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Does Adam Smith's Invisible Hand Work for Financial Markets: Comments

By Amaresh Das

Southern University at New Orleans, United States

Abstract- Adam Smith theory of the Invisible Hand is fundamentally flawed. The neoclassical theory based on it relies on market models in which economic agents interact with the market forces that are not governed by Universal Law of Nature; such models ignore correlations that lead to booms and depressions. To prove rigorous theorems financial economists also assume that market fluctuations follow a certain statistical distribution a la a thermodynamic equilibrium approach. Do they really score a major breakthrough? No - the dominant 'equilibrium principle' of the market is only a hope, not a reality: It lacks proper empirical underpinning. Statistics and mathematics do not help.

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I. Adam Smith and The Dynamics of Markets

The idea of Adam Smith's invisible hand is to assume that markets are described by stable equilibria. 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 finance theory is motivated by, and deals from the start with, empirical data and modeling via non equilibrium stochastic dynamics[1]. There are only a very few known relations in statistical dynamics that are valid for systems driven arbitrarily far-from-equilibrium. One of these is the fluctuation theorem, which places conditions on the entropy production probability distribution of nonequilibrium systems. Another which is recently discovered and which is far from an equilibrium expression relates, as in physics, nonequilibrium measurements of the work done on a system to equilibrium free energy differences.

In thermodynamics physicists define the empirical temperature t of an equilibrium system with energy E and volume V where for any of n mentally constructed subsystem of the equilibrium system we have

$$t = f\ (E_1, V_1) = f\ (E_n\ V_n) \qquad (1)$$

This condition, applied to system in thermal contact with each other, reflects the historic origin of the need for an extra, nonmechanical variable called temperature. In thermodynamics, instead of temperature, one can as well take any other intensive variable, for example, pressure or chemical potential. The financial analog of equilibrium would then be the absence of arbitrage possibilities, that there is only one price of an asset

$$p = f\ (\phi_1, \psi_1) = f\ (\phi_n, \psi_n) \qquad (2)$$

This is the neoclassical condition that would follow from utility maximization. Starting from neoclassical condition, Smith and Foley (2002) have proposed a thermodynamic interpretation of $p = f\ (z)$ based on utility maximization. In their discussion a quantity labeled as 'entropy' is formally defined in terms of utility maximization but the quantity so-defined can't represent disorder / uncertainty because there is no liquidity, no analog of the heat bath, in neoclassical equilibrium theory. The 'bounded rationality models' in macroeconomics attempts to define the absolute value of money and is motivated by the fact that a standard neo classical economy is a barter economy, where p is merely a label as described in Beinhocker (2006)

In statistical mechanics, Boltzmann was the first to give a statistical or a probabilistic definition of entropy. Boltzmann entropy is defined for a macroscopic state of a system while entropy which is even more popular - Gibbs entropy - is also defined over an ensemble that is over the probability distribution of macro states. Both Boltzmann and Gibbs entropies are, in fact, the pillars of the foundation of statistical mechanics and are the basis of all the entropy concepts in modern physics. A lot of work on the mathematical analysis and practical applications of both Boltzmann and Gibbs entropies was done, yet the subject is not

Author: Southern University at New Orleans, & University of New Orleans, New Orleans, USA. e-mail: adas2@cox.net

[1] Experts teach standard finance theory as if it would merely a subset of abstract theory of stochastic processes. There lognormal pricing of assets combined with 'implied volatility' is taken as the standard model. The 'implied volatility is not always required when using the lognormal distribution because empirical volatility can be deduced from the observed market distribution. Explicit tests for non-linearity and dependence (Kaplan tests) also give very unstable results in that both acceptance and strong rejection can be found in different realizations of our model. All in all, this behavior is very similar to experience collected with empirical data and our results may point towards an explanation of why robustness of inference in this area is low. However, when testing for dependence in second moments and estimating GARCH models, the results appear much more robust and the chosen GARCH specification closely resembles the typical outcome of empirical studies.

closed, and still is open awaiting a lot of work on their characterization, interpretation, and generalization in physics and other areas.

II. Boltzman H – can it be Applied to Invisible Hand

Physicists consider a monotonic fluid of N particles. The ensemble is defined by the N – particle distribution

$$W_N\ (x_1 , p_1 ; x_2 , p_2 .... ; x_N , p_N ; t\ ) \qquad (3)$$

which gives the probability density function in the full space phase of the system. The Gibbs H is then

$$H_G \ = \ \int W_N \ \ log\, W_N\, d\, \tau \qquad (4)$$

and the corresponding Boltzman H is

$$H_B \ = \ N \ \int W_1 \ log\, W_1\ d\, \tau_1 \qquad (5)$$

where $W_1\, (x_1 , p_1 ,; t\ )$ is the single particle probability density

$$W_1\ (\ x_1 , p \ ; \ t\ ) = \int \ W_N\ \mathrm{d}\, \tau_{\text{-}1} \qquad (6)$$

The basic inequality of the Gibbs and Boltzman *H* in physics function was, as shown in Jaynes (1985), mathematically correct. But it is thought that, in consequence of the 'laws of large systems' the difference between them would be practically negligible in the limit of the large system. Past attempts to demonstrate the second law (of thermodynamics) other than gases have generally tried to retain the basic idea of the Boltzman *H* theorem. Since Gibbs *H* is operationally consistent, one has resorted to some kind of coarse-graining operation, resulting in a new quantity *H*, which tends to decrease. Such attempts can't achieve their purpose, because, mathematically, the decrease in *H* is due only to the artificial coarse-graining and it can't therefore have any physical significance. To illustrate we need the following theorem:

Theorem 1

The Gibbs and Boltzman functions[2] satisfy the inequality

$$H_B \qquad H_G \qquad (7)$$

with equality if and only if W_N factors almost everywhere into a product of single particle functions

$$W_N = (1\ .\ N\ ) = W_1 (1\ .\ W_N (\ N\ ) \qquad (8)$$

There is a relationship between Gibbs-Boltzman function and the entropy. In equilibrium in finance it is required that the total excess demand for an asset vanishes on the average. Correspondingly, the average asset price is constant. One may then turn to statistics for a more widely applicable of equilibrium, the idea of statistical equilibrium[3]. In this case we see that the vanishing of excess demand on the average is a necessary but not sufficient condition for equilibrium. As Boltzman and Gibbs (see Rasmussen et al (2006) have shown, 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. Given any probability distribution we can write down the formula for 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 ala Boltzman and Gibbs[4].

$$S\,(\mathrm{t}) = \int_{-\infty}^{\infty} \ (\ x , t \ )\, In\ f\ (\ x ,, t\ )\, d\ x \qquad (9)$$

The idea is that disorder is more probable than order, so low entropy (the right hand side of the equation (3) corresponds to less probable states. The equation (3) is cited here to illustrate the notion that statistical equilibrium is the notion of maximum disorder under a given set of constraints. Let W denote the number of ways to get m heads and $n - m$ tails with n coins. The former state is much more probable because there are many different ways to achieve it. $W = n! \ / \ (n \ /2)! \ (n\ /2)!$ Where $n! = n\ (n\text{-}1)\ (n\text{-}2)\ .\ .\ .\ .\ (2)\ (1)$. In the latter case there is only one way to get all heads showing $W = 1$. Using Boltzman formula for entropy $S = In\ \ W$, then the disordered state has entropy S on the order of n in $log\ 2$ while the ordered state has $S = In\ 1 = 0$. The equation (1) shows that the entropy $S\ (t)$ can never

[2]The theorem holds for any symmetrical function. The magnitude of the difference between H_G and H_B depend on the distribution function. As soon as we understand between Gibbs-Boltzman functions and entropy, it is immediately obvious that this is precisely the dynamical property we need.

[3] As McCauley [4] 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.

[4] Statistical Mechanics is a grandiose theoretical construction whose founding fathers include the great names of. Maxwell, Boltzmann and Gibbs . We may recall that it is fundamental for the study of condensed matter, which could be said to be statistical mechanics by antonomasia. Therefore statistical mechanics can be considered the science mother of the present day advanced technology, which is the base of our sophisticated contemporary civilization. Its application to the case of systems in equilibrium proceeded rapidly and with exceptional success: equilibrium statistical mechanics gave - starting from the microscopic level - foundations to Thermostatics, its original objective, and the possibility to build a Response Function Theory. Applications to nonequilibrium systems began, mainly, with the case of local equilibrium in the linear regime following the pioneering work of Lars Onsager (see, for example, Casimir (1945) .

reach a maximum because *f*, which is approximately exponential in returns *x*, spreads without limit.

Now, in finance, consider 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[5]. In this case one can see that the vanishing of excess demand on the average is a necessary but not sufficient condition for equilibrium. If entropy approaches a maximum the equilibrium requires that *f* approaches a limiting distribution $f_0(x)$ that is time independent as *t* increases. Such a density is called an equilibrium density. If, on the other hand the entropy increases without bound, as in diffusion with no bounds on returns as in (3), 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_0.

The pair correlation function

$$R(\Delta t) = \sigma^2 e^{2\beta \Delta t} \tag{10}$$

arises from the process

$$d v = -\beta v\, dt + \sqrt{d(v,t)\, d B(t)} \tag{11}$$ [6]

with the diffusion coefficient given by $d = \beta(v^2) =$ constant. In statistical physics v is the velocity of a Brownian particle[7] and the equation (5) for this model describes the approach of an initially non equilibrium velocity distributions to the Maxwellian one as time increases. The relaxation time for establishing equilibrium $r = 1/2\beta$ is the time required for correlations. If we could model market data so simply with v representing the price *p*, then the existing force $-\beta p$ with $\beta \geq 0$ would provide us with a simple model of Adam Smith's stabilizing invisible hand. The time required for establishing equilibrium $\tau = 1/2\beta$ is the time required for correlations (5) to decay significantly and for the entropy to reach a stable value[8]. That stability can't be guaranteed by a restoring force alone can be shown by the example of a lognormal price model where

$$dp = r\, pdt + \sigma\, p\, dB \tag{12}$$

If we restrict to the case where $r < 0$ then we have exactly the same restoring force (linear function) as in (6).

The absence of entropy representing a disorder in neoclassical equilibrium theory can be contrasted with thermodynamics in the following way; for assets in a market let us define efficiency as:

$$e = min\left(\frac{D}{S} \quad \frac{S}{D}\right) \tag{13}$$

Where *S* and *D are* net supply and net demand for some asset in that market that market. In neoclassical equilibrium the efficiency is 100%, $e = 1$, whereas the second law of thermodynamics via the heat bath prevents 100 % efficiency in any thermodynamic machine. That is, the neoclassical market equilibrium condition $e = 1$ is not a thermodynamic efficiency unless we would be able to interpret it as the zero temperature result of an unknown thermodynamic theory (100% efficiency of a machine is thermodynamically possible only at zero absolute temperature). In stark contrast, the neoclassical economists assume an unphysical equivalent of a hypothetical economy made up of Maxwellian demon like agents who can systematically cheat the second law perfectly.

Let's see some more details; The Gaussian and lognormal distribution (related by a coordinate transformation) form the basis for standard finance theory. The exponential distribution forms the basis for many of the empirical approaches in finance and economics. Suppose that $x = ln(p(t+\Delta t) / p(t)$ If the probability density *f* is Gaussian in returns x then we have a lognormal distribution, with a prediction of a correspondingly small probability for 'large events' (large price differences over a time interval Δt). If however, the returns distribution is exponential then we have fat tails in the variable $y = p(t + \Delta t) / p(t)$ with density $g(y) = f(x)\, dx/dy$ with scaling components. The exponential distribution plays a special role in the

[5] 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,

[6] See Das (2013)

[7] 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.

[8] The equilibrium solution of the lognormal Wax process, equation (3) expressed in returns $x = \ln p/p_0$ can be written as $f(x) = C e^{-2rx/\sigma^2}$; The time dependent lognormal distribution, the Green function of the Wax equation (3) does not approach this limit as $t \to \infty$. Negative returns $r = -k < 0$ are equivalent to a Brownian particle in a quadratic potential $U(p) = k p^2/2$ but the p- dependent diffusion coefficient delocalizes the particle. This appears non intuitive, though.

theory of financial data for small to moderate returns. In that case we will find that all exponents depend on the time lag Δt. That is, the distribution that describes financial data is not a stationary one but depends on time. More generally, any price distribution that is asymptotically fat in the price $g\ (p) \approx p^{-\mu}$ is asymptotically exponential in returns $f(x) \approx e^{-\mu x}$

Fait tails mean that big price swings occur with appreciable probability. Big price swings mean that an appreciable fraction of agents in the market are trading in extreme prices. If you buy at the low and sell at the high end then you could make money but this amount to outguessing the market, a task that the Efficient Market Hypothesis (EMH) believers in finance declare to be systematically impossible. The most current statement of the EMH is that there are no patterns / correlations in the market that can be exploited for profit as shown in Fama and French (2007). The difficulty in trying to beat the market is that all you do is to compare stock prices, and then you are primarily looking at the noise. The EMH is approximately correct in this respect. But then Warren Buffet does not look only at prices. The empirical market distribution of returns is observed to peak at the current expected return, calculated from initial investment time *t* but the current expected return is hard to extract accurately from empirical data and also presents us with a very lively moving target: it can change from time to time to time and can also exhibit big swings.

III. Adam Smith in Even with Conventionalstatistics

We cannot use mathematics and conventional statistics systematically to explain why America collapsed financially after following the advice of neo classical economists regarding deregulation and opening up of markets to external investment and control[9]. We cannot use the standard financial 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 the standard theory of financial markets and option prices based on expectations of small fluctuations. One cannot have both completely unregulated markets and stability at the same time; the two conditions are apparently incompatible. Equilibrium of financial markets is just impossible with a diffusion coefficient assumed constant (eq.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[10].

Adam Smith and his contemporaries believed without proof that there must be laws of economics that regulate supply and demand analogous to the way that the laws of mechanics govern the motion of a ball. Maybe Smith did not anticipate that an unregulated financial market can develop big price swings where supply and demand cannot come close to matching each other. The idea that 'the market knows best' is a neoclassical assumption based on the implicit belief that an invisible hand stabilizes the market and always swings it toward equilibrium. The only information provided by the market is about the value of an asset is its current market price and no other information is available. But how can the market 'know best' if no other information is available? Or, even worse, if it consists mainly of noise as described by a Markov process?

Contrary to the early random walk literature, a number of studies have found evidence of positive autocorrelation in security returns over weekly and monthly time horizons; and second there is an indication of negative serial correlation in longer horizon returns over periods of several years. Despite several researchers' claims of large arbitrage opportunities from

[9] So far in deregulated electricity and water markets there is no evidence that the lowering of consumer costs outweighs the risk of having firms play games trying to make big wins by trading options on those services. The negative effects on consumers in California and Buenos Aires do not argue in favor of deregulation of electricity and water

[10] Start with the convolution of individual distributions

$$P(x) = \int \ldots \int dp_1(x_1) \ldots \quad dp_n(x_n)$$

$$\delta\left(x - \sum x_k / \sqrt{n}\right) \quad (9a)$$

subject to the constraint $x = \frac{1}{\sqrt{n}} \sum_{i=1}^{n} x_k$ (9b)

Using the Fourier transform representation of the delta function yields

$$\phi(k) = \prod_{i=1}^{N} \phi_i(k / \sqrt{n}) \quad (9c)$$

Where ϕ_k is the characteristic function of p_k and provides a way to derive the Central Limit Theorem (CLT), To show the limitation of CLT, consider the asymmetric exponential density

$$f_1(x) = \theta(x) \alpha e^{-\alpha x} \quad (9d)$$

Using (5) & (6) yields the density $f(x, N) =$

$$\phi(x)\ \alpha \frac{x^{N-1} e^{-\alpha x}}{(N-1)} \quad (9e)$$

Clearly, this distribution is never Gaussian for either arbitrary or large values of x. Since the most probable and mean values approximate each other for large *N*, we see that CLT will asymptotically describe *small* fluctuations about the mean. However, the CLT does not describe the fluctuation of very small or very large values of *x* correctly for any value of *N*.

exploiting the autocorrelation in short-term returns, it is doubtful whether any abnormal returns remain after accounting for the trading spreads, commissions and other costs involved in pursuing this kind of short-term momentum strategy. Longer term mispricing, however, could constitute a more serious violation of market efficiency as seen in Jovanovic and Schinckus (2013).

The research on time series dependencies in returns which has had the largest impact, at least with practitioners, is the study by DeBondt and Thaler(1985). They look at returns over longer horizons, finding that stocks which have underperformed the most over a three- to five-year period average the highest market-adjusted returns over the subsequent period, and vice versa. They explain this pattern of return reversal as an overreaction in the market in which stock prices diverge from fundamental value. DeBondt and Thaler have observed a similar phenomenon, arguing that such price behavior is consistent with positive feedback trading. Whether these longer horizon patterns of mean reversion really exist is a matter of controversy, since sub period results suggest that the patterns observed by many are not all that robust over time. Time-varying expected returns could also explain these patterns, without requiring us to assume that prices deviate from fundamental value over extended intervals. Nevertheless, there is a growing literature that seeks explain observations such as these in terms of the sentim0ent of non-rational noise traders[11].

The financial market is complex in that the empirical distribution is not fixed once and for all by any law of nature. Rather, it is also subject to change with agents' collective behavior, but the time scale of entire distribution to change in functional form can be much greater than the time scale for changes in the expected return. The only empirical method for estimating the expected returns is to assume that the future will be like the past, which ignores complexity altogether. Here clearly we are not referring to the ever present diffusion that broadens a given distribution but about a sudden change, for example, as from Gaussian to exponential returns, or from exponential to some other distribution.

From our experience in nonlinear dynamics we know that our simple looking local equations of motion can generate chaotic and even computationally complex solutions. They are concerned with the procedural aspects of attaining market equilibria in a decentralized setting and argue that principles on the complexity of feasible computation should rule in or out widely held models. Researchers applying microscopic simulations in economics and finance were interested in explaining the *sudden* drop in the U.S. stock market. The interest was mainly in question of efficiency and stability of different forms of market organizations and regulation as well as the impact of introducing computer-assisted trading. Interestingly, the microstructure literature later moved on to other questions, namely, analysis of asymmetric information models to be tackled in a rigorous statistical manner. Of course, it was only a matter of time until financial models became so complicated that they could not be solved analytically and had to be supported by numerical analysis[12].

An important subsequent variation is financial modeling by De Granwe *et al* (1993) is perhaps a more elaborate dynamics that led to chaotic behavior of exchange rates. In particular, chaotic dynamics derived from the interaction of agents with different prediction functions for future price movements are the topic of a comprehensive research project on some new 'adaptive belief systems' starting with the work of Brock and Hommes (1997), Kozhikade, (2013).

IV. Conclusion

The financial theories ignore the fact that there is no evidence from market data to support the notion of Adam Smith's stabilizing Invisible Hand that forms the theoretical basis of the neoclassical equilibrium market model. Because of the lack of socioeconomic laws of nature and because of the nonuniqueness in explaining statistical data, we have more difficulties than in thermo dynamics and natural sciences. We should try to replace the standard arguments about equilibrium with some empirically based non equilibrium dynamic models. Parenthetically, some policy assessment could be made in this connection on the extent to which modern complex systems theory can be applied to markets. Certainly, this may constitute a paradigm shift from the mainstream policy analysis. This might need to study computer simulations to gain insight into policy dynamics, and avoid the assumption that the economy is a system in equilibrium. This avoids assumptions of any representative agent model, which attributes outcomes in a collective system as a simple sum of the rational actions of individuals.

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[11]General financial equilibrium problem is expected to be large-scale in practice, since one may wish to disaggregate sectors and instruments as finely as required. Hence, some recent work, for example, the one by Nagurney (2002) proposing a decomposition algorithm that resolves such large-scale problems into simpler sub problems is especially appealing. Towards this end, Nagurney proposed a variational inequality decomposition algorithm, based on the modified projection method, which not only can be solved using quilibration algorithms but can also be implemented on parallel architectures.

[12] Luckily, Bayesian learning methods allowed large classes of asymmetric information to be tackled in vigorous statistical models. Market microstructure theory' provides only theoretical work and lacks any reference to microscopic simulations.

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