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A small step towards unification of economics and physics

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Abstract

Unification of natural science and social science is a centuries-old, unmitigated debate. Natural science has a chronological advantage over social science because the latter took time to include many social phenomena in its fold. History of science witnessed quite a number of efforts by social scientists to fit this discipline in a rational if not mathematical framework. On the other hand a tendency among some physicists has been observed especially since the last century to recast a number of social phenomena in the mould of events taking place in physical world and governed by well-known systems and equations of physics. It necessitated the introduction of social physics as a new inter-disciplinary subject. Obviously this attempt is aimed at explaining hitherto unsolved or highly debated issues of social science. Physicists are showing special interest on problems on economics, ranging from some topics of normative economics to the movement of prices of derivatives. Statistics has been widely used in these attempts and at least two sub-disciplines of the subject, namely, stochastic process and time series analysis deserve special mention. All these research activities gave birth to another inter-disciplinary subject named as econophysics. Interestingly, global financial crisis of 2007–08 has revived the need of determination of prices of derivatives in a more accurate manner. This article adumbrates a sketch of the theoretical synthesis between physics and economics and the role played by statistics in this process.

Keywords Econophysics · Mathematization of economics · Monte Carlo simulation · Social physics · Statistical inference · Stochastic process

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1 Introduction

Integration of science obviously entails unification of natural science and social science. K. Popper was of the opinion that theories of social science more than often offer an approximation of the real picture (Popper 2002, p. 319); he referred to the concept of verisimilitude in this context. To him it was the Theory of Relativity which became victorious among Einsteinian mechanics, Marxian discourse, Freudian analysis and Adlerian activity. While working as an assistant of A. Adler he faced the propaganda 'save the phenomenon' personally for the first time in his life (Popper 2002, pp. 45–6). As an incisive critic Popper analytically contradicted the theory of historical inevitability, one of the main planks of Marxism, in his 'Poverty of Historicism' (Popper 1957). Status of biological science, in spite of itself being one of natural science, is yet to be completely grabbed in cause-and-effect flow-charts—theory of immunology and functioning of brain are cases in point. One interesting development took place in the field of science during seventies of the last century. It is the advent of chaos theory. This discipline brings together mathematical and non-mathematical subjects like physics and biology closer than ever before; moreover it elegantly bridges natural and social science by establishing similarity between them. If nothing else, chaos theory has shown its ability of halting rabid compartmentalisation of science (Gleick 1998, p. 5).

Greek philosopher Anaximander was the first enquirer who was in search of an orderly arrangement of the universe (Munitz 1986, p. 21) and thus began the quest of pure knowledge by mankind, giving birth to science and unquestionably it was natural science. Intellectuals, centuries after centuries, have been deeply influenced by the organic view, as envisaged by Hegel, in order to muster a grand overview. A quick glance at the thought process of young Russell:

"During this time[1] my intellectual ambitions were taking shape. I resolved not to adopt a profession, but to devote myself to writing. I remember a cold, bright day in early spring when I walked by myself in the Tiergarten, and made projects of future work. I thought that I would write one series of books on the philosophy of sciences from pure mathematics to physiology, and another series of books on social questions. I hoped that the two series might ultimately meet in a synthesis at once scientific and practical. My scheme was largely inspired by Hegelian ideas. Nevertheless, I have to some extent followed it in later years, as much at any rate as could have been expected. The moment was an important and formative one as regards my purposes." (Russell 1967, p. 116).[2]

Historically speaking, social scientists tried to explain various social phenomena in post-Newtonian era, taking cue from physics and mechanics in particular; many of them were economists. Both Ricardo and James Mill endeavoured to fit political economy in a thoroughly deterministic framework, perhaps with an intention

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[1] Just after his first marriage in December, 1894.

[2] To be noted here that both Marx and Russell surmounted Hegelian spell in their later lives but their points of departure were altogether different and discussion of this topic is beyond the scope of this article.

of creating reprints of contribution made by Euclid and Newton in their respective fields. W. S. Jevons was greatly influenced by laws of physics and essence of mathematical calculus while formulating theory of marginal utility. To him economic theory was a "calculus of pleasure and pain" (Schumpeter 1994, p. 1056). Principle of minimization of energy had an undeniable role in the formation of theory of maximization of utility (Sinha and Chakrabarti 2012, p. 46). The trend turned out to be almost opposite when we observe that some physicists started working on problems of economics in the last century. Actually attempts of elucidating various social phenomena by the accepted theories of physics have a long history indeed and the name of the discipline which deals with this is known as social physics. Statistics is used as the bridge joining economics and physics; econometrics, as a sub-field of statistics, has been found to be of much help in this process.

This article picks up one particular item from the grand project of unification of natural and social science; it aims to highlight possibilities of synergy between physics and economics in solving some problems in economics. It gives an outline of mathematization of economics and devoted two sections on social physics and econophysics, separated by a discussion on statistical inference. Advent of statistical mechanics has opened up a vista so that physicists can make use of some statistical properties to explain some socio-economic phenomena. Affinity of econophysics with econometrics and stochastic processes demands a little more elaboration of econophysics and that is why this article treats social physics and econophysics in an almost mutually exclusive manner. Monte Carlo simulation is an important technique used not only by statisticians but econophysicists as well; methodology and limitations of this technique have been discussed in one section of this article. Global meltdown in the world of finance during the years 2007–08 has been mentioned as a case study to further the cause to be cautious in selection of models and assumption of (statistical) distributions. The application of model introduced by F. Black, M. Scholes and R. Merton (BSM model) for pricing of options is a purely technical issue; one of the sections of this article comments on tenability of this model against the backdrop of performances shown by stock markets. Finally the efficacy of statistics as a bridging discipline (between physics and economics) has been discussed with a conjectural hint at the prospect of mathematics for facilitating this bridging procedure more effective.

2 Mathematization of economics

Economics deserves a prominent place in social science. An eventful journey started from Aristotle's 'Nicomachean Ethics' depicting the extent to which the subject was intertwined with ethics and morality and it will be wrong to conclude that the endeavour was culminated in Adam Smith's 'The Wealth of Nations'—the discipline remained non-mathematical even after publication of the book. In addition to W. S. Jevons, whose name has already been mentioned, L. Walras, V. Pareto, I. Fisher and V. Volterra are the pioneers in their efforts to explain economics in a sound mathematical way (Scott 2018). Mention is also to be made of C. S. Peirce, who was the first economist to introduce this practice on American soil (Wible and Hoover

2015). One highly debated suspicion remains that hyperactivity in mathematization of economics in post World War II America was due to some political reason and it is the same reason which caused the deportation of all discussion of philosophy of science in the safe haven of epistemology and it was the movement of Unity of Science which became the ultimate victim in the process (Weintraub 2017).

Although it would be an overstatement that with the advent of positive economics the process of mathematization of economics unfolded but there is little doubt that positive economics kindled an idea of finding out proximity of economics to mathematics. Cambridge School had a great tradition in the history of economics from J. N. Keynes and H. Sidgwick to P. Sraffa. Unfortunately, the School failed to continue the (J.N.) Keynesian inclination towards normative-positive distinction throughout its later days. A quotable lamentation from J. Robinson, hopefully, will not be out of context: "In Cambridge we had never been taught that economics should be *wertfrei* or *that the positive and normative can be sharply divided*." (Robinson 1964; quoted from Hutchison 1981, p. 57, italics by Hutchison).

Any discussion on rationalization of economics will remain incomplete without mentioning Austrian School. C. Menger set a certain definition of 'exact' laws; these laws needed not be mathematical and more importantly, they could not be tested empirically or mathematically. Finally, Menger came to the conclusion that these 'exact' laws had very limited application in the field of economics (Hutchison 1981, pp. 181, 183). Hutchison observed two phases in evolution of theories demonstrated in the works of F. Hayek; Hayek was an advocate of general laws in social science irrespective of human interpretation or cognition. But this view changed with the passage of time. His Nobel lecture testified to the fact that Hayek was no longer expecting exact results from social science in his later life (Hutchison 1981, pp. 210–9).[3]

Perhaps the publication of 'The General Theory of Employment, Interest and Money', authored by J. M. Keynes in 1936 prompted the economists to search for a 'general' theory of economics. But what worked well in pre-World War II Britain could not be repeated with equal success in other parts of the post-war world; the effect of 'Keynesian revolution' was dwindling in industrialised countries with strongly regulated economic policy and also in the third world countries. The need for some alternatives became an urgent one especially from the seventies of the last century. Economists were gradually taking help from statistics to analyse data; ultimately another new subject econometrics was able to connect economics and statistics [however, Econometric Society was formed in as early as 1930 (Bjerkholt 2017, p. 175)]. M. Friedman spoke about the quantity theory of money in 1956 (Bordo and Rockoff 2013, p. 156). Friedman slackened the inseparable bonding between governance and finance, thereby shifted from the Keynesian formulation. His monetary policy stemmed from a liberal outlook on statecraft resulting into free market. Capital found a wide space to fly about because the effect of regulation reduced and treading activities faced lesser impediment. Market analysts began to examine economic data and experts on stock market tried forecasting on future movements

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[3] This dual position of Hayek as described by Hutchison has been contradicted by Scheall (2015).

of prices of derivatives, using statistics. Free market ensured free flow of capital and global financial crisis of 2007–08 has shown that, if not administered or regulated accordingly (leave alone grasping the theoretical aspect and implication of the model), it may backfire.

3 Social physics

French social scientist Henry de Saint-Simon of eighteenth century was of the view that formation of society and all human interactions are subject to some physical laws. We can even stretch backward up to seventeenth century to cite the works of Thomas Hobbes on theory of state; Hobbes found similarity between rules of statecraft and laws of inertia (Perc 2019). It was post-Galilean Europe and thus we gather evidence of fitting social phenomena to some universal physical law even in the past when physics was just emerging as the most prominent hard science. While opining that "Nature is orderly in all her works, but this is a mode of government that counteracts nature" (Paine 1953, p. xiii) political thinker T. Paine certainly had a Newtonian configuration in his mind. It was not difficult in those days to relate the Smithian 'invisible hand' and laws of gravitation, their inevitableness being the common thread (Perc ibid). Mention is to be made of a slim volume by R. Lammel, which bore the names of 'social' and 'physics'; the name of the book was 'Sozialphysik' and it was published in 1925 (Schulz 2003, p.v).

As has been stated earlier the scenario changed in the last century when some physicists suggest that quite a number of social problems are solvable using methods meant for physics if we focus on the collection of people (family, team, community, company, country etc.), sacrificing the individual entity of man. Statistical regularity shown by collection of gaseous molecules in a closed chamber is a clear motivation behind such an approach. This collective effort, characterised by types of co-operation and strategy can maximize welfare; on the other hand these methods are of use to reduce moral conflict, avoid warfare and thereby minimize cost, the other desideratum economists usually insist upon. Vast literature on this aspect is already in place nowadays and it is flourishing. This game-theoretic approach has been enriched by theoretical physics (which has traversed a long way from Galilean-Newtonian determinism), statistics, network theory, information technology and big data analysis backed by computer-based knowledge (Capraro and Perc 2018; Perc 2019). Treating moral behaviour as the root cause of all (man-made) prosperity and decadence of human civilization this school of thought tries to rationalize it through application of Monte Carlo simulation, statistical physics etc.

4 Known known

This situation is related to all events which are free from uncertainty. In the physical world Newtonian mechanics is a faithful candidate for this deterministic state of affairs. In the realm of financial economics, when all information on market is known to the investor and therefore private or in-house information makes no sense, we may say it is a Known Known case. Obviously this is a utopia and is better known as strongly efficient market. If everything is known to the retailer and consumer in the market then the proverbial Smithian 'invisible hand' will, all of a sudden, discover itself out-of-job. If the life-span of all the policyholders of a life insurance company and future movement of rate of interest are known to the insurer beforehand then the difference between expected death strain and actual death strain will vanish trivially and there will be no need to earmarking reserve. From the other side of the counter: if the policyholder precisely knows her date of death then the necessity of effecting policy will be void to her! Unfortunately, we cannot cite any realistic economic activity which could be a good example of Known Known situation. Perhaps the reason behind this is that outcomes of experiments of social science, unlike those from natural science, are a complex combination of many factors and it is not possible to incorporate all of them in a single prediction formula.

5 Known unknown

Statistics serves two purposes. Statistical methods is concerned with classification of data and evaluation of some estimates of parameters like mean, variance and higher order moments whereas statistical inference deals with testing of hypotheses regarding these estimates and the possible ranges wherein parameters corresponding to these estimate will lie. Statistical inference may be looked upon as a special branch of decision theory. Two-way function of human brain as data bank and data processor shows a similarity in functional aspects between statistics and human brain. In this section we will focus on statistical inference.

Let us start with the equation:

$$y_i = a + b_1 x_{1i} + b_2 x_{2i} + \cdots + b_k x_{ki} + e_i \tag{1}$$

where y_i is the ith observation of the variable y to be predicted,

x_{mi} is the ith observation of the mth auxiliary variable x_i, for all m = 1(1)k, a is a parameter,

This is a linear regression equation; values of y are predicted using values of auxiliary (they are known) variable x_{mi}'s. Error committed to predict y_i is e_i. Statistical analysis is employed to minimize this error, preferably with some distributional assumption of this error part. Statistical inference or, linear statistical inference (since (1) is linear here) begins from this stage—we can estimate parameters, test hypotheses, build confidence intervals of parameters a, b_m, for all m = 1(1)k. Leaving aside theoretical intricacies we only state here that the mathematical derivation of critical region in statistical inference boils down to a single inequation with two unknowns. Difficulty in solving two unknowns from a single inequation has been tackled by keeping one of them fixed and minimizing the other. These two unknowns are called probability of Type I and Type II error where Type I error is rejecting the null hypothesis (H_0) when it is true and Type II error is not rejecting H_0 when it is false. Probability of Type I error is kept at a fixed level and it is the probability of Type II error which is minimized in the process. This is a very short and sketchy description of Neyman–Pearson lemma, the fundamental tool of statistical inference. So the process is not free from error. The statistician, while making any inferential statement, is highly aware of this fact and as such, she mentions, in the same breath that fixed probability of error of issuing such a statement. Statistics certainly has an edge over aver all other disciplines—it predicts, it knows that this prediction is subject to error and it confesses the probability of committing such an error. The 'Unknown' error part metamorphoses into 'Known' in this sense. One amazing fact about statistical inference is that the poem 'Statistics', written by American poet C. Sandburg almost hundred years ago, may still stand as a lyrical manifestation of statistical inference, in spite of the fact that the poet himself, quite understandably, was aware neither of its theoretical derivation nor its operational aspects (Sandburg 1914–15).

Various branches of natural and social science use statistics as a tool when they go for inference. Outcomes from both of them have shown that the world is hardly free from uncertainty. In the realm of physics this uncertainty is most pronounced in quantum physics although the concept of quantum probability is quite different from statistical probability. Many results of experimental physics take recourse to hypothesis testing to reach final conclusion. No wonder if one surmises that all scientific theories are hypotheses.

The distributional assumption of the error part plays a vital role in this context. The normal (another name is Gaussian) distribution is frequently used in statistical analysis of data because it has some beautiful user-friendly property like mean-median-mode equality, perfect symmetry, zero coefficient of kurtosis etc. Another great advantage of using this distribution is that it involves only two parameters. Of course Central Limit Theorem has an alluring power to entice statisticians in assuming normal distribution but application of this Theorem does demand a fairly large number of observations; not all experiments on social science and even biological science can fulfil this condition.

6 Unknown unknown

The distributional assumption of the error part is legitimate insofar as the observed values of the to-be-predicted variable roughly follow a systemic pattern. But what if the pattern is abrupt, non-repetitive and shows no conscious design? There are phenomena in natural and social science in our world like this and we call them 'Unknown Unknown's. This idea has a proximity to chaos theory. The global financial meltdown is surely an example of this type. The year 2015 can be cited as a disturbed year due to deaths caused by Ebola, spurt in international terrorism and the afflicting financial crisis and none of these events followed any discernable pattern.

7 Econophysics

Econophysics was born as a new discipline in the year 1995, the name was due to H. E. Stanley and the place where the baptism took place was Kolkata (Sinha and Chakrabarti 2012, p. 46). But its core issues had already begun to be discussed and debated by financial economists and physicists nearly two decades ago. The discipline, in general, is in search of a universal law to elucidate problems of economics. It divides all the responsible factors into two parts – relevant and irrelevant. The very essence of dynamism in physical world warrants the invoking of time (t) as a variable. Movement of price of derivatives becomes a complex system (a domain of physics) to an econophysicist where t is the running variable. This complexity is due to the irrelevance of some of the factors. Both types of factors have their own degrees of freedom.[4]It has been observed that movement of price of commodities show a peculiar tendency of showing self-similar pattern; B. Mandelbrot delved into the topic and finally became the pioneer of theory of fractals. Periodicity of recurrence of this self-similar pattern is connected with the idea of scaling. Now if we assume that logarithm of price of derivatives follow normal (i.e., Gaussian) distribution then what will be irretrievably lost is the scaling behaviour of data. Physicists and economists left no stone unturned to find a distribution (or process, to suite the actual purpose) capable of exhibiting scaling property and surprisingly, it has been found that the solution is in the armoury of economics itself – it is the Pareto law. The exercise may seem to boil down to ‘bringing of coals to Newcastle’ (Rosser 2016) but it reinforces the fact that the exchange of ideas between physics and economics is in full swing. There are quite a number of laws used in statistical mechanics which show the same property but Pareto law enjoys the most basic form (Rosser ibid). Some examples of phenomena obeying Pareto law are size-frequency distribution of earth-quake, velocity-length distribution of fully developed turbulence (in physical world) and distribution of wealth, total amount of loss to an insurance company due to accident, St. Petersburg paradox (in socio-economic field) (Schulz 2003, p. 102). Levy process is the analogue of this law in the realm of complex system. The process has the merit of showing asymptotic power law behaviour but one of its main drawbacks is that it has infinite variance, in general. Rigorous mathematical treatment establishes that Gaussian law is a special case of Levy functions (restricting the value of a parameter, thereby ensuring that variance of the distribution is finite). The model has been suitably calibrated according to the need and it was observed that stable Levy process could be a good fit for movement of price of derivatives. Infinite variance of Levy process poses problems to the physicists because theoretical physics demands physical interpretation of parameters involved; truncated Levy process has been introduced in order to overcome this difficulty (Jovanovic and Schinckus 2013, p. 327). However, this peculiar feature is not so problematic to the economists because they are to accept it mathematically

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[4] Here the term ‘degrees of freedom’ is used as a concept in physics. Statistics borrows this and some other terms like ‘moments’, ‘entropy’ from physics and uses them with appropriate change of connotation.

and explain it as a result of interplay of a vast number of factors, relevant as well as irrelevant, given the system itself is complex. Gaussian assumption is not tenable in very small time interval in this complex system. From this perspective one can sum up the story of econophysics as a narrative torn by the dilemma between Pareto law and Gaussian assumption.

The famous epistemological divide between rationalism and empiricism has its manifestation in macroeconomics and microeconomics. Macroeconomics chiefly depends on empirical observations whereas microeconomics is based on more exact mathematics. The leap from micro to macro is a challenge to econophysicists; the task becomes even harder due to the coupled degrees of freedom imposed by many hidden irrelevant factors which give rise to chaotic perturbation in movement of price. Consumer (trader, in finance) behaviour is one of the factors, as for example. We can find out other similar factors which cannot be included in a well-defined rational economic system. Still some predictable randomness in the microeconomics has been compared with some thermodynamic system in micro level; but econophysicists faced insurmountable problem in extending the idea up to macro stage in an economic system. The laws of classical thermodynamics require the system to be in stationary state; we are not yet sure about the nature of state of an economic system. Here the journey from micro to macro is not a smooth projection as has been the case in thermodynamics. A plausible hypothesis is that changes in macroeconomic level take place in collective modes; due to this reason econophysicists give so much importance on collective enterprises, as has been alluded to in Sect. 3.Repeated observations of some parameter(s) of an economic system keeping the boundary conditions intact is not possible.[5] It is to be added that econophysics and econometricians are also interested in modelling the underlying rate of interest in determining the price of the derivative. There are various models in vogue e.g. Vasicek, Cox-Ingersoll-Ross, Hull-White models etc. with their situation-specific advantages and of course, limitations. One of the main reasons of using these rates (technically known as term structure of interest rates) is that unlike the price of a derivative these rates are free from unit.

Since econophysics is looking for a universal law it does not favour piece-meal adjustments. However, introduction of Levy process is undoubtedly a progress towards the cherished goal of synthesisation. Econophysics introduces various models with an aim to capture the reality prevailing in financial market only *approximately*; the challenge is, therefore, to develop a general theory.

8 Models in economics and Monte Carlo simulation

Scientists use ceteris paribus assumption in scientific modelling keeping in mind the target phenomenon; social scientists use this assumption more frequently than natural scientists. Economics is not an exception. Selection of models is of crucial

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[5] Astronomy, in spite of being a non-social science, suffers from the same deficiency but the reason is different. Periodicity, if at all, of recurrence of celestial phenomena is abnormally low.

importance in economics and econometrics and it may happen that in spite of ceteris paribus assumption outcome of the model after feeding data is different from the real world situation.

According to Glaserman (2004, p. 1), traditional probability theory associates an event with certain outcomes to a measure (volume, in some more catchy terminology) known as probability whereas Monte Carlo method does just the opposite: it calculates the volume associated to an event. The starting point of this method is to generate (pseudo) random numbers, treating them as observations from a uniform distribution. But the original distribution may not be uniform. Blissfully, most of the statistical distributions are formed in such a manner that a single observation pertaining to those distributions can be (theoretically) retrieved from the cumulative probability and parametric values involved. For those distributions which fail to satisfy this property some numerical methods are to be employed. Simulation method is used to generate data which are supposed to follow a certain statistical distribution and then to calculate estimate of various parameters of that distribution. Numerical values of parameters, which we are *not* estimating, are to be specified at the beginning; this type of specification is based on either further investigation or a priori belief. It is possible to perform statistical testing to ascertain these observations really conform to that distribution. We cannot get rid of distributional assumption.

Monte Carlo simulation method has been widely used in financial economics to generate data, in conformity with a particular model. The expression of expectation and higher order moments may be cumbersome for quite a number of statistical distributions; the situation becomes all the more complicated when we observe that we have to deal with stochastic process and many dimensions. Price of a derivative is usually expressed as expected value of a random variable. One can employ Monte Carlo simulation method to estimate the expected value and subsequently generate data under the model using this estimate. This bulk of data would be of help to analyse the model. Estimation of expected value is usually performed sequentially, time (t) being the running variable. The Monte Carlo method helps here to overcome the difficulty of evaluating highly complicated complex integrations. The exercise may be a case of strikingly good fit with respect to that particular model but the question remains: what if the model itself fails to depict the reality? Economics deals with a number of, possibly ever changing, socio-economic factors and it is not unlikely that one model successfully employed ten years back now fails to reflect the real world scenario. In 1983 Simon White, Carlos Frenk and Marc Davis, through computer simulation, speculated the distribution of galaxies of the universe which was found to be in conformity with observed data. Thus omnipresence of dark matter in the universe was proved (Rowan-Robinson 1999, p. 91). We pick up this example from natural science to show that here also computer simulation has been applied on a particular model[6] but the observed data are originating from a standard reference (the vast universe, in this case). In social science, on the contrary, we are missing this standard reference; the observations are really outcomes specified by time or

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[6] Quite a number of models are in vogue in cosmology and the subject is, chiefly owing to observational obstacle, not at all free from speculation; fortunately this example is free from any such hindrance.

by some other determinants like place of observation, stemming from interplay of various parameters. Observed movement of share prices may well be a grotesque one compared to the figures of yesterday due to sudden imposition of trade embargo by some country to another. One may conclude that a technique as sophisticated as computer simulation cannot salvage the prediction from error; the danger of selection of inaccurate model and/or misjudgement on distributional assumption is always lurking.

Another noteworthy feature of Monte Carlo simulation method is that it starts from random number produced by computers in order to generate data specific to a model but numbers generated by computers are not random as such.[7]

9 Global financial crisis and its effect on insurance sector

It is well known that the 2007 crisis started in February–March when more than 25 US sub-prime lenders declared bankruptcy. Rate of interest of US Federal Reserve tumbled from 5.25% on 18th September 2007 to 2.25% on 18th March 2008 and massive amount of bail-out package and loans were disbursed by governments of US, Germany, UK among others (The Geneva Report 2010, p. 5–17). Threadbare analysis initiated by economists reveals that apart from lapses in regulation and lack of surveillance there are some other factors like wrong methods applied to estimate parameters which are responsible for such an economic disaster. Those who are in search of theoretical rather than operational remedies point to the neo-classical mind-set which hovers around economic equilibrium. It has been opined that dynamism, possibly some sort of cyclicality added to it, has to be injected in this notion of equilibrium (Sheng 2009).

Apart from AIG (American Insurance Group) and Fortis no other insurance company had to bear the brunt of 2007 disaster (The Geneva Report 2010, p. 63–4). A deep sigh of relief was heard from both sides of the Atlantic from the headquarters of giants of insurance industries, in spite of the fact that 'Bancassurance' was no less a popular marketing strategy in both Europe and America. May be the corporate houses which are doing business in both sectors segregated fund and thus insurance sector was insulated from the crisis. According to regulators and whistleblowers, it was the credit risk, among all other risks (banking and insurance, in totality, deal with investment risk, mortality risk, morbidity risk, credit risk, exchange risk and the like), which must be under the scanner henceforth. Public sentiment on the vulnerability of financial institutions gets influenced by 'too big to fall' philosophy. Systemic risk does not shrink with increase in volume of business. Insurance industry has a comparatively lesser exposure to systemic risk as against banking industry.

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[7] The statistical connotation of the word random is not the same as the English phrase 'at random'. The distinction between a variable and a random variable is that random variable assumes a value (or value within an interval, if the case is continuous) with specific probability whereas there is no concept of specific probability attached with a variable. Thus a specific probability is glued to the idea of a random variable and the inability of a computer to generate truly random number is an extension of this anomaly.

Still some more vigilance and surveillance are required in the former because an overwhelming crash in global capital will definitely impact procurement of new business, disbursal of claim, loan, surrender value, survival benefit of an insurance company and secondly, transaction of insurance-linked securities has already been started, albeit the volume being tiny so far.

10 BSM model

Since flight of capital is a major issue of financial globalisation it is wise to consider various forms of financial assets. They are forward contracts, future contracts, options etc.; they differ mainly in operational and administrative aspects. But all of them have a common name derivative (we have already used the term in Sects. 2, 7 and in the abstract). Such a nomenclature stems from the fact that their valuation depends on other variables.

The study of financial economics was introduced in 1960s and gradually developed various models with an aim to pricing of assets. BSM model was first employed when the subject itself attained some maturity. The fact remains that some demerits of the model were detected almost at the time of its debut but the model survived mainly because of its easiness in terms of mathematical tractability (it is consisting of only two parameters viz. mean and variance) and, of course, it was supported by the overwhelming implication of Central Limit Theorem.

General formulas for future price movements of some of these assets are yet to be derived explicitly. L. Bachelier's work in 1900 paved the way of pricing of options. He invented Brownian motion independently, five years before Einstein did it (Sinha and Chakrabarti 2012, p. 46). Brownian motion is a particular stochastic process. So far we have mentioned statistics as a subject on several occasions in this article. A statistical distribution generally involves parameters (we are not considering non-parametric treatment of the subject here). These parameters are functions of time (t) in stochastic process.[8] Such a switch over from simple-to-manage statistical distributions to stochastic process is justified in the sense that price movement is invariably a function of time and so are its parameters. This treatment is also supported by the fact that physicists now analyzing the problem of pricing of derivatives from an angle of complex system, as has been mentioned in Sect. 7.

The BSM model assumes that the statistical distribution of stock price is geometric Brownian motion. Brownian motion is a stochastic process analogous to normal distribution in the domain of classical statistics. The name geometric is attributable to the fact that future stock prices, according to BSM model, follows natural logarithm of this Brownian motion. Thus, if we go to the root then it suffices to discuss the tenability of the assumption of normal distribution. A comparison between observed stock prices and BSM data shows that the model fails to capture *all* marginal possibilities, some outliers are there and a leptokurtic statistical distribution,

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[8] To be mentioned here that in stochastic process it is not strictly t always; it may be some other incremental variable like number of agents (n).

sacrificing the mesokurtic normal distribution would be a better choice. Another assumption of the model is that the volatility is *same* for all option prices with *same* underlying asset, *same* date of expiry and *different* strike prices. The financial crash in Chicago Board Option Exchange in 1987 shows that the graph of observed implied volatility against strike prices is not a flat straight line, it has one curvature. Financial economists began to question the efficacy of BSM model after the discovery of this 'volatile smile' (Brisset 2017, p. 555–6). B. Mandelbrot was highly sceptical about BSM model (Brisset 2017, p. 560).

11 Statistics as a discipline

We have seen in earlier sections the role played by statistics in bringing ideas and concepts of physics and economics close together. Questions used to arise regarding the efficiency of statistics in bridging two widely different subjects namely physics and economics which are so different in their contents and objectives. To answer this question it will be prudent to keep in mind that statistics *supplies* the mathematical tools in the process of analysis of data. It is worthwhile to recall prophesy of P. C. Mahalanobis: "Statistics, like engineering, requires all the help it can receive from mathematics; but (statistics) can never become a branch of mathematics." (quoted from Goon et al. 1983, p. vi). However, S. Stigler questions the contents of curriculum and the method of teaching the subject: "Much of the material presented in modern courses on statistical methods for social sciences is superficially similar to texts available by 1830, and yet the adoption of these methods for the different purposes of the social scientists were so glacially slow that it amounted to a reinvention." (Stigler 1990; quoted from Brisset 2017, p. 560). Still there is no denial that amelioration at least of a modest kind has been possible in this bridging process due to technical help offered by statistics. Introduction of Levy process and other developments testify to this. Frequent use of Gaussian distributional assumption and application of Central Limit Theorem may be sources of reservations of theorists. The concept of 'strange attractor' in chaos theory is certainly not in conformity with statistical regularity in the strict sense of the term but the very idea of statistical regularity may be extended to grasp such and other 'strange' phenomena.

So now we are rather forced to look back at mathematics. Is the key to unify physics and economics (and why not natural and social science, in general) with a hitherto unforeseen revolution in the realm of mathematics, as the pioneers of chaos theory are advocating for? Interestingly, T. S. Kuhn remained almost silent on revolution(s) in mathematics in his famous book 'The Structure of Scientific Revolutions' (Kuhn 1962). No example from mathematics found a place in this book (Kenney 1990, p. 119). One particular view is that two distinct revolutions took place in the history of mathematics. One of them is the abstractness manifested in the sprouting of geometry, real and complex analysis, number theory, set theory. The other one is none but 'computer revolution' itself (Fillion 2019, p. 200).

According to cosmologist R. Penrose the Correct Quantum Gravity (CQG, his own terminology) possibly holds the solution to the conundrum of consciousness (Penrose 1990, p. 578). If one extends this idea then she may come to the conclusion that it is the CQG through which we may establish the link between natural science and social science because the latter is inextricably dependent on cognitive activity. Effect of cognition on consumer behaviour is obvious and thus one may conclude that CQG, if properly develops, will be of immense help to rationalise not only behavioural economics but the economic system as whole. Both of chaos theory and CQG require a possibly different mathematical treatment, heralding a new epoch.

12 Conclusion

We have examined the possibilities of unification of physics and economics by recording historically the exchange of ideas between them. We have also noted the contribution of sub-disciplines like econometrics, time series analysis, network theory, game theory etc. and computer science in achieving the cherished synergy. Mathematization of economics was a precursor to the use of statistics and econometrics in the field of economics. It has been emphasised that one has to be cautious while assuming statistical distribution and selecting appropriate model in working with data for prediction, otherwise simulation process may mislead us. The whole gamut of social physics along with (its sibling, we may add) econophysics is model-based in general and this approach is certainly creating problems to econophysicists who are in search of a general law. This model-based approach owes its formation to the legacy left by economics, and to a lesser extent, statistics. The historical sketch this article has endeavoured to deliver has left some room for an adventurist longing for a 'paradigm shift' to occur in the world of mathematics in not too distant future in order to attain a holistic view. The unpleasant truth is that the Kantian introspection has hardly lost its relevance even today: "Two things fill the mind with ever new and increasing admiration and reverence, the more often and more steadily one reflects on them*: the starry heavens above me and the moral law within me.*" (Kant [1788] (2008), 5:161–2, quoted from Guyer 2006, p. 1, emphasis original).

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