TIME to OUTGROW ‘PHYSICS ENVY’

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Abstract

The Global Financial Crisis exposed among others many frailties of Neo-Classical Economics, especially in Macroeconomics and Financial Economics. Many of these frailties come from the Neo-Classical core beliefs. These core beliefs are required to allow for formal mathematics to be employed, which itself is felt necessary to enhance the science claim of Economics. In other words, ‘Physics envy’. But how do we go about extricating Economics from the shadows of Physics? One promising avenue is in the way we handle randomness. Economics, like Physics, starts with a well-defined and fixed distribution function. Physics is very fortunate that its subjects (say atoms) are dumb—they do not behave strategically. In Economics and the social sciences, subjects can behave strategically; the same agent can be “0” at one time and “1” in the other in a stochastic way, which makes Economics hard. The core assumptions see to it that behavior is confined to a tractable sphere where mathematics is useful, say, fixed preference (type) and perfect markets. This also means that the radius of applicability of Neo-Classical Economics is narrow. We assume that agents choose not only baskets of goods but also their type to suit the social/physical environment. This is like phenotypic plasticity in Biology only in steroids. The choice of types being done under imperfect information can lead to information cascades where agents rely only on observation of others’ behavior to guide their own. This in turn produces herding and/or regime shifts. This may mean that Gaussian distribution can no longer reflect randomness in broader economic reality.

INTRODUCTION

‘Physics envy’ is a pejorative description used by detractors of Economics and other disciplines for the tendency to ape the methodology and assumptions of Physics in order to boost their claim to being a science. Physics, since the monumental achievements of Newton’s Principia, has exerted this gravitational pull on all the other fields of study that aspire to be installed in the pantheon of science. The label was first coined in Biology (Cohen, 1971: “Physics envy is the curse of Biology”). In Economics itself, the seed was planted by marginalists of the 19th century but became the dominant force after WWII with Paul Samuelson’s Foundations of Economic Analysis and the migration to Economics of a whole host of math-savvy students (K. Arrow, G. Debreu, J. Nash, etc). Physics envy has many faces but I will refer particularly to three working principles:
(1) *The Ergodic Hypothesis*: That the distribution that generates future data is the same distribution that generated the past and the present data. In other words, there is a fixed reality which exists outside of us and though we don’t know it perfectly today, we will know it with increasing precision as more and more data becomes available. This is also sometimes known as *Plato’s axiom*: there are immutable Platonic forms T for which all observable realizations t are imperfect representations. P Samuelson (1969) as well as Lucas and Sargent (1981) championed this as the hallmark of true science which if Economics ignores will relegate to a sub-field of History. The implicit claim is that the biosphere and the econosphere are, like the planetary system, ergodic, that is, their reality is fixed and immutable.

(2) *The Dirac Aesthetic*: What is true must be beautiful. What is beauty but mathematical elegance displaying symmetry, completeness and inevitability. The iconic examples here are Einstein’s Theory of Relativity and Newton’s *Principia*. Dirac wrote (1963):

“It seems to be one of the fundamental features of nature that fundamental physical laws are described in terms of a mathematical theory of great beauty and power, needing quite a high standard of mathematics for one to understand it. You may wonder: Why is nature constructed along these lines?... One could perhaps describe the situation by saying that God is a mathematician of a very high order, and He used very advanced mathematics in constructing the universe.”

_The Evolution of the Physicist's Picture of Nature_, Scientific American (1963)

This has a long tradition in science going all the way back to Pythagoras who believed that natural numbers were the ultimate building blocks of the universe. Claimed an avid follower, Galileo Galilei: “The Book of Nature is written in the language of Mathematics.” All impulses of interest must be measurable and all relations and hypotheses between them must be rendered in mathematical formulas. The implication is that the building blocks of reality must be mentally transformed to satisfy the requirement of mathematization. Concepts that do not have real social reality counterparts—such as extensionless points, continua, symmetries, atomism, homo economicus, etc.—were introduced and readily accepted. The result was an increasingly powerful microscope trained to an ever shrinking sphere of validity. In Economics too, the Dirac rule took the form of the identity of elegant mathematics with truth.

(3) *Reductionism*: Explanations of phenomena must spring from the most fundamental constituents of reality. In the case of Economics, this means
deducing explanations for market outcomes from the behavior of market agents. Thus, a macroeconomics without an elegant micro-foundation is soft-headed. But market agents in the real world form a motley crowd of diverse behavioral tendencies, values, freedoms and pathologies which, at the outset, suggest only chaos. If the reductionist project can push through according to the Dirac aesthetic, the discipline must impose strong uniformizing conditions on the behavior of this crowd to render them mathematically tractable. These take many forms:

With respect to agents:

a. *Homo Economicus*: Agents are self-interested and socially-blind;
   - They are strictly rational in the Von Neumann-Morgenstern expected utility sense;
   - They have preferences that are fixed and stable which they optimize, subject to well-known constraints;
   - They employ an infinite and costless computational capacity to find the equilibrium point.
   - Firms are *Homo economicus* facing a different objective function.
   - All relations are well-behaved to allow for existence of equilibrium.

With respect to markets and efficiency:

b. complete powerlessness, since consumers and firms are ‘atomistic’ (the term is iconic of Physics envy);
c. zero transactions cost;
d. no public goods;
e. no externalities;
f. complete markets; and
g. perfect information.

With respect to the information and the macro and financial markets:

h. rational expectations among agents;
i. informationally efficient, thus, zero-arbitrage markets;
j. the representative agent supported by some aggregation theorem.

With respect to allowing for imperfect information:

k. The ergodic hypothesis: all randomness is reflected either by a perfectly known well-defined distribution function over well-defined set of options or if imperfect in the sense of residual error, the error can be progressively whittled down by more data and the application of the Law of Large Numbers.
These simplifications circumscribe a well-behaved theoretical social reality \( r \). We call \( r \) the ‘toy reality’ of Economics, which differs from objective social reality \( R \). If the use of \( r \) allows substantive mapping of events in \( R \), this collection of abstractions is useful. They define “parsimony” in every good model. The imperative of reductionism is to make \( r \) as parsimonious as possible. The one property requirement for \( r \) is that it harbors equilibria preferably unique and stable. That is where ergodicity weighs in: no matter where one starts one always end up in the same unique equilibrium. The employment of formal and increasingly high powered mathematics to \( r \) results in (a) the discovery and characterization of this equilibrium, and (b) the production of strong hypotheses about reality. We test these hypotheses and if these are not rejected, infer that they are not rejected in \( R \).

One has of course to be careful. The language of economists use is expansive. To most members of the Economics profession apply Samuelson’s (1969) description: “In a real sense there was a dichotomy in our minds; we were schizophrenics.” Long-run money neutrality in quantitative models did not jibe with non-neutrality in qualitative model. So what? Most economists in real policy arena will consider the social context. Of course, if one aspires to the top of the profession, one should not be bothered by the social context. R Solow (1985) observed regretfully in 1985: “My impression is that the best and brightest proceed as if economics is the physics of society.” This is false because “…much of what we observe cannot be treated as the realization of a stationary stochastic process without straining credulity.”

Economics—specifically Neo-Classical Economics—has achieved impressive heights in social thought: general equilibrium theory; the fundamental theorems of welfare; efficient contracting under asymmetric information; the Arrow Impossibility theorem; Black-Scholes option pricing; portfolio theory; long-term and endogenous economic growth; second-price sealed bid auction, etc. It has provided plausible explanations for all sorts of familiar economic phenomena, such as risk-sharing and performance contracts; rationing of bank loans; bank runs; truthfully revealing mechanisms, etc. But their validity in \( r \) does not always mean validity in \( R \). Unfortunately, to paraphrase a familiar saying, you can take human agents out of the jungle but you can’t take the jungle out of human agents.

Nonetheless, it is in \( r \) where beauty resides no matter that it stumbles in its forward view. \( R \) is the forbidden domain of barbarians who could not possibly overturn Pax Romana. Nonetheless, it did. As P Krugman (2009) put it: “As I see it, the economics profession went astray because economists, as a group, mistook beauty, clad in impressive-looking mathematics, for truth.” Translation: \( r \) does not adequately span \( R \).

This is not the first time that aesthetic sensibility led science astray. The so-called Platonic Axiom hamstrung astronomy so long because it insisted that heavenly bodies move in perfect circles since circular motion is the only motion that avoids a vacuum. J. Kepler’s discovery that planetary motion was elliptical and I. Newton’s demonstration of its mathematical necessity started astronomy on the right course. Even then it did not happen overnight. And reductionism itself has had a spectacular stumble of all places in Mathematics: David Hilbert in 1900 conjectured (Hilbert’s Second Problem) that all of
Mathematics could be reduced into a finite, complete and consistent set of axioms. Kurt Godel in 1931 surprised the mathematical world when he proved that there exist true mathematical statements in all formal systems encompassing natural numbers that are undecidable. This means that these systems are incomplete. Such systems also cannot demonstrate its own consistency. This left the Hilbert reductionist program in tatters.

The ‘Neo-Classical reality’ is a lamppost with a limited area of illumination; a limited domain of applicability. It naturally fails to explain certain—sometimes spectacular—phenomena, notably booms and crashes. One of these is the Global Financial Crisis.

The Global Financial Crisis of 2007-2008 is widely blamed (e.g., Fox, 2009, The Myth of the Rational Market (Harper Business)) on two most important core beliefs in Macroeconomics and Financial Economics: Efficient Market Hypothesis (EMH) and the Rational Expectation Hypothesis (REH). These two core beliefs have combined to erect an imposing theoretical edifice that has ruled these two disciplines almost with iron hand.

EMH, in its various forms, claims that financial markets are informationally efficient—meaning, that no investor can make profits in excess of the average on risk-adjusted basis. E. Fama—who also introduced the label EMH—defined the categories of informational efficiency, viz., weak form, semi-weak form and strong form efficiency. The strong form efficiency claims that no one can do so even with hidden information. (Obviously falsified by the ‘insider trading law’ and the spectacular profits of convicted insider traders). B. Malkiel’s 1982 best seller celebrated the ‘arbitrage free’ implication of the EMH (see Dothan, 2008, for a proof that markets that reflect all available information precludes the existence of profitable trading strategies) and blasted the arbitrage seeking grand illusion held by stock market denizens. They pretend to make money; we pretend to cash their checks. But alas, the grand illusion stayed and won’t go away.

The REH has many faces: that every rational agent’s ‘model’ is the correct model, and since there is only one correct model (in the ergodic universe, that is), this essentially makes agents informationally identical. This achieves immense tractability which, otherwise, will not be there due to heterogeneous people’s beliefs. Economics, for better or for worse, has chosen the reductionist ideal: deducing economic phenomena from the actions of many interacting agents. This runs into the ‘curse of dimensionality’ (the many-body problem): if each agent is endowed with an equation of motion, the array of equations may not be solvable for the equilibrium outcome. For tractability, the Neo-classical, including the neo-Keynesian program, had to adopt very strong simplifying assumptions called the rational expectations hypothesis (REH). In REH, an agent’s subjective joint probability distributions are functions of the equilibrium (also assumed unique due to ergodicity), thus, making the objective and subjective probability ultimately identical. The average belief is never wrong even if the individual agents are sometimes wrong. As Hansen and Sargent (2008) put it: “Rational expectations theorizing removes agents’ personal models as elements of the model.” It is a small step to the miraculous representative agent of the Dynamic Stochastic General Equilibrium.
Both these core beliefs rightly or wrongly underpinned the faith in the self-healing power of the market and thus of the belief in the welfare-decreasing effect of state intervention in the financial market. A. Greenspan’s refusal to intervene in the bubble in the real estate market was reportedly due to his stated belief that the efficient market heals itself of its maladies. Bubbles will not persist under REH and EMH as rational arbitrageurs will feast on herd and systematically erroneous traders. But even if markets fail as they do in bubbles, state intervention only makes things worse not only because bureaucrats themselves are information-constrained (constrained Paretoness) but also because they can be malicious. (A popular rendition of market fundamentalism is the half-joke: “Harvard: if the market fails, let the state do it; Chicago: If the state fails, let the market do it; George Mason: If the market fails, let the market do it”). The last pretty much covers Greenspan’s attitude.

Indeed, almost any explanation can find its justification in the genesis of the financial crisis (global imbalance; an orgy of market failures; moral hazard and asymmetric information; conflict of interest, say, among credit rating agencies; irrational exuberance; herding behavior; black swan events, etc). I will dwell only on some most constructively promising to the extraction of Physics envy from Economics.

A LITTLE HISTORY

A little history is useful. Ever since Paul Samuelson proved (1965) the proposition that fully anticipated prices are martingales, that is, prices of this genre are un-forecastable, Financial Economics has been increasingly ruled by the claim that financial markets are informationally efficient. The godfather of both Samuelson and Eugene Fama’s 1965 dissertation was Bachelier’s seminal (1900) dissertation that described stock price movements as a Brownian motion (a process later to be rediscovered and fruitfully used (1905) by A. Einstein). It also turned out to be a virtual Eden of quantitative modeling. For a discipline already infected with ‘Physics envy’, enhanced no less by Paul Samuelson (who opined that Economics should turn itself into an outpost of Physics in the social arena), this was a godsend. In 1967, Roberts suggested the categories of efficiency in financial markets and claimed that markets are ‘weak-form efficient’. What Fama (1970) used as moniker—‘efficient market hypothesis’ (EMH) to describe the state of markets where prices reflect all available information and no trading strategy can make money—promptly became a convenient slogan and dogma. Added impetus was given by the results that price changes weighted by the aggregate marginal utilities of risk-averse agents are unpredictable (Le Roy, 1973; Rubinstein, 1976). The micro-foundations for EMH was provided by Lucas (1978) who showed that risk-averse agents exhibiting ‘rational expectations’ fully embody all information, and only risk-adjusted marginal utility discounted prices qualify to be martingales. Since Lucas’ ambition to rewrite the whole of Macroeconomics based on rational expectations (The Lucas Critique) was coming to fruition, Financial Economics and Neo-Classical Macroeconomics came to be woven from the same fabric: REH and EMH.
Informational efficiency bedded down snugly with such well-developed mathematical constructs such as ‘random walk’, ‘Markov process’, and ‘Brownian motion’. Their near cousin, ‘geometric Brownian motion’—central in the option pricing ‘Black-Scholes model’ due to Black and Scholes (1973) and Merton (1973)—is a Gaussian distribution at the limit. Its other reincarnation ‘arbitrage-freedom’ was compared (yet another Physics pull) favorably with the venerable ‘conservation principle’ in Physics (Paul and Baschnagel, 2002). The Neo-Classical lamppost was finally erected.

ANOMALIES

On the assumption of expected utility rationality and self-seeking among agents, the increasingly respectable Behavioral Economics led by Robert Shiller (2004, Irrational Exuberance) and rooted in the pioneering work of Kahnemann and Tversky (Prospect Theory) and intellectual offsprings in cognitive psychology (e.g., Ariely, D., 2009, Predictable Irrationality) have identified numerous anomalies. Decision making of real people is characterized by systematic violations of the Von Neumann-Morgenstern axioms. Neo-Classical orthodoxy will no doubt hide behind the Friedman rule: Forecasts, not assumptions, make the science! As well as on the Friedman claim that market competition will select decision making routines with systematic errors (rules-of-thumb, framing-based, etc) for extinction along the ‘Dutch Book’ logic (see e.g., Lo, 2004). This impressive logic holds true in $r$. In fact, it may be the opposite in $R$: strictly rational decision-makers may already have become extinct in $R$! Let’s revisit the forecasts.

In the Global Financial Crisis, it is precisely the forecast that went awry. The question posed by Queen Elizabeth in a briefing at the London School of Economics in 2008 was telling: “Why did nobody notice it?” Prof Garicano’s reply was even more telling. He told the Queen: "At every stage, someone was relying on somebody else and everyone thought they were doing the right thing.” That sounds very much like birds flocking. Perhaps nobody was looking or everybody had incentive to look away.

So we turn to the implications (nee the forecasts) of the Neo-Classical model. Here, anomalies also abound. Large price movements associated with bubbles and crashes—by the reckoning of the orthodox model based on Gaussian-type distributions—should occur once every hundred years. Instead, they occur about every ten years. Likewise, instead of stock volatility being constant, stock price volatility has been changing. The first order auto-correlation coefficient that should be falling as markets became deeper, having instead a cyclical variation and lower in the 1950’s than in the 1990’s (Lo, 2004), that is an anomaly. The so-called ‘equity premium’ where over very long periods, risk adjusted stock returns outperform other assets, is an anomaly recognized even by rational expectations modelers (see, e.g., Hansen and Sargent, 2007). That the Random Walk Hypothesis is rejected for weekly stock returns indexes (Lo and MacKinlay, 1988) is an anomaly. That low P/E stock returns beat high P/E stock returns (Dreman, 1998; Shiller, 2005) is an anomaly. The October 1987 stock market collapse, the 1998 LTCM debacle, the 2001
dot.com bubble and crash, and the 2007-2008 financial crash—all these qualify as anomalies!

Less rigorous but more interesting, the thousands of ‘trend chasers’ surviving and prospering in Wall Street and around every stock exchange are anomalous. Apparently, the Friedman rule did not apply to them: those who make systematic errors will be selected for extinction by the market competition! The ‘Oracle of Omaha’ Warren Buffet who consistently beat Dow Jones by meticulous research into the minutiae of firms is an anomaly—at least, according to the strong version of EMH. Michael Burry, the star of the book *The Great Short*, who was ostracized for betting against mortgage-backed securities using credit default SWAPs and criticized by Alan Greenspan as a one-off Lady Luck play was an anomaly.

**The CHARACTER of RANDOMNESS**

**Gaussian Is Not Where It’s At**

That stock price collapse occurs much more frequently than the orthodox finance model will own up could be due in part to the distribution function employed. Econophysics is a discipline which applies the methods of Statistical Physics to economic phenomena, viz., in finance and industrial economics. It was originally designed to come to grips with the intractable ‘many body problem’. It avoids dealing with individual member motivation and, instead, concentrates on the behavior of the ‘ensemble’. In an ergodic universe, this makes sense since the time average always equal the ensemble average over long periods and large population. In other words, it can ignore the Neo-Classical reductionist imperative to understand economic phenomena only from the behavior of individual agents.

More careful analysis of the price process by econophysicists has become available. Mandelbrot (1963) was the first to show that asset prices do not exhibit the Gaussian distribution first proposed by Bachelier (1900). Mandelbrot proposed the Levy distribution to account for the frequency of large price changes that would have near-zero probability under the normal curve. He coined the phrase now symbolizing the increasing if grudging recognition of beyond-the-lamppost events: ‘fat tails’. Fat-tailed distributions do not have finite variance and do not tend to the Gaussian distribution at the limit. In financial markets, Mantegna and Stanley (1994) showed that for a very large number of observations of Standard and Poor 500 index, the distribution that emerged was the truncated Levy distribution. They also found that price increments are correlated in time, which correlation should be zero if the process is geometric Brownian and EMH is valid. Likewise, volatility fluctuates with time and is not constant as the EMH would have it (Gopikrishnan et al., 2000 and Stanley et al., 2000). What these means is that such fundamental financial economics results such as the Black-Scholes based of geometric Brownian motion and, ultimately, EMH (the no arbitrage version) are missing the point! Wrote Galegati el al., (2006):
“The evidence for the fat-tailed distribution of asset prices changes noted [by Mandelbrot] has now been established beyond doubt as a truly universal feature of financial markets. A genuinely original and very important contribution of econophysics, using the technique of random matrix theory, has been the discovery that the empirical correlation matrix of price changes of different assets or classes of assets is very poorly determined. This finding undermines Markowitz portfolio theory and the capital asset pricing model, still regarded as powerful and valid theories by many economists.”

Econophysicists are not beholden to the rationality assumption so sacred in Economics. They resort to bonding or mimicry (Cont and Bochaud, 2000; Eguiluz and Zimmerman, 2000) to explain the presence of serial correlation of asset prices, the persistence of arbitrage, the occurrence of bubbles and crashes. A possible explanation is the outbreak of herding behavior: this means that agent decisions are not independent and, thus, not describable by a normal distribution at the limit. Bonding or mimicry generates herding behavior, which leads to fat-tailed distributions (Cont and Bouchaud, 2000; Eguiluz and Zimmermann, 2000).

Radical Uncertainty

It is also possible that in certain abnormal settings, radical uncertainty rules. Most of mainstream models of behavior under uncertainty are built on the assumption that randomness exists only in the form of a known and well-behaved distribution function over a known set of alternatives—FH Knight’s concept of ‘risk’. Knight, as well as JM Keynes, worried more about ‘radical uncertainty’ where the governing probability distribution itself is unknown or unknowable and/or where the set of alternatives is not known because some elements are emergent (Simon, 1955). After all, emergent phenomena in the form of innovations are the kernel of economic growth, according to J. Schumpeter. To quote Frydman (2009) who advocates Imperfect Knowledge Economics in a blog commenting on Kaletsky’s “Goodbye, Homo Economicus” and on mechanical models in general:

“Regardless of whether these models are based on REH or behavioral considerations, they represent the causal mechanisms that supposedly underpin change on individual and aggregate levels through mechanical rules. Thus, they ignore the key feature of modern economies: the fact that individuals and companies engage in innovative activities, discovering new ways of using existing physical and human capital and technology, as well as new technologies and new capital in which to invest.

Moreover, the institutions and the broader social context within which this entrepreneurial activity takes place also change in novel ways. Innovation in turn influences future returns from economic activity in ways that no one, including economists, and market participants, can fully foresee, and thus that do not conform to any rule that can be pre-specified in advance.”
I would like to emphasize the idea that the social context is always evolving both from exogenous and endogenous factors, such as via innovation, and economic agents have to keep adopting. As we shall see below, this is also the central theme of George Soros’ theory of reflexivity.

A Taxonomy of Uncertainty

By far, the most promising avenue for breakout of Physics envy is a new taxonomy of uncertainty proposed by Lo and Mueller (2010). They decided to explore the space between risk and radical uncertainty and came out with a taxonomy of five categories:

Taxon 1: Deterministic model of complete certainty:

Newtonian mechanics is the template locator of this space. Here, Newton’s laws of motion govern behavior. Nothing is hidden. Once the initial conditions are fixed, the system is completely time-reversible, that is, all past and future states of the system can be solved for. This is the universe of Pierre Simon de Laplace’s *Celestial Mechanics*. When asked by Emperor Bonaparte where God enters in his model, he boasted: ‘*I have no need of God in my universe!*’

Taxon 2: Risk without Uncertainty:

This follows Knight’s (1921) definition of risk: randomness is governed by a specified probability distribution defined over a completely known set of outcomes. It is at this level where probability theory enters most economic models. For example, the famous mean-variance utility is derived by postulating a two-moment distribution function (mostly normal distribution) over levels of income.

Knowing the relevant probability distribution exactly means knowing all the rules and the odds. There are no hidden information relevant to the outcome.

Taxon 3: Risk with Fully Reducible Uncertainty:

‘Fully reducible uncertainty’ means that the randomness can be rendered closer and closer to Taxon 2 uncertainty with sufficiently large amounts of data using the tools of statistical analysis. Lo and Mueller further state: “Fully reducible uncertainty is very much like an honest casino, but one in which the odds are not posted and must therefore be inferred from experience. In broader terms, fully reducible uncertainty describes a world in which a single model generates all outcomes, and this model is parameterized by a finite number of unknown parameters that do not change over time, and which can be estimated with an arbitrary degree of precision given enough data.” The system is known as ergodic. This is where Physics properly resides and where many social science disciplines aspire to be. This is the outer boundary of Economics’ reality $r$.

Taxon 4: Partially Irreducible Uncertainty:

We can do no better than the description of Lo and Mueller:
“Partially reducible” uncertainty applies to situations in which the underlying machinery generating the observed data cannot be completely deduced by gathering data, however large. The sources of this irreducibility are either (i) stochastic or time-varying parameters that frequently vary as to resist accurate estimation; (ii) complex nonlinearities as in chaotic systems; or (iii) non-stationarities and non-ergodicities that render inoperable the Law of Large Numbers; (iv) unknown and unknowable factors affecting the system; or (v) model uncertainty.

“Although the laws of probability still operate at this level, there is a non-trivial degree of uncertainty regarding the underlying structures generating the data that cannot be reduced to Level-2 uncertainty, even with an infinite amount of data. Under partially reducible uncertainty, we are in a casino that may or may not be honest, and the rules tend to change from time to time without notice.”

I would like to emphasize model uncertainty. Model uncertainty obtains when the data may be being generated by more than one model. Iconic here are the models which switch from one probability distribution to another in generating the data, and where the switch is itself a stochastic event. Regime shifts are the rule here.

Lo and Mueller concludes in the face of such partial reducibility:

“Accordingly, model-building in the social sciences should be much less informed by mathematical aesthetics, and much more by pragmatism in the face of partially reducible uncertainty. We must resign ourselves to models with stochastic parameters or multiple regimes that may not embody universal truth, but are merely useful, i.e., they summarize some coarse-grained features of highly complex datasets...In this respect, economics may have more in common with biology than physics.”

In this uncertainty space, the ideas of Stuart Kaufmann of the Sta Fe Institute are compelling. Kaufmann in (2008) argues that the Biosphere as well as the Econosphere are radically different from the Physical universe for the reason that Simon (1955) first adduced to support bounded rationality: Emergence. Their principal characteristics of these spheres are reproduction and completion of thermodynamic work cycles by autonomous agents that produce new forms contingent on the environment. In other words, Darwinian pre-adaptation and natural selection selection. The IPAD and Facebook are emergent realities that could not have been predicted even with a completed physical Theory of Everything.

**Taxon 5: Irreducible Uncertainty:**

This is a state of total ignorance; that is to quote Lo and Mueller “...ignorance that cannot be remedied by collecting more data or using more advanced methods of statistical
inference or more powerful computers, or thinking harder and smarter. Such uncertainty is beyond the reach of probabilistic reasoning, statistical inference, and any meaningful quantification.” This is Knight’s and Keynes’ radical uncertainty. This is where religion and faith find solace and thrive. The idea of faith and religion being two “non-overlapping magisteria” is rooted in irreducible uncertainty.

**CHOICE OF TYPE and INFORMATION CASCADES**

How may regime shifts occur in society? In Neo-Classical economics, agents have fixed and stable preferences. In other words, each agent has one and only one behavioral type. Given that type, he/she optimizes, given the for-the-moment fixed environment. Given the numerous evidence that type (preference) is not stable, we postulate that agents choose their type from a finite set of types; in other words, an agent’s type is itself a strategic variable. We call this *multi-level choice* (Fabella, 2009): agents first choose their type after observing their surrounding environment; having chosen their type, they optimize on the use of their resources. Type multiplicity is not new; it is a staple in adverse selection and mechanism design models where an agent has “one true type” but can reveal a type other the true one. In our view, agents have different true types in different circumstances. It is in keeping with the saying, “*When in Rome, act as the Romans do,*” When in Rome you maximize your life chances by blending. It is also in keeping with the Augustinian plea, “*Lord, make me chaste but not yet!*” There are many behavioral dichotomies that agents can choose from: {homo economicus versus homo reciprocus}; {risk-averse versus risk-loving}, etc.

Type choice is a generalization of the very innovative proposal by Lo (2004) coming under the label of Adaptive Expectations Hypothesis (AEH) where agents choose the decision making heuristics they employ contingent on the environment. Some such heuristics are strict rationality, EMH, satisficing, bounded rationality, imitation, etc. In multi-level choice, agents choose not only their market basket but also their type and thus heuristics and their objective functions (preference) depending upon the environment or group they operate in. The goal (and thus type) of an agent as CEO of a corporation differs from his/her goal as head of the family. The behavioural type chosen in a volunteer environment differs from the type chosen in an *quid pro quo* exchange environment. Fellow traveller of choice of type is the choice of identity in Akerlof and Kranton’s *Identity Economics*. In this book, the authors argue very forcefully that the role of group membership and of norms must be embraced to increase the relevance of Economics. The following reveals their core belief:

“To some extent individuals may choose not only their actions but also their identity. Social categories are more or less ascriptive; but people often have some choice over who they are. As we noted before, for example, immigrants can decide whether to assimilate. Studying these decisions would be a long-run analysis, similar again to supply and demand, where, in the long run, firms and consumers can exit or enter a market. This choice of identity, again, is not necessarily
conscious. In the long run, also, people can change norms and ideals and the very nature of the social categories.”

We differ from the Akerlof and Kranton view that identity choice as just a long-run phenomenon. Neo-Classical Economics does not deny taste change; it only says that the time horizon over which it happens is so long, we can ignore it. Indeed my own interest in choice of type stems from how rapidly it can change. Because an agent is at once a member of many groups, some of them virtual, some perceptual, he/she literally flits from one type to another even in the same day. Non-ergodicity starts at the level of the human agent.

Now imperfect information surrounds whichever type is best for the agent in a fast changing environment like the bubbly financial market. Since signals are partial and noisy, agents may supplement their own information by inferring other agents’ information through observation on what they do. At some point their perception of reality is completely dominated by what others do. This produces what is known as ‘information cascade’ which, in turn, produces ‘herding’ (Banerjee 1992; Bickchandani, Hirshleifer and Welch, 1992; 1998). In this case, there is a rapid transition from strict Bayesian rationality to strict mimicry. Thus, traders who are normally risk-averse type may—due to a perception of emerging bullishness—switch to the rank of the bulls (irrational exuberance), or traders who are very bullish may—due to small changes in the trading space—switch to the rank of the bears. Type choice under information cascade can result in rapid regime shifts.

The LTCM fiasco can be understood in this way: In the wake of the Russian debt default, bonds belonging to the same risk-class but with the same revenue flow began to diverge in price. This presented a perfect arbitrage opportunity: short the high priced bonds and buy low price bonds in the same risk- and revenue flow-class, then hold the bonds to maturity. But the usual arbitrage crowd failed to show up as safety-seeking dominated arbitrage-seeking. It is possible to interpret it as a stampede brought about by agents changing their type in mass from regular arbitrage-seeking to safety-seeking due to a perception that the previous operating distribution has been replaced by an unknown one and all bets are off. (R Merton and others seemed to interpret this as the effect of capital constraint: arbitrageurs unable to finance the investment required).

**ROBUSTNESS and “DEEP” but CIRCUMSCRIBED UNCERTAINTY**

Recognition of model uncertainty was made salient by Hansen and Sargent (2007). As observed, most economic modeling starts with an objective function (say, cost function) and a pre-specified probability distribution to reflect risk. If well-behaved, optimization produces the best option (lowest cost option) or a ranking of options. This routine is called
‘predict-and-act’ in engineering. The problem arises when the uncertainty is what they label ‘deep’, that is, when no single joint probability distribution describes the uncertainty; the probability distribution is imperfectly known, that is, the probability distribution adopted is only one element in the circumscribed set of probability distributions and only one of these probability distributions is the true data generator. Then the constructed model is by their label just an ‘approximating model’ and there is a cost associated with being removed from the true model. This brings about what Hansen and Sargent (2007) called ‘fear of model misspecification’.

In their celebrated book *Robustness*, Hansen and Sargent (2007) apply the results of ‘Robust Decision Making’ from other disciplines, viz., Engineering, to search for decision rules and strategies that are robust against model misspecification. This dovetails well with the Generalized Method of Moments estimation developed by Lars Hansen for estimating parameters when the distribution function of the data is not known. This means that the criterion for assessing different options is not optimality but robustness (e.g., a trade-off of some optimality in return for smaller sensitivity to assumption breakdown). The heuristic, satisficing, replaces maximizing and computer simulation is the tool of choice.

REH modeling is special in that the approximating model is, in fact, no different than the true model. Thus, Hansen and Sargent try to extend the REH modeling to encompass the fear of misspecification in the modeler. Even then, their results are valid only when the ‘deep uncertainty’ is circumscribed and set of distributions is known. Thus, the approach fails when the uncertainty is beyond ‘deep’.

**Safety-First in Policymaking**

The concept of robustness so important in engineering—for example, in the construction of bridges—has also become important in economic and financial policy especially post Global Financial Crisis. The normal response to fear of model misspecification (and catastrophe) is redundancy: the employment of many layers of safety valves to check the progress of an emergent disaster when some assumption becomes violated. (Apparently, the usual assumptions were violated in the case of Typhoon Yolanda so that the disaster preparations based on those assumptions also failed). This has very important implications for regulators of the financial markets. In the face of such heightened uncertainty, it is better for the regulator to err on the side of safety, that is, resort to redundancy: firewalls between casino and regular banking, capital adequacy ratio, stress test, macro-prudential and too-big-to-fail measures.

**COMPLEXITY and ASYMMETRIC INFORMATION**

Kenneth Arrow’s view (2008, Risky Business) on origins of the Great Recession hangs on two ideas: asymmetric information and complexity. One trend in from the 1950’s was that deep markets can solve many market failures, especially missing markets in risk taking, which spawned a multitude of risk-pooling instruments (derivatives, default swaps, options, etc.), which are basically welfare-improving. A signal result in this direction is the
famous Wilson and Postlewaite (1978) theorem that ‘profit’ from dishonest revelation (thus, manipulability) disappears as the market becomes very large by replication. Instruments that are missing in shallow markets will emerge in deep ones. The other trend is that as markets grow, they also create increasing complexities, interlocking dependencies and even more intractable information asymmetries. With super-rational agents, this may be ignored. But with boundedly rational agents, this can lead to the impairment of the robustness of the system. Fewer and fewer people apparently understood the increasingly complex derivatives designed to reduce risk in the mortgage-backed securities. These nevertheless attracted increasing investment because the high returns meant you are crazy if you are out. The risk pooling virtue of these new instruments paled in comparison to the emerging asymmetric information and the moral hazard it produced. In such situations, herding behavior (who’s making money now and how?) may look more and more the only way to proceed. With increasing fragility, there may be bubbles and crashes. In this case, it happened.

GEORGE SOROS and REFLEXIVITY

Then there is George Soros! He became celebrated (notorious) as the man “who broke the bank of England” in 1992 when he shorted the British pound in favor of the German Deutchmark and forced the ‘Black Wednesday’ devaluation of the pound sterling and the eventual collapse of the EMS. He was castigated by Mahathir of Malaysia as the arch-vulture capitalist that “sucked the blood out of less developed economies in the wake of the Asian Crises of 1998…” He also studied under such luminaries as Friederich Hayek, Karl Popper and Lionnel Robbins at the London School of Economics when Economics meant ‘thinking’ rather than ‘mathematizing’.

When not making money or promoting ‘open societies’, his economic views—coming under the rubric of the ‘Theory of Reflexivity’—though not yet properly worked out, are interesting and deserve more notice than it has so far attracted. It starts with the idea that Economics cannot be Physics because in Physics, the observer is outside the reality he/she is observing; he/she has no appreciable impact on the behavior of that reality. In the social sciences, the observer operates (thinks and acts) inside the reality he/she observes. His/her actions, based on observation, change that reality which thus can change his/her observation which, in turn, changes his/her actions, and so on. The now famous Soros-speak on financial markets is a propos here:

“I operate using a different theory according to which financial markets cannot discount the future because they not merely discount the future, they help shape it.”

This is what he calls the ‘Social Uncertainty Principle’, an obvious takeoff from Heisenberg’s ‘Uncertainty Principle’ in the physics of the very small, where the act of observation injects enough energy into the system being observed as to disturb the behavior of that system. Thus, it seems he wants to depart from the Physics of Newton but probably not from the Physics of Planck. True enough, when Soros led the charge to force the
devaluation of the British pound in the 1990s, he and his ilk were essentially shaping the future landscape of the European Monetary System.

Neo-Classical economics employs many mechanisms to suppress the Soros-type reflexivity in r. The perfectly competitive market, the EMH, and the small country assumption in trade where the individual has zero influence on system outcomes, are examples. This feedback loop effect between observer and reality is not original to Soros. For example, it is known as ‘second order cybernetics’ in Cybernetics Theory (Umpleby, 2001) or as a two-variable discrete dynamical system in dynamical systems theory (Kwong, 2008). Nor is it completely unoccupied in Economics: ‘price cobwebs’ reflect a feedback which may return to, or diverge from, initial equilibrium; the so-called ‘Ricardian equivalence’ conceived to refute the Keynesian fiscal activism, precisely exploits this relation between perception and action among hyper-rational agents to frustrate via negative feedback the purposes of expected fiscal spending. Here, negative feedback operates to enforce the stability of the long-run full employment equilibrium because the rational agents are ‘sure’ what that equilibrium is, and that higher taxes will follow. It is the way Soros employs feedback that seems compelling.

This, in turn, produces what Soros calls ‘dynamic dis-equilibrium’ or far-from-equilibrium’ events, which can persist long enough to result in a serious wealth creation or destruction. Soros distinguishes between three regimes: Normal/Classical: Convergent or Mean-reverting; Far-From-Equilibrium/Fragile: divergent but self-limiting since backed only by imperfect information and herding; and Far-From-Equilibrium/Robust: divergent and permanent resulting in a new normal, since backed by real Schumpeterian innovation. To quote Soros (1992):

“So we can observe three very different conditions in history: the ‘normal’, in which the participants’ views and the actual state of affairs tend to converge; and two far-from-equilibrium conditions, one of apparent changelessness, in which thinking and reality are very far apart and show no tendency to converge, and one of revolutionary change in which the actual situation is so novel and unexpected and changing so rapidly that the participants’ views cannot keep up with it.”

The normal regime seems to be the terrain mapped by Neo-Classical economics. The ‘Far-from-equilibrium-fragile’ is the terrain where bubbles and crashes occur and where subjective valuations far outstrip objective valuation. However, others may mistake this fragile regime to be ‘Far from equilibrium robust’ as Greenspan seemed to have read the pre-crisis global crisis situation.

Since the same system can experience through time all three regimes, it is not enough to reflect only the normal regime as does Neo-Classical Economics. The Holy Grail here is a comprehensive model with the capacity to seamlessly exhibit all three regimes. In particular it must imbed Regime 1 (normal) and either Regime 2 (boom) or Regime 3 (new normal). It must incorporate the transition mechanism between Regime 1 and Regime 2 and the return mechanism or the ‘break’ from Regime 2 to Regime 1.
Soros’ reflexivity emphasizes regime switching and irreducible residual uncertainty. However it is largely silent as to how and when the switching comes about. That challenge will surely win a Nobel for the person who will crack the switching code.

**CONCLUSION**

In social and economic modeling, the difference between Neo-Classical reality \( r \) and objective reality \( R \) may be massive, and that gap may be irreducible and cannot be remedied simply by gathering more and more data. The reasons are many and among these are non-ergodicity, non-stationarities, regime-switching, and chaotic systems. In other words we are dealing with what North calls a ‘non-ergodic universe’ in the social sciences whereas Physics deals with an ergodic one. The actors of the Physical universe (such as atoms and planets) are ‘dumb’; the denizens of the social universe are clever strategic actors. Physical reality such as the planetary system exists independently of man whereas economic reality such as the Internet are products of man. Economic reality is emergent rather than fixed. Thus, Physics envy, even if requited, is not going to close the gap and improve performance. The Physics template demands rigorous formalism and progressive reductionism in search of the fixed reality. These in turn demands the conceptualization of an economic actors according to the demands of mathematics, thus, the core beliefs of Neo-Classical Economics. This combination results in the Neo-Classical reality we call \( r \), which is elegant but illuminates only a small part of \( R \). Strong hypotheses are generated for \( r \) which are inferred to hold for the objective reality \( R \). \( R \) encompasses all influences such as those identified by Psychology, Sociology, Anthropology, Political Science, etc. Actually observed phenomena are products of \( R \) but they are to be predicted by the use or explained and understood in terms of \( r \). The gap between \( r \) and \( R \) may be irreducible and the power of \( r \) to predict or explain emanations of \( R \) may be forever impaired. We have argued how this could be so in terms of the way randomness is reflected in economic models. The explicit recognition of the strategic behavior by actors in \( R \), say, in the form of choice of type, may produce macro behavior outside \( r \). Otherwise, Neo-Classical economics, however elegant, will often prove wanting if not dangerous.

The lesson we should learn as economists is deep humility. We should know that we do not know a great deal about objective reality using the Neo-Classical lens. The policy implication is that in the face of such uncertainty, the government needs to put in place institutions that insure the robustness of the market system without unduly throttling its dynamism, such as capital adequacy, macro-prudential measures, firewalls between casino and depositary functions of banks and periodic stress tests. Measures to mitigate too-big-to-fail risks make even more sense. These may mean that profitability of banks may erode and economic growth may slow down in the short-run but the system is more robust. In the long-run and through regime changes, welfare may be better served by policies ensuring robustness.

The theory implication is that economic models should be time-scale and social context-dependent or both with the awareness that context can change slowly or
catastrophically. A universal model of the economy is not forthcoming. “The long-run” can be very short. Economic History should be returned to its proper place in the economics curriculum. But the proper strategy for change in world view in the economics profession is not to jettison wholesale Neo-Classical theory but to subsume it in a more comprehensive model which incorporates the non-ergodic parts of R. How this is done is the challenge of the next decade.
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