problem that haunts the REH research program is the same one that doomed socialist planning: assuming away non-routine change does not eliminate its importance, so searching for a fully predetermined account of market outcomes is futile.[13] What makes markets essential in modern economies is that they are the best institution available to help society to cope with and take advantage of non-routine change and the imperfect knowledge that it engenders.[14] To assume away this role is to enter a world that has little connection to what markets and rational individuals really do.

Rationality Turned Upside Down

What economists imagine to be "rational forecasting" would be considered obviously irrational by anyone in the real world who is minimally rational. After all, a rational, profit-seeking individual understands that the world around her will change in non-routine ways. She simply cannot afford to believe that, contrary to her experience, she has found a "true" overarching forecasting strategy, let alone that everyone else has found it as well. Indeed, as Frank Knight emphasized, the ability to earn profits stems in large part from taking advantage of non-routine change: "if all changes were to take place in accordance with invariable and universally known laws, [so that] they could be foreseen for an indefinite period in advance of their occurrence, . . . profit or loss would *not* arise" (Knight, 1921, p. 198, emphasis added).

Rather than imputing to individuals superhuman cognitive and computational abilities, as is widely believed, the Rational Expectations Hypothesis presumes just the opposite: market participants forgo using whatever cognitive abilities they do have. REH models suppose that individuals do not engage actively and creatively in revising the way that they think about the future. Instead, they are presumed to adhere steadfastly to a single mechanical forecasting

[13] For an early rigorous argument that the contemporary search for fully predetermined models bears an uncanny resemblance to the central planner's futile ambition, see Frydman (1983). For an extensive discussion, see Frydman and Rapaczynski (1993, 1994). Frydman and Goldberg (2011) place this argument in the context of modern macroeconomics and finance theory.

[14] Because aggregate outcomes stem from the tradng decisions of participants who must cope with ever-imperfect knowledge, markets are not nearly perfect at setting prices and allocating capital, as conventional REH models would have us believe. Sometimes prices reach excessive levels, which implies a role for the state beyond setting the rules of the game. For a conceptual framework of this role and IKE policy measures aimed at dampening excess, see Frydman and Goldberg (2009, 2011).

strategy at all times and in all circumstances. Thus, in the context of real-world markets, REH presumes that participants are obviously irrational. When institutional developments occur that alter the process driving market outcomes, they supposedly look the other way, and thus either abjure profit-seeking behavior altogether, or forgo profit opportunities that are in plain sight.

What Should Models (Not) Do?

Outside the imaginary world of stasis and thought uniformity, there is an obvious and inherent conflict between portraying the consequences of profit-seeking participants' decision-making, particularly their forecasting behavior, in real-world markets and economists' insistence that the portrayals be fully predetermined. Regardless of whether a fully predetermined model is internally consistent or inconsistent, it fails to represent even minimally reasonable decision-making, let alone individual rationality, and the consequences of such behavior for market outcomes.

We should emphasize that our critique of contemporary models is not that they are abstract or mathematical. Useful scientific models abstract from features of reality that are irrelevant to an adequate account of the phenomenon that the model seeks to explain. The hope is that the omitted considerations really are relatively unimportant to understanding the phenomenon.

The need to exclude many potentially relevant considerations is particularly acute if one aims to account for outcomes with mathematical models, which *ipso facto* use of a small number of assumptions to explain complex phenomena. The bolder the abstraction that one seeks, the more important it is to scrutinize the assumptions that are "termed crucial...on the grounds [of their] intuitive plausibility or capacity to suggest, if only by implication, some of the considerations that are relevant in judging or applying the model" (Friedman, 1953, p.26).[15]

The fatal flaw of contemporary macroeconomic and finance models is that they rule out by design the central importance of non-routine change for how profit-seeking participants make decisions, and for what markets really do in modern economies. Assuming away non-routine change and the imperfect knowledge that it engenders not only denies markets their *raison d'être*; it also gives rise to epistemological difficulties and goes a long way toward explaining the empirical failures of contemporary macroeconomic and finance models.

[15] When confronted with criticism that their assumptions are unrealistic, contemporary economists brush it off by invoking Milton Friedman's (1953, p. 23) dictum, stated in his well-known essay on economic methodology, that "theory cannot be tested by the 'realism' of its assumptions." In fact, at no point did Friedman suggest that economists should not be concerned about the (in)adequacy of their models' assumptions. For an argument that Friedman's influential essay has been misinterpreted as legitimizing contemporary models' core assumptions, see Frydman and Goldberg (2011, chapter 1).

Real-World Macroeconomics

Our critique of contemporary economic science suggests that addressing its models' epistemological and empirical difficulties requires jettisoning their core premise and opening them to non-routine change and imperfect knowledge. A key aspect of such a research program is that it involves according market participants' forecasting behavior an autonomous role.

Economists have generally resisted reintroducing autonomous expectations as an input into their models – as was common prior to the REH revolution – in the belief that doing so would base their models on irrationality, thereby rendering them unable to account for longer-term regularities. Behavioral-finance theorists dismissed this concern, arguing that individual forecasting was not only fraught with a broad array of irrationalities, but that these irrationalities were systematic: market participants were assumed to stick with their non-REH forecasting rules, even in the face of systematic forecast errors. This presumed stability of non-REH forecasting rules was supposed to address Lucas's conclusion that non-REH fully predetermined models were "the wrong theory" of longer-run regularities.

On the face of it, Lucas's argument is uncontroversial. The assumption that market participants *systematically* forego profit opportunities cannot provide a reasonable basis for understanding their behavior and its implications for how aggregate outcomes unfold over time in capitalist economies, which, after all, provide powerful incentives for profit-seeking behavior.

However, as we have seen, imposing REH-consistency does not provide a solution to this conundrum. In order to bring macroeconomics and finance theory closer to reality, we need to restore the autonomy of expectations in our models, but in a way that does not jettison the idea that profit-seeking is important for understanding outcomes. This requires that we recognize the inherent limits to our knowledge that arise from non-routine change.

The Aims of Imperfect Knowledge Economics

How can economic analysis jettison fully predetermined representations, and thereby be opened to non-routine change and imperfect knowledge, while continuing to portray individual and aggregate behavior in mathematical terms? How would this conceptual shift enable economists to accord market participants' expectations an autonomous role, and yet avoid presuming that they forego profit opportunities systematically?

Imperfect Knowledge Economics (IKE) provides answers to these essential questions. In modeling market participants' expectations, IKE enables economists to incorporate *both* fundamental considerations, on which REH theorists focus, and the psychological and social

considerations that behavioral economists emphasize. Moreover, despite their recognition of market participants' and *economists'* ever-imperfect knowledge about the process driving change, IKE macroeconomic and finance models generate empirically testable implications.

Between Animal Spirits and Fully Predetermined Models

Any fully predetermined model with a time-invariant structure will eventually become obsolete. Over time, different structures thus will be needed to adequately represent outcomes on the individual and aggregate levels. Contemporary models that allow for change in the way that individuals make decisions and aggregate outcomes unfold over time fully pre-specify how their causal structure changes. They typically define a number of pre-set structures and a rule, usually probabilistic, that governs when and which of these structures is supposed to represent outcomes at each point in time.[16]

Opening such fully predetermined representations to non-routine change on the individual and aggregate levels involves eliminating one or more of the conditions that constrain *exactly* how the model's structure might change over time, and implies that economic models would cease to represent outcomes in standard probabilistic terms. For example, jettisoning the constraint that the set of all potential structures that might be needed to represent outcomes adequately at each point in time can be pre-set – fully known in advance – precludes the possibility that the set of all potential outcomes, and their probabilities, can be fully pre-specified in terms of some set of causal factors.

[16] For an early example of such an empirical "segmented-trends" model of currency swings, see Engel and Hamilton (1990). Frydman *et al* (2012), also presented at this conference, provide theoretical foundations for this empirical specification, and show how it can be obtained by imposing additional restrictions on change that would convert an IKE model of long swings in asset markets into a fully predetermined model.

Recognition that uncertainty in economics cannot be represented in standard probabilistic terms has a venerable history. As early as 1921, Knight and John Maynard Keynes questioned the relevance of standard probability theory for understanding profit-seeking decisions. Knight argued that such decisions "deal with situations which are far too [non-routine]. . .for any sort of [unique] statistical tabulations to have any value for guidance" (Knight, 1921, p. 198). Keynes (1921) shared Knight's profound doubts concerning the usefulness of standard probability theory for understanding change in individual decision-making and market outcomes. As he strikingly pointed out in his analysis of the implications of imperfect knowledge for understanding financial markets' outcomes: we "cannot depend on strict mathematical expectation, since the basis for making such calculations does not exist" (Keynes, 1936, pp. 162–63).

Early modern economic analysis, particularly that of Keynes, is sometimes interpreted as claiming that economic decisions, particularly in financial markets, stem only from erratic "animal spirits." Knight's view of uncertainty – often referred to as "Knightian uncertainty" – is also often interpreted that there are no regularities in the way that market participants make decisions. Of course, if that were the case, no economic theory that aims to account for outcomes in these markets with mathematical models would be possible. As Phelps (2008, p. A19) put it, "animal spirits can't be modeled." Indeed, in arguing that animal spirits, broadly defined, are the key to understanding macroeconomic outcomes and swings in asset prices, Akerlof and Shiller (2009) do rely solely on a narrative mode of analysis.

Although IKE recognizes the inherent limits to economists' knowledge that arise from non-routine change, it does not adopt the extreme view that formal macroeconomics and finance theory is impossible. Indeed, IKE stakes out an intermediate position between narrative accounts, which *ipso facto* cannot be formally confronted with empirical evidence, and contemporary models, which can be formally tested, but have failed empirically, owing primarily to their attempts to represent change and its consequences with overarching probabilistic rules.

As in their fully predetermined counterparts, the key assumptions that impute empirical content to IKE macroeconomics and finance models are those that characterize change, particularly in how market participants revise their forecasting strategies. Although IKE stops short of fully pre-specifying change, it recognizes that economic behavior must display some regularity if formal economic theory is to generate implications that can be falsified by empirical evidence.

IKE explores the possibility that in some contexts, individual decision-making, particularly concerning revision of forecasting strategies, exhibits qualitative regularities. Moreover, we argue that, in general, one should not expect even qualitative regularities on the individual level to persist indefinitely. That is, they become manifest – or cease to be relevant – at moments that

no one can fully pre-specify. Consequently, the conditions that specify an IKE model's representations of individual decision making – and thus of the aggregate outcomes that they imply – are not only qualitative and context-dependent, but also contingent.

Non-Standard Use of Probabilistic Formalism

IKE also stakes out an intermediate position concerning the use of probability theory in economic modeling. Although it does not represent outcomes with one overarching probability distribution, IKE departs from the position of Knight and Keynes and makes non-standard use of probabilistic representations in formalizing the qualitative and contingent regularities that specify its models.

In a conventional economic model, with a single overarching conditional probability distribution representing outcomes at each point in time – and thus how they unfold over time – the relationships between the moments of the distribution and the model's causal variables constitute its empirical implications, which can be confronted with time-series data.

By contrast, because the conditions that they use to characterize change are qualitative, IKE models represent outcomes at every point in time with myriad probability distributions. Nevertheless, the conditions that specify IKE representations 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. Such partially predetermined probabilistic representations constitute the empirical implications of IKE models.

A Genuine Return of Autonomous and Diverse Expectations

Because they do not represent aggregate outcomes with an overarching probability distribution, IKE models can accord market participants' expectations an autonomous role – that is, treat them as an input rather than an output – without presuming that individuals systematically forego obvious profit opportunities. By not relying on a fully predetermined probability distribution, IKE avoids Lucas's presumption that autonomous representations of forecasting behavior imply systematic forecast errors in real-world markets. Moreover, because an IKE model is consistent with myriad distributions on the aggregate level, it is also compatible with market participants' differing interpretations of how market outcomes will unfold over time.

For example, in asset markets, this diversity takes on a striking form: at every point in time, there is a group of "bulls," who forecast an increase in price, and a group of "bears," who forecast a

decrease. Because IKE represents forecasting with qualitative and contingent conditions, its models are compatible with many probability distributions whose conditional first moments imply an increase in price, and with many others whose conditional first moments imply a decrease. By not fully predetermining diversity, IKE enables an economist to recognize its importance. Indeed, as Hayek emphasized, the diversity of expectations is crucial to the distinction between resource allocation by an individual or group of individuals – such as central planners – and that by markets in capitalist economies.

Integrating Fundamental Factors with Psychological and Social Considerations

The search for fully predetermined models that accord an explicit role to market participants' forecasting in driving outcomes, such as asset prices, led economists and finance theorists to two classes of models: REH models that focus on the role of fundamental factors, and behavioral-finance models that emphasize non-fundamental factors, such as psychological and social considerations. But this dualism of fundamental and non-fundamental factors is largely an artifact of their fully predetermined structure. In fact, both economic fundamentals and non-fundamental factors, such as confidence, established conventions, and shared history, are likely to be important for understanding outcomes on the individual and aggregate level.

Indeed, recognition of knowability's inherent limits implies that fundamental considerations and computations based on them cannot by themselves account for how market participants make decisions. As Keynes put it,

> We are merely reminding ourselves that human decisions affecting the future, whether personal or political or economic, cannot depend on strict mathematical expectation, since the basis for making such calculations does not exist; and...that our *rational* selves [are] choosing between alternatives as best as we are able, calculating where we can, but often falling back for our motive on whim or sentiment or chance (Keynes, 1936, p. 162, emphasis added).

For Keynes, unlike for behavioral economists, reliance on psychological factors in decision-making is not a symptom of irrationality. Rational individuals in the real world use knowledge of facts; but, because their knowledge of how outcomes will unfold over time is inherently imperfect, calculation alone is insufficient for decision-making.

Although Keynes emphasizes that psychological considerations, such as market sentiment, play an important role in individual forecasting, he also points out that "we should *not* conclude from this that everything depends on waves of irrational psychology" (Keynes, 1936, p. 162).

Likewise, we have argued that psychological considerations themselves could not *sustain* the recurrent long swings that we observe in asset prices (Frydman and Goldberg, 2011). Indeed, empirical evidence concerning the role that fundamental and psychological actors play in participants' trading decisions in the US stock market suggests that changes in fundamental factors strongly influence how confidence and other sentiments unfold over time.[17]

Beyond psychological factors, Keynes also emphasized that imperfect knowledge leads each market participant to rely on social conventions when ascertaining how the other participants might think about the future course of outcomes. As Dow (2013) put it in discussing Keynes' approach to understanding individual decision-making,

> Individuality or agency allows for individual choice as to whether or not to follow social convention. But sociality means that social-conventional judgment provides the norm, such that expectations are formed *interdependently* with expectations in the market. This [non-routine] social interactionism is a key ingredient of Keynes's…view of the economic system.

The complex interdependence between fundamental, psychological, and social considerations in determining how market participants forecast outcomes and make decisions suggests that these influences can *at best* be represented with qualitative and contingent conditions. After all, even if there are some regularities in how these considerations influence an individual's forecasting, and more broadly her decision making, we would not expect such regularities to follow fully predetermined rules or to persist indefinitely. We would also expect that such regularities are likely to be context-dependent.

The importance of psychological and social factors in an individual's decision-making also goes a long way toward explaining behavioral economists' remarkable empirical success in uncovering the gross inconsistencies of conventional models based on *a priori* considerations. Once economists decided to look for evidence of how individuals actually behave, rather than assuming that they need only identify a set of *a priori* assumptions that would characterize how individuals *should* behave, the empirical failures of such assumptions in characterizing forecasting or preferences became plain.[18]

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[17] For a presentation of this empirical evidence and extensive discussion, see Frydman and Goldberg (2011, chapter 7 and 9).

[18] See our earlier discussion for references to REH's empirical failures. Kahneman and Tversky (1979) have argued that standard specifications of "rational" preferences, such as those based on the expected utility hypothesis of von Neumann and Morgenstern (1944), are grossly inconsistent with empirical evidence concerning how individuals make choices, even under probabilistic uncertainty.

Rethinking the Scope of Economics

The empirical failure of models that appeal to *a priori* assumptions about individual behavior, and the shift to reliance on representations based on empirical regularities,[19] undermines the widespread belief that contemporary economics can rigorously explain the findings of other, "soft" social sciences. In fact, this shift away from *a priori* assumptions requires that economists incorporate findings from psychology and other social sciences in constructing more empirically relevant models.

IKE makes use of behavioral economists' and other social scientists' empirical findings to specify the representations of market participants' decision-making that underpin its accounts of aggregate outcomes. However, unlike the behavioral-finance approach, IKE formalizes these empirical regularities with qualitative and contingent conditions.

For example, psychological studies have uncovered much evidence that individuals revise their beliefs in the face of new evidence gradually.[20] In our model of exchange-rate swings, we formulize this finding in terms of qualitative and contingent constraints on how market participants revise their forecasting strategies. We show that, despite the model's openness to non-routine change, it implies that the exchange rate tends to undergo long-lasting swings away from and back toward benchmark values.[21]

However, the importance of the social context implies that, in searching for empirical regularities that might be useful in modeling an individual's decisions, economists will need to look beyond insights from psychology. For example, Frydman *et al* (2012) makes use of Keynes's (1936) insight that conventions among market participants play an important role in individual decision-making in asset markets. We also draw on our understanding of the qualitative regularities that have characterized aggregate outcomes, and suppose that market participants, too, must 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

[19] Behavioral economists' success in turning economists' attention to the importance of the "psychological realism" of their models' assumptions marks an important methodological shift away from the position that prediction is all that matters. The behavioral approach recognized that when a class of models encounters empirical difficulties on the scale that REH models did, the likely reason is that their assumptions, as abstract as they necessarily must be, are grossly disconnected from the reality that the models aim to explain and predict.

[20] See Edwards (1968) and references therein. For an application in a fully predetermined behavioral-finance model, see Barberis et al. (1998).

[21] Frydman and Goldberg (2007, chapter 9) provides another example of IKE's use of behavioral findings. We show how Kahneman and Tversky's formulation preferences, the so-called prospect theory, can be applied in models that are open to imperfect knowledge on the part of economists and market participants. The companion paper prepared for this conference, Frydman *et al* (2012), makes use of such a specification of preferences.

counter-movements, plays a key role in our model of the uncertainty premium in currency markets.

Sharp versus Contingent Predictions

Contemporary economists' effort to find a model that could "sharply" predict the complete set of future market outcomes and probabilities is not the first such endeavor in the social sciences. In his influential refutation of the claim that "historicism" might one day enable social science to "predict the future course of history," Karl Popper pointed out that any such approach is futile "to the extent to which [historical developments] may be influenced by the growth of our knowledge" (Popper, 1957, pp. xi-xii).

Because market outcomes – especially outcomes in financial markets – crucially depend on changing understandings of the process and psychology that underpin individual expectations, our critique of contemporary macroeconomics and finance theory can be viewed as further refutation of the historicist's vain ambition. And yet Popper was strongly, he was quick to point out that his withering critique of efforts to develop fully predetermined accounts of history

> does not, of course, refute the possibility of every kind of social prediction; on the contrary, it is perfectly compatible with the possibility of testing social theories – for example, economic theories – by way of predicting that certain developments will take place under certain conditions. It only refutes the possibility of predicting historical developments to the extent to which they may be influenced by the growth of our knowledge (Popper, 1957, p. xii).

Toward Qualitative and Contingent Predictions

The qualitative and contingent predictions generated by our IKE model of asset-price swings in Frydman and Goldberg (2013b) exemplify what Popper would regard as a feasible goal of economic theory. Although our model predicts that, under "certain conditions," an asset price will undergo a sustained movement in one direction, it does not predict when such upswings or downswings will begin or end.[22]

Beyond building on Popper's insights concerning the possibility, scope, and character of prediction in the social sciences, our IKE model of asset-price swings exemplifies Hayek's claim that, "Our capacity to predict will be confined to...general characteristics of the events to be expected and not include the capacity for predicting particular individual events" (Hayek, 1978,

[22] See Soros (2009) for an account of fluctuations in asset prices that is based on "fallibility," a term that is closely related conceptually to imperfect knowledge.

p. 33). Although an IKE model, by design, stops short of predicting "particular individual events," such as when an asset-price swing will begin and end, it does generate predictions concerning their "general characteristics" – for example, that they tend to be quite persistent. Thus, by examining alternative models' implications concerning the persistence and related features of such swings, an economist may compare explanations of economic phenomena.

In a companion paper, Frydman *et al* (2012) develops such an approach to econometric testing, and concludes that an IKE model provides a significantly better account than standard and REH-based "bubble" models of swings in currency markets.[23] This study shows that, despite placing imperfect knowledge and non-routine change at the center of economic analysis and limiting our ambition solely to generating qualitative predictions, IKE models may still yield "predictions which can be falsified and which therefore are of empirical significance" (Hayek, 1978).

Probing the Frontier of Formal Macroeconomic and Finance Theory

In Frydman and Goldberg (2007) and recent papers, we show how IKE models shed new light on salient features of the empirical record on asset prices and risk that have confounded international macroeconomists for decades. IKE also provides a new way to explain why asset-price swings sometimes become excessive, and shows how the hitherto neglected relationship between financial risk and price swings can help us to understand how excessive price swings come to an end. This analysis provides a conceptual framework for prudential policy aimed at dampening excessive price swings and thus reducing the social costs inflicted when they reverse direction.[24]

Although the application of IKE to financial markets appears promising, it is too early to substantiate its broader usefulness in macroeconomic and policy modeling. If qualitative and contingent regularities can be established in contexts other than asset markets, IKE's nonstandard probabilistic formalism can show how to incorporate them into mathematical models. However, when revisions of forecasting strategies (or more broadly, change on the individual and aggregate levels) cannot be adequately characterized with qualitative and contingent conditions, empirically relevant mathematical models of how market outcomes unfold over time may be beyond the reach of economic analysis. In this sense, IKE explores the frontier of what formal macroeconomic and finance theory can deliver. How far, and in which contexts, this boundary can be extended is the crucial open question.

[23] Our approach to testing the implications of IKE models against those of REH models makes use of Cointegrating VAR Methodology and Inference, developed by Soren Johansen and Katarina Juselius in many papers over the last two decades. For book-length treatments, see Johansen (1996) and Juselius (2007).
[24] See Frydman and Goldberg (2009).

References

Abreu, Dilip and Markus K. Brunnermeier (2003), "Bubbles and Crashes," *Econometrica*, 71, 173-204.

Akerlof, George. A. and Robert J. Shiller (2009), *Animal Spirits: How Human Psychology Drives the Economy and Why It matters for Global Capitalism*, Princeton, NJ: Princeton University Press.

Barberis, Nicholas, Shleifer, Andrei and Robert Vishny (1998), "A Model of Investor Sentiment," *Journal of Financial Economics*, vol. 49, 307-43.

Cagan, Phillip (1956), "The Monetary Dynamics of Hyperinflation," in Milton Friedman, ed., Studies in the Quantity Theory of Money, Chicago: University of Chicago Press.

Camerer, Colin, Loewenstein, George and Matthew Rabin (2004), *Advances in Behavioral Economics*, Princeton, NJ: Princeton University Press.

Campbell, Y. John, Andrew W. Lo, and A. Craig MacKinlay (1997), *The Econometrics of Financial Markets*, Princeton, N.J.: Princeton University Press.

De Grauwe, Paul and Marianna Grimaldi (2006), *The Exchange Rate in a Behavioral Finance Framework*, Princeton, NJ: Princeton University Press.

DeLong, Bradford J., Shleifer, Andrei, Summers, Lawrence H. and Robert J. Waldman (1990), "Positive Feedback Investment Strategies and Destabilizing Rational Speculation," *Journal of Finance*, 45, 375-395.

Dow, Sheila (2013), "Keynes on Knowledge, Expectations and Rationality," forthcoming in Roman Frydman and Edmund S. Phelps (eds.), *Rethinking Expectations: The Way Forward for Macroeconomics*, Princeton, NJ: Princeton University Press.

Edwards, Ward (1968), "Conservatism in Human Information Processing," in B. Kleinmuth (ed.), *Formal Representation of Human Judgement*, New York: John Wiley and Sons.

Engel, Charles and James D. Hamilton (1990), "Long Swings in the Exchange Rate: Are They in the Data and Do Markets Know It?" *American Economic Review*, September, 689-713.

Friedman, Milton (1953), *Essays in Positive Economics*, Chicago, Ill.: The University Of Chicago Press.

Frydman, Roman (1982), "Towards an Understanding of Market Processes: Individual Expectations, Learning and Convergence to Rational Expectations Equilibrium," *American Economic Review*, 72, 652-668.

Frydman, Roman (1983), "Individual Rationality, Decentralization and the Rational Expectations Hypothesis," in Frydman, Roman and Edmund S. Phelps (eds.), *Individual Forecasting and Aggregate Outcomes: "Rational Expectations" Examined*, New York: Cambridge University Press, 97-122.

Frydman, Roman and Michael D. Goldberg (2007), *Imperfect Knowledge Economics: Exchange Rates and Risk*, Princeton, NJ: Princeton University Press.

Frydman, Roman and Michael D. Goldberg (2008), "Macroeconomic Theory for a World of Imperfect Knowledge," *Capitalism and Society*, 3, 3, Article 1, http://www.bepress.com/cas/vol3/iss3/art1/

Frydman, Roman and Michael D. Goldberg (2009) "Financial Markets and the State: Price Swings, Risk, and the Scope of Regulation," *Capitalism and Society*, 4, 2, Article 2, http://www.bepress.com/cas/vol4/iss2/art2/

Frydman, Roman and Michael D. Goldberg (2012b), "Opening Models of Asset Prices and Risk to Non-Routine Change," revised version prepared for presentation at the Annual Conference of the Institute for New Economic Thinking, Berlin, April, forthcoming in Roman Frydman and Edmund S. Phelps (eds.), *Rethinking Expectations: The Way Forward for Macroeconomics*, Princeton, NJ: Princeton University Press.

Frydman, Roman and Michael D. Goldberg (2013a), "The Imperfect Knowledge Imperative in Modern Macroeconomics and Finance Theory," forthcoming in Roman Frydman and Edmund S. Phelps (eds.), *Rethinking Expectations: The Way Forward for Macroeconomics*, Princeton, NJ: Princeton University Press.

Frydman, Roman and Edmund S. Phelps (1983), "Introduction" in Frydman, Roman and Edmund S. Phelps (eds.), *Individual Forecasting and Aggregate Outcomes: "Rational Expectations" Examined*, New York: Cambridge University Press, 1-30.

Frydman, Roman and Edmund S. Phelps (2013), "Which Way Forward for Macroeconomics and Policy Analysis?" forthcoming in Roman Frydman and Edmund S. Phelps (eds.), *Rethinking Expectations: The Way Forward for Macroeconomics*, Princeton, NJ: Princeton University Press.

Frydman, Roman and Andrzej Rapaczynski (1993), *Markets by Design*, unpublished manuscript.

Frydman, Roman and Andrzej Rapaczynski (1994), *Privatization in Eastern Europe: Is the State Withering Away?*, Budapest and Oxford, UK: Central European University Press in cooperation with Oxford University Press.

Frydman, Roman, Goldberg, Michael D., Juselius, Katarina and Soren Johansen (2012), "Long Swings in Currency Markets: Imperfect Knowledge and I(2) Trends," mimeo.

Hamilton, James D. (1988), "Rational-Expectations Econometric Analysis of Changes in Regime: An Investigation of the Term Structure of Interest Rates," *Journal of Economics Dynamics and Control*, 12, 385-423.

Hayek, Friedrich A. (1945), "The Use of Knowledge in Society," *American Economic Review*, 35, 519-30.

Hayek, Friedrich A. (1948), *Individualism and Economic Order*, Chicago: The University of Chicago Press.

Hayek, Friedrich.A. (1978), "The Pretence of Knowledge," Nobel Lecture, 1974, in *New Studies in Philosophy, Politics, Economics and History of Ideas*, Chicago: The University of Chicago Press.

Johansen, Soren (1996), *Likelihood Based Inference on Cointegration in the Vector Autoregressive Model*. Oxford, UK: Oxford University Press.

Juselius, Katarina (2007), *The Cointegrated VAR Model: Methodology and Applications*, Oxford, UK: Oxford University Press.

Kahneman, Daniel and Amos Tversky (1979), "Prospect Theory: An Analysis of Decision Under Risk," *Econometrica*, 47, 263-291.

Keynes, John Maynard (1921), *A Treatise on Probability*, London: Macmillan, 1957.

Keynes, John Maynard. (1936), *The General Theory of Employment, Interest and Money*, Harcourt, Brace and World.

Knight, Frank H. (1921), *Risk, Uncertainty and Profit*, Boston: Houghton Mifflin.

Lawson, Tony (1997), *Economics and Reality*, London: Routledge.

Lawson, Tony (2001), "Back to Reality", *Post-Autistic Economics Newsletter*, Issue No. 6, May, Article 2. http://www.btinternet.com/~pae_news/review/issue6.htm.

Lucas, Robert E. Jr. (1976), "Econometric Policy Evaluation: A Critique," in Brunner Karl and Allan H. Meltzer, *The Phillips Curve and Labor Markets*, Carnegie-Rochester Conference Series on Public Policy, Amsterdam: North-Holland Publishing Company, 19-46.

Lucas, Robert E., Jr. (1986), "Adaptive Behavior and Economic Theory," *The Journal of Business*, Vol. 59, No. 4, S401-S426.

Lucas, Robert E. Jr. (2001), "Professional Memoir," mimeo. http://home.uchicago.edu.

Lucas, Robert E., Jr. (2004), "My Keynesian Educations," in De Vroey, Michael and Kevin D. Hoover (eds), *The IS-LM Models: Its Rise, Fall, and Strange Persistence,* Annual Supplement to Volume 36 of *History of Political Economy,* Durham, NC: Duke University Press, 12-24.

Muth, John F. (1961), "Rational Expectations and the Theory of Price Movements," *Econometrica*, 29, 315-335.

Nerlove, Marc (1958), "Adaptive Expectations and Cobweb Phenomena," *The Quarterly Journal of Economics,* Vol. 72, No. 2, 227-240.

Obstfeld, Maurice and Kenneth Rogoff (1996), *Foundations of International Macroeconomics,* Cambridge, US: MIT Press.

Phelps, Edmund S. (1970), "Introduction: The New Microeconomics in Employment and Inflation Theory," *Microeconomic Foundations of Employment and Inflation*, New York: Norton.

Phelps, Edmund S. *et al*. (1970), *Microeconomic Foundations of Employment and Inflation*, New York: Norton.

Phelps, Edmund S. (1983), "The Trouble with 'Rational Expectations' and the Problem of Inflation Stabilization," in Frydman, Roman and Edmund S. Phelps (eds.), *Individual Forecasting and Aggregate Outcomes: "Rational Expectations" Examined*, New York: Cambridge University Press.

Phelps, Edmund S. (2007), "Foreword," in Frydman, Roman and Michael D. Goldberg, *Imperfect Knowledge Economics: Exchange Rates and Risk*, Princeton, NJ: Princeton University Press.

Phelps, Edmund S. (2008), "Our Uncertain Economy," *The Wall Street Journal*, March 14th.

Popper, Karl R. (1957), *The Poverty of Historicism*, London and New York: Routledge.

Popper, Karl R. (1990), *A World of Propensities*, Bristol: Thoemmes Antiquarian Books.

Sargent, Thomas J. (2001), *The Conquest of American Inflation*, Princeton, NJ: Princeton University Press.

Sargent, Thomas J. (2005), "An Interview with Evans, George W. and Seppo Honkapohja," *Macroeconomic Dynamics*, 9, 2005, 561-583.

Sargent, Thomas J. (2011), "United States Then, Europe Now," *Nobel Lecture,* http://www.nobelprize.org/mediaplayer/index.php?id=1741

Shiller, Robert J. (1981), "Do Stock Prices Move too Much to be Justified by Subsequent Changes in Dividends," *American Economic Review*, 71, 421-36.

Shleifer, Andrei (2000), *Inefficient Markets*, Oxford: Oxford University Press.

Soros, George (1987), *The Alchemy of Finance*, New York: Wiley.

Soros, George (2009), "Financial Markets", Lecture 2 of the Central European University Lectures, October: http://www.ft.com/cms/s/2/dbc0e0c6-bfe9-11de-aed2-00144feab49a.html

Von Neumann, John and Oscar Morgenstern (1944), *Theory of Games and Economic Behavior*, Princeton, NJ: Princeton University Press.