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The Concept of Equilibrium in Economics and Finance: A Critique

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Abstract: The paper comments on what the standard concept of equilibrium in neo classical economic theory and finance ignore: that there as yet no evidence from the analysis of real, unmassaged market data to support the notion of Adam Smith's stabilizing Invisible Hand. The practice of Paul Samuelson of making occasional reference to physics is explored. It was argued that the practice was neither 'merely' stylistic nor idiosyncratic, but instead was motivated by mathematical issues. Examples were drawn from neo classical price theory. If any project of turning economics and finance into a hard science, then it would surely be worth looking into.

Key words: The neoclassical economy · Entropy · The pair correlation function · Bohr's principle · Correspondence principle · La Chatelier principle

INTRODUCTION

The history of economics revolves around the idea of equilibrium and has done so since the early theories of Leon Walras and Stanley Jevons. Leon Walras in 1874 conceptually founded the ideas of marginal utility when he drafted a hypothetical economy using a series of equations that equaled the number of unknowns. Equilibrium prices and quantities solve this system of complexity and demonstrate prices and quantities drive the economy toward equilibrium. Stanley Jevons was the first to formulate economics as a mathematical science, though in a rudimentary way, in the early 1860s by formulating the ideas of economic utility.

Paul Samuelson, a modern day neoclassicist, set the tone for the 'appropriate' demeanor to be displayed vis-a-vis science in the twentieth century and this involved the construction of an elaborate *rapprochement* with the developments in twentieth century physics. However much the average economist cited Milton Friedman's famous1953 essay on 'method', it was Samuelson and not Friedman who by both word and deed was responsible for the twentieth century image of an economist as 'scientist'. Economics has since been referred to as a science, in relation to that of physics, more so today than ever before[1]. The neoclassical economics, deals with the concept of equilibrium and other mathematical concepts, as objective facts-absolute certainties. What economics received from the neoclassical economists was new mathematical techniques and a patina of superficial references to physics. Thermodynamics, general relativity, quantum mechanics and grand theories of unified forces are all characteristically modern physics because they fundamentally revised the very structure of explanation in physical theory, relative to that of the nineteenth century. Thermodynamics introduced irreversibility into Laplace determinism and quantum mechanics extirpated continuity at the micro level; relativity regarded energy conservation merely as an expendable analytical convenience. Each innovation reinvested notions of explanation and the boundaries of our experience. Nevertheless, the dowry the displaced scientists brought with them to neoclassical economics did not include any of those fundamental conceptualizations. The question naturally arises whether all the effort could make the neoclassicism 'better'. This is what we exactly seek to pursue. Section 1 posits the simplest model of market

[1]The Nobel Prize (1997) citation for Paul Samuelson: "…for the scientific work through which [Samuelson] has developed static and dynamic economic theory and actively contributed to raising the level of analysis in economic science." Richard Cooper writes that Foundations redirected the advanced study of economics toward greater and more productive use of mathematics.

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dynamics with two examples. Section 2 considers the premier principles with an effort to understand the motivations behind the curious habit of turning economics into science. Section 3 concludes with a few comments.

Section 1: The Best Approximation to Market Dynamics!: The starting point is the postulate of maximizing behavior. The point is not (or not only) that everyone is out to maximize, even if true. Rather, first- and in particular higher-order (derivative) conditions of equilibrium at the maximum imply local behavioral relations [1]. The stability of equilibrium with sufficient other hypothetical qualitative restrictions then generates testable hypotheses. Even where there is no context for purposive maximizing behavior, reduction to a maximization problem may be a convenient device for developing properties of the equilibrium, from which, however, no teleologicalornormativewelfare significance is warranted[2].

Because the laws of physics or better yet the known laws of nature are based on local invariance principle, they are independent of initial conditions like absolute time and absolute position in the universe. We can't say the same about markets: socio-economic behavior is not necessarily universal but may vary from country to country. Mexico is not like China, which in turn is not like the USA, which is not like Germany or Guatemala. Many economists would like to ignore the details and hope that a single universal 'law of motion' governs markets but this idea remains only a hope. We can try to describe mathematically what has happened in the past but there is no guarantee that the future will remain the same [4,4]. If we assume that prices are determined by supply and demand then the simplest model is

$$\frac{dp}{dt} = \varepsilon(p,t) \qquad (1)$$

where ε is excess demand. With the assumption that asset prices in financial markets are random, we also have

$$dp = r(p,t)\,dr + d(p,r)\,dB(t) \qquad (2)$$

where $B(t)$ is a Weiner process[5]. This means that excess demand $dp/dt = 0$ is approximated by drift r *plus* noise $d(p,t)\,dB/dt$.

Neo classical theories give a different interpretation to (2). They assume that it describes a sequence of temporary price equilibria'. The reason for this is that they insist on picturing ' price ' in the market as the clearing price, as if the market would be in equilibrium. This is a bad picture: limit book orders prevent the market from approaching any equilibrium. The only dynamically correct definition of equilibrium is that in (1), $dp/dt = 0$ which is to say that the total excess demand for an asset vanishes $\varepsilon(p) = 0$ In any market so long as limit orders remain unfilled, this requirement is not satisfied and the market is not in equilibrium.

Standard economic theory and standard finance theory have entirely different origins and show very little, if any, theoretical overlap. The former with no empirical basis for its postulates is based on the idea of equilibrium whereas the finance theory is motivated by and deals from the start with, empirical data and modeling via non equilibrium stochastic dynamics. The finance theory criticizes the economists' application of the word 'equilibrium' to processes that vary rapidly with time and far from dynamic equilibrium, where supply and demand certainly do not balance. There are several practical instances of equilibrium in finance, the one prominent

[2]Theorems derived in welfare economics, Samuelson notes, are deductive implications of assumptions that are not refutable, thus not meaningful in a certain sense. Still, the social welfare function can represent any index (cardinal not) of the economic measures of any logically possible ethical belief system that is required toorderany (hypothetically) feasible social configurations as 'better than',' worse than', or 'indifferent' to each other. It also definitively elucidates the notion of Pareto Optimalityand the "germ of truth in Adam Smith's doctrine of the 'Invisible hand, Samuelson, (1983); Fischer (1987).

[3]Primarily, though world events and new research opportunities drew many physicists and mathematicians into finance and economics. As Mirowski (2002) in his Machine Dreams emphasizes, the advent of physicists working in large numbers in finance coincided with the reduction in physics funding after the collapse of the USSR. What Mirowski does not emphasize is that it also coincides, with a time lag of roughly a decade, with the advent of the Black-Scholes theory of option pricing and the simultaneous start of large-scale options trading in Chikago, the advent of deregulation as a dominant government philosophy in the 1980s and beyond and the collapse of the USSR.

[4]All of these developments opened the door to globalization of capital and led to advent for modeling in economics and finance.

[5]We adhere to this interpretation in all that follows.

being the capital asset pricing model (CAPM). Again, the CAPM description [3, 4] of equilibrium also fails because the parameters in CAPM vary with time. The idea of the efficient market hypothesis from which the CAPM idea followed was formulated as a fair game condition. The idea of a fair game is one where the expected gain/loss is zero meaning that one expects to lose as much as one gains during many trades. Consider a single risky asset with expected return R combined with a risk-free asset with known return R_o Le t f denote the fraction invested in the risky asset. The fluctuating return of the portfolio is then given by $x = f x_1 + (1 - f) R_0$ and, therefore, the expected return of the portfolio is $f R_1 + (1 - f) R_0 + f \Delta R$ where $\Delta R = R_1 - R_0$.

The portfolio standard deviation or root mean square fluctuation is $\sigma = f \sigma_1$ where $\sigma_1 = (x - R_1)^2)^{1/2}$ the standard deviation of the risky asset is. We can therefore write

$$R = R_0 + \frac{\sigma}{\sigma_1} \Delta R \qquad (3)$$

Which we can generalize later to include many uncorrelated and also correlated assets. In this simplest case the relation between return and risk is linear in the portfolio standard deviation. The greater the expected return the greater the risk. If there is no chance of return then a trader or investor will not place the bet corresponding to buying the risky asset. Since $x(t)$ does not generally define a fair game, the drift-free variable $z(t)$, where $z(t + \Delta t) = x(t + \Delta t) - R \Delta t$ and $\Delta z = \Delta x(t) - R \Delta t$ can be chosen instead. The fair game condition is that $\Delta(z) = 0$ or $z(t + \Delta t) = z(t)$. So long as the market return $x(t)$ can be described approximately as a Markov process then there are no systematically repeated patterns in the market that can be exploited to obtain gains much greater than R. This is the original interpretation of the EMH. However, with consideration of the CAPM this idea was modified above average expected gains require greater risk, meaning that the so-called β [6] is larger.

Persistent beating of the market via insider information violates the strong from of the EMH. A more realistic viewpoint is that most of us are looking at noise (useless information, in agreement with the weak form) and that only relatively few agents have useful information that can be applied to extract unusual profits from the market, The Physicist-run Prediction Company is an example of an company that has apparently extracted unusual profits from the market for over a decade. In contrast, the economist-run companies LTCM and Enron have gone belly-up. Being a physicist certainly doesn’t guarantee success but if you going to look for correlations in market data, then being a physicist might be of some help. As a matter of fact, with the advent of the physicists, called ‘econo physicists’, a new fertile research frontier has opened up.

Physicists in the modern days now aggressively turn to statistics for a more widely applicable idea of equilibrium, the idea of statistical equilibrium[7]. In this case we see that the vanishing of excess demand on the average is a necessary but not sufficient condition for equilibrium. As Boltzmann and Gibbs [5] have taught us, entropy measures disorder. Lower entropy means more order, higher entropy means less order. The idea is that disorder is more probable than order, so low entropy corresponds to less probable states. Statistical equilibrium is the notion of maximum disorder under a given set of constraints. Given any probability distribution we can write down the formula for the Gibbs entropy of the disturbance. Therefore a very general course-grained approach to the idea of stability in the theory of statistical process would be to study the entropy

$$S(t) = \int_{-\infty}^{\infty} f(x, t) \ln f(x,, t)\, dx \qquad (4)$$

Of the returns distribution (p, x) with density $f(x, t) = dP / dt$. If the entropy increases toward a constant limit, independent of time t and remains there then the system will have reached statistical equilibrium, a state of maximum disorder [8]. In this case one can see that the vanishing of excess demand on the average is a necessary but not sufficient condition for equilibrium.

[6]Warren Buffet criticized the CAPM and has ridiculed the EMH. According t??o Buffet, regarding all agents as equal in ability (the so called 'representative agent' of latter day neoclassical economic theory) is like regarding all players on an ice-hock- team equal to the team's star. This amounts to a criticism of the strong form of the EMH and seems well taken , [6].

[7]As emphasizes, though, in his Machine Dreams, the advent of physicists working in large numbers in finance coincided with the reduction in physics funding after the collapse of the USSR. What Mirowski does not emphasize is that it also coincides with a time lag of roughly a decade, with the advent of the Black- Scholes theory of options pricing.

[8]One can say the same about children and their clothing: in the book Machine absence of effective rules of order the clothing will be scattered all over the floor (higher entropy). But then the mother arrives and arranges everything nearly in the shelves, attaining lower entropy. ‘Mama’ is analogous to a macroscopic version of Maxwell’s famous Demon.

If entropy approaches a maximum the equilibrium requires that f approaches a limiting distribution $f_o(x)$ that is time independent as t increases. Such a density is called an equilibrium density. If, on the pother hand the entropy increases without bound, as in diffusion with no bounds on returns as in (2), then the stochastic process is unstable in the sense that there is no statistical equilibrium. Instead of using the entropy directly, we might as well discuss our course-grained idea of equilibrium and stability in terms of the probability distribution, which determines the entropy. The stability condition is that the moments of the distribution are bounded and become the time independent at large times. This is usually the same as requiring that f approaches a t-independent limit f_o.

Example 1

The pair correlation function

$$R(\Delta t) = \sigma^2 \ e^{2\beta \ \Delta \ t}$$

arises from the Wax (1954), McCauley (2004) process

$$d \ v = -\beta \ v \ dt + \sqrt{d\ (v, t)\ d\ B(t)} \tag{5}$$

With the diffusion coefficient given by d= $\beta(v^2)$ constant. In statistical physics v is the velocity of a Brownian particle [9] and the equation (3) for this model describes the approach of an initially non equilibrium velocity distributions to the Maxwell Ian one as time increases. The relaxation time for establishing equilibrium $\tau = 1/2\beta$ is the time required for correlations (3) to decay significantly for the entropy to reach a stable value [10]. That stability is not guaranteed by a restoring force alone can be shown by the example of a lognormal price model, where

$$dp = r \ pdt + \sigma \ p \ dB \tag{6}$$

If we restrict to the case where $r < 0$ then we have exactly the same restoring force (linear function) as in (3).

Example 2

We can advance the point by citing other examples incorporating elements from both economics and finance. The equation (3) has a variance that grows as $\Delta t^{1/2}$ of short times, but approaches constant at large times and defines a stationary process in that limit. (Maxwellian equilibrium). The dynamical model (4) is the basis for the Black-Scholes model of option pricing. Notice that model (4) has no equilibrium in the fine-grained sense but nevertheless the density $f\ (x,\ t)$ approaches statistical equilibrium. The idea of dynamic stability is of interest in stochastic optimization and control, which has been applied in theoretical economics and finance and yields stochastic generalization of Hamilton's equations. Actually the drive to incorporate the formation of Hamiltonian dynamics is one pertinent example of the triumph of technique over theoretical insight. If the neoclassicists had opted to consciously appropriate a legitimate Hamiltonian dynamics from physics, then they would have to make a route similar to that pioneered in physics. For example in dealing with the utility function in microeconomics, it will be nice and desirable if the utility function used describes the temporal location of commodities, so they write down a Hamiltonian like

$$H = \int_0^\infty u\ (c\ )\ e^{\ gt} \ + \ E\ (p_1) \tag{7}$$

where $U\ (\ c)$ is a utility function predicated upon the consumption of a single good with price p_l. Far from being some sort of novel theoretical innovation, all this accomplished is to render the mathematics tractable at the expense of reducing 'utility' to a homogeneous value substance which could be discounted back from the future to time t at rate g. The fact that there was only one price should have been a giveaway that the problem is solved by neutralizing the question[11].

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[9]If we could model market data so simply with v representing the price p then the restoring force- βp with $\beta >0$ would provide us with a simple model of Adam Smith's stabilizing Invisible hand.

[10]The equilibrium solution of the lognormal Wax process, equation (3) expressed in returns In can be written as; The time dependent lognormal distribution, the Green function of the Wax equation (3) does not approach this limit as t . Negative returns r = - k < 0 are equivalent to a Brownian particle in a quadratic potential U (p) = k but the p- dependent diffusion coefficient delocalizes the particle. This appears non intuitive.

[11]Another unrelated attempt to appropriate Hamiltonians might superimpose as production function which translate unexplained endowments into a single consumption good but this also would be a surreptitious reversion to an embodied substance theory, effectively identical to the labor theory of value,

The mathematics of Hamiltonians [12]... might seem novel to economists, but at bottom, it was still nineteenth-century physics. The shiny toys might distract attention but the knowledgeable players understood that it all never ventured outside the rigidly deterministic world of the Laplace an equations but without doing justice to the constraints implied by the Laplace an world view The newer generation had some acquaintance with the profound upheaval s in twentieth century physics and they felt some inclination to make reference to it: but how, given their allegiance to the neoclassical program..

Section 3: the Neoclassical Economics and Three Principles: We can show how the equilibrium concept fails by referring to the following two principles which act as the two principal props of the neoclassical economy.

The Correspondence Principle: In Paul Samuelson (1941, 1947)), there is proposed a 'correspondence principle' with the unstated intention of evoking resonances with Bohr's principle. The stated purpose of the Samuelson correspondence principle was to suggest that dynamic stability analysis in a neoclassical context could lend some structure to the comparative static results in neoclassical price theory [13]. The correspondence principle therefore, emphasizes the importance of the dynamic properties of a market model with Walrasian price adjustment. If such a market is in dis-equilibrium (Figure 1b), the market clears through the assumption that excess demand/supply leads to a price increase/fall. It can be demonstrated (Figure 1a) that the sufficient condition for the market to have stable equilibrium is that the absolute value of the slope of

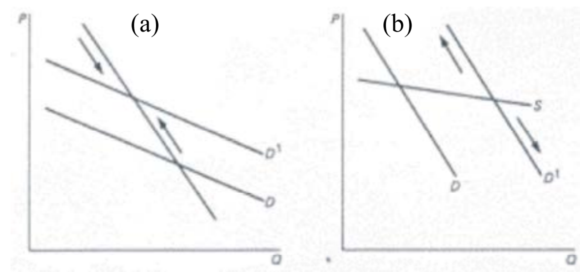

Fig. 1a: (Stability of Walrasian adjustment)
Fig. 1b: (Instability of Walrasian adjustment)

the demand function should be less than the absolute value of the slope of the supply function. (Note that this allows for the supply function to be negatively sloped.) In such a case, the comparative static exercise of seeing what happens to price as demand increases yields a 'normal' positive relationship.

How does corresponding principle differ from the original Bohr's Principle? Bohr's correspondence principle (Sells (1980, Bohr (1976)), provided a way to find the semi classical quantization rule for a one degree of freedom system. It was an argument for the old quantum condition which focused solely on invariance. Bohr was reluctant to generalize the rule to systems with many degrees of freedom. This step was taken by Sommerfeld (1964) who proposed the general quantization rule for anintegrable system:

$$J_k = hn_k \qquad (8)$$

Each action variable is a separate integer, a separate quantum number. This condition reproduces the circular orbit condition for two dimensional motion: let r and θ be polar coordinates for a central potential. Then θ is already

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[12]In Hamiltonian mechanics, a classical physical system is described by a set of canonical coordinates $r = (q, p)$ *where* each component of the coordinate q_i, p_i is indexed to the frame of reference of the system. The time evolution of the system is uniquely defined by Hamilton's equations:

$$\frac{dp}{dt} = -\frac{\mathrm{dH}}{\mathrm{dq}} \; ; \; \frac{dq}{dt} = +\frac{\mathrm{dH}}{dp}$$

where $H = (q, p, t)$ is the Hamiltonian, which corresponds to the total energy of the system. Alternatively we can combine the vectors of q and p into the vector $z = (q, p)$

$$\frac{dz}{dt} = \mathrm{J}\,\Delta\,(\mathrm{z})$$ where ΔH is the gradeient of H and $$J = \begin{bmatrix} \mathrm{D}_{\mathrm{dxd}} & \mathrm{I}_{\mathrm{dxd}} \\ I_{dxd} & \mathrm{Q}_{\mathrm{dxd}} \end{bmatrix}.$$

where $2d$ x $2d$ matrix whose gradients are defined also in terms of identity and zero matrices, see Andrieu and Thom (2008)

[13]The key insights about comparative statics (named the correspondence principle) states that stability of equilibrium implies testable predictions about how the equilibrium changes when parameters are changed.

an angle variable and the canonical momentum conjugate is L, the angular momentum. So the quantum condition for L reproduces Bohr's rule:

$$\int_0^{2\pi} L d\theta = 2\pi L = nh \tag{9}$$

This allowed Sommerfeld to generalize Bohr's theory of circular orbits to elliptical orbits, showing that the energy levels are the same. He also found some general properties of quantum angular momentum which seemed paradoxical at the time. One of these results was that the z-component of the angular momentum, the classical inclination of an orbit relative to the z-axis, could only take on discrete values, a result which seemed to contradict rotational invariance. This was called*space quantization*for a while, but this term fell out of favor with the new quantum mechanics since no quantization of space is involved. In modern quantum mechanics, the principle of superposition makes it clear that rotational invariance is not lost. It is possible to rotate objects with discrete orientations to produce superposition of other discrete orientations and this resolves the intuitive paradoxes of the Sommerfeld model.

Now, given the actual Bohr's results why would Samuelson want to evoke the spirit of Bohr? At the most prosaic level, Samuelson's mathematical model has no connection with the models (single dimension or multi dimension) of Bohr, either in the 'old' or the post-1925 quantum mechanics.

Le Chatelier Principle: Let us mention another principle in this connection, the one Samuelson referred to in his Nobel Prize acceptance speech (Samuelson (1972). This was Le Chetelier Principle that led to the experimental study of thermodynamics. In 1884 he enunciated a general principle that defined how systems inchemical equilibriummaintain their stability, stating that any system in stablechemical equilibrium, subjected to the influence of an external cause which tends to change either its temperature or its condensation (pressure, concentration, number of molecules in unit volume), either as a whole or in some of its parts, can only undergo such internal modifications as would, if produced alone, bring about a change of temperature or of condensation of opposite sign to that resulting from the external cause. Suppose a system in thermodynamic equilibrium is constrained so that only two parameters α and λ, can vary.

Let α be acted upon by an external influence first holding λ constant and then allowing it to vary. The Le Chatelier Principle asserts that, if δ_{11} is a variation holding λ constant, while δ_{11} is a variation with λ free to adjust then

$$|\delta_{11}| < |\delta_1 \alpha| \tag{10}$$

In a loose interpretation, letting λ float free increases the 'ability of α to resist the change exerted by the external influence [14]. Samuelson appropriated the Principle in 1947 and applied it to the slopes of Marshallian demand curves in the relative instances when other prices are fixed and then are allowed to vary. In the Nobel lecture, Samuelson applied it to the neoclassical theory of the firm.

However, if you look upon the monopolistic firm hiring ninety-nine inputs as an example of a maximum system, you can connect up its structural relations with those that prevail for an entropy-maximizing thermodynamic system. Pressure and volume and for that matter absolute temperature and entropy, have to each other the same conjugate or dualistic relation that the wage rate has to labor or the land rent has to acres of land.... Now one can state what perhaps might be called Le Chatelier-Samuelson Principle. The heavy curve of longer-run adjustment with other price constant (other quantity of course thereby itself adjusting *mutatis mutandis* to restore the maximum- profit equilibrium), must less steep or more elastic than the light curve depicting the demand relation when the other input is held constant (Samuelson (1972)).

The formulation referred to in this Nobel lecture only holds for the case of infinitely slow reversible processes, which in effect takes the dynamics out of thermodynamics and therefore the Samuelson- Le Chatelier Principle has had little connection to the content of the thermodynamics. As Gilmore (1983) commented, Samuelson discussion is 'entirely devoid of dynamical consideration'

A system is atequilibrium when all forces on it are balanced and it can rest in that state indefinitely. For instance take a pencil and lay it flat on a table. It is atequilibrium there. There is also another equilibrium

[14]In 1911 Ehrenfest demonstrated the weakness of the principle by coming up with counterexamples which reversed the inequality sign. He speculated that the principle could only be saved by reformulating it in terms used by the physicists, namely, the inequality would only hold when the two parameters α and λ were both' intensive' or both 'extensive' quantities but not when they were mixed. See Kay (2001).

where it is balanced on its tip, but it is very hard to put it in that equilibrium. Now not all equilibria are created equal. As table equilibrium is one where any perturbation of the system will cause it to head back towards that equilibrium. Anunstable equilibrium is one in which some perturbation exists that causes it to head away from that equilibrium. In the example of the pencil, laying flat on its side is a stable equilibrium, while balancing on its tip is unstable. The key fact to remember about unstable equilibria is that they have a tendency to not stick around. No real system is perfectly balanced and the imperfection will grow over time until equilibrium disappears on its own. This is why we run into lots of pencils lying on their sides and none balanced on their tips [15].

Samuelson ignored Ehrenfest's clarification of the principle, which stated that mixed extensive and intensive terms would undermine the inequality as in equation (8). Since ne0classical economics is essentially an imitation of energetics, then the price/force variable should correspond to an 'intensive' magnitude and the commodity/space variable should correspond to 'extensive' or capacity magnitude. Samuelson wanted α and λ to be price and quantity respectively but that would mean mixing types of parameters and therefore in fully specified Walrasian system there exists no guarantee that the slopes of the demand curves will always stand in the same relationship. In other words, if only Samuelson had taken the physics metaphor as a serious heuristic device, he would have noted just how tenuous his own version of the Le Chatelier principle was.

CONCLUSION

The laws of economics, as Samuelson who said it once, are probabilistic in nature, for future events and not the events themselves. There are not even any empirically or even qualitatively correct models of economic behavior beyond the stochastic dynamical models of economic and financial markets. In economics, we do not know any universal laws of markets that could be used to explain even qualitatively correctly the phenomenon of economic growth, recessions, depressions, the lopsided distribution of wealth, the collapse of Marxism and so on. We cannot use mathematics systematically to explain why America collapsed financially after following the advice of neo classical economics and deregulating opening up its markets to external investment and control. We cannot use the standard economic theory to explain mathematically why Enron and WCom and the others collapsed. Such extreme events are ruled out from the start by assuming equilibrium in neo classical economic theory and also in the standard theory of financial markets and option prices based on expectations of small fluctuations. Neither can we use any finance theory. One cannot have both completely unregulated markets and stability at the same time; the two conditions are apparently incompatible. Equilibrium of financial markets is impossible with a diffusion coefficient assumed constant. (equation 5). In particular, even the central limit theorem cannot be used to derive a Gaussian without the assumption of local invariance principles. Because the local invariances form the theoretical basis for repeatable identical experiments whose results can be reproduced by different observers independently of where and at what time the observations are made.

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[15-19]If we run across a system that has settled down to the point that it has a status quo we can notice, that system is extremely likely to be at some sort of equilibrium. Based on this point, we can be pretty sure that it is a stable equilibrium. But Le Chatelier principle is just a description, nothing else, of what it means to be at a stable equilibrium. The net result? It appears that drivers are safer, pedestrians are less safe and benefits to society are less clear than a naive analysis would predict.

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