NETWORKING EUROPE: STEPPING STONES FROM INCOME AND WEALTH TO COST

PETER RICHMOND*

"All the mathematical sciences are founded on relations between physical laws and laws of numbers, so that the aim of exact science is to reduce the problems of nature to the determination of quantities by operations with numbers."

James Clerk Maxwell, On Faraday's Lines of Force, 1856

Introduction

In 1970s I was working for Unilever in their research laboratory in Port Sunlight. My time was principally spent studying problems associated with colloids, a topic that today seems to be termed nanotechnology. My focus was the application of statistical physics to help understand the properties of colloidal dispersions. At the time I subscribed to the house journal of the American Institute of Physics and was intrigued some time in 1975 to read an article discussing the application of statistical physics to quite different problems, namely imitation theory exemplified, as I recall, by the structure of shoals of fish. I also came across articles by ET Jaynes on the application of maximum entropy models to scheduling. I remember getting quite excited about this, seeing potential for the application to consumer choice and product placement. Following discussions with colleagues, I wrote an internal company report for the marketing department but sadly nothing came of it and with pressure to do other things I gave the issue no more serious thought. Two decades were to pass before I returned to the topic. After a long spell in research and general management I returned to academia via a senior Marie Curie research fellowship to spend time in the physics department in Trinity College Dublin (TCD) ostensibly to work on colloids with Denis Weaire who led a large and active research group concerned with foams. However at the same time the European Physical Society was sponsoring at TCD the 1st international meeting concerned with the application of physics to financial analysis (APFA). This meeting in 1999 was tremendously successful acting as a focus for the growing community of physicists engaged in the area; it also reignited my own latent interest in the application of statistical physics to financial, economic and social systems.

Dublin – and the island of Ireland – was, during this period, growing strongly. For almost the first time since the mid 19th century, the population was not declining through emigration. A new prosperity and confidence was emerging. Political progress was being made in Northern Ireland. New research agencies were being established to support university research and training. The European Commission through its Directorate General offered new funding opportunities for aspirant researchers. Against this background in the decade that followed it proved possible to establish a small but vibrant community of researchers within college. This activity was stimulated with a new course on econophysics that, each year over the next decade, drew in a small but enthusiastic group of maths and physics undergraduates.

Income and wealth distributions

An interest in the nature of income distributions came about following a meeting with Sorin Solomon at the 2nd APFA meeting in Liege. This led to a long and fruitful

* Centre for Adaptive Systems Laboratory, University College, Dublin 4 Ireland.

collaboration. The topic also drew in the interest of Stefan Hutzler in the physics department with whom I have also continued to collaborate since that time[1–6].

Sorin was asking questions about income and wealth distributions in society. That income and wealth is not distributed uniformly in society appears obvious. But how is wealth distributed? What is the form of the distribution and does it depend on time, history or locations? These questions had been posed ever since Pareto over 100 years ago noticed that the rich end of the distribution followed a power law and this feature seemed to be universal. To Pareto and indeed to most physicists this suggests that some fundamental dynamics was in play. Pareto himself proposed that people, in the course of their life could move through the distribution in both directions 'determined by 'whether they are or are not well fitted for the struggle of life'. If they drop below the minimum income, they 'disappear'; In the region of low incomes, he continues, 'people cannot subsist whether they are good or bad'. In Pareto's ideology the high end region forms a future aristocracy and future leadership. The political ideology to which Pareto subscribed was at the heart of the German NSDAP who used them for the basis of concentration camps and is now totally discredited. However the idea that a static distribution does not imply a static society holds true. This has formed the basis for the recent studies by a number of physicists. Following our initial meeting, Sorin Solomon and I developed a simple agent model that had within it a mechanism for redistribution of money between agents. The model extended the multiplicative stochastic law of Gibrat that leads to the log normal distribution. A new mechanism was introduced that allowed at each time step a 'taxing' of assets of each agent proportional to their individual assets combined with a redistribution of the average of the total so taxed to each agent. This generalized stochastic 'Lotka Volterra' model led immediately to a Pareto power law tail within the overall distribution function. The solution to this equation seemed able to account for the empirical data. In the review article[6] it was shown that the solution fits well UK income data taken over the decade 1992-2002 over many orders of magnitude of income. Interestingly this data spanned two different administrations that managed UK affairs during the period.

Simultaneously other colleagues were also exploring the idea from the perspective proposed by Mandelbrot some years previously. Madelbrot's idea was that transactions between agents were similar to the exchanges in energy and momentum between molecules during collisions and so it should be possible to exploit all the methods of statistical physics developed for molecules[7]. In 1986 Angle published the first in a series of papers that presented a simple stochastic agent model that essentially exploited Mandelbrot's proposal and which led indeed to the emergence of inequality in wealth distributions[8-10]. Angle's approach was based upon evidence attributed to archaeological excavations that suggested to him that inequality within a community first emerged as the agricultural revolution took hold and there grew an abundance of food. Angle put for forward two propositions summarized as follows:

1. Where people are able to produce a surplus, some of it would be fugitive and leave the possession of the original producers.
2. Wealth confers on those who possess it the ability to continue to extract wealth from others. So the rich would tend to take surplus away from the poor.

Angle suggested that losers have wealth taken away by theft, taxation, extortion, voluntary exchange or gift and proposed a simple exchange or collision rule for exchange of assets between interacting agents. The work was taken up and extended by Chakrabarti[11-12] and Yakovenko[13].

The collision rule for this model can be described simply: at an encounter, each agent may save or set aside a fraction of his/her assets. The remainder is put on the table with the assets of the second agent. A coin is then thrown and the winner takes a previously specified fraction of the total assets on the table leaving the remainder for the loser of the game. During this process the net total value of assets possessed by the two agents is conserved. No new money is created during the interchange. This approach yields a distribution that can be fitted to the middle and lower range of the distribution. However it does not in its simple form yield a power law tail in the high end of the distribution function. Generalizing the model to allow the fraction selected at each pairwise interaction to take on a random value does yield a power law tail but, as shown by Repetowitz *et al*[14], the power law is restricted to the value of unity.

In 2002, Slanina proposed a different exchange law that did yield a Pareto power law tail with index having the potential to fit real data[15]. Of even more interest was that the functional form of the distribution function so obtained was equivalent to that obtained from the generalized Lotka Volterra model developed by Solomon and Richmond and discussed above. The specific exchange rule proposed by Slanina was deterministic. At each encounter between agents, the agents exchanged a fraction β, assumed constant of their individual assets. But now the joint asset value of the agents was not conserved during a pairwise encounter, rather the total asset value could increase by a fraction, m. This, Slanina, identified with the creation of wealth as a result of the investment process.

On the basis of these results there seem to be two essential ingredients if a Pareto tail in the distribution of wealth is to be obtained. First there must be a mechanism for redistribution of assets; secondly their must during the encounter be a creation of perhaps destruction of the total wealth of the agents. Non conservation of assets during encounters seems to be important. Exchange processes that conserve wealth seem not to lead to a power law tail. The system is not in the usual equilibrium state where a gamma or Maxwell Boltzmann distribution is the inevitable outcome.

Some economists who had more or less ignored this problem since the early work of Gibrat have been critical of these approaches rooted in ideas that can be traced back to the statistical physics of Boltzmann and Maxwell after whom the velocity distribution of molecules is named. Others have been more positive. Lux has advocated the development of models more in line with standard principles of economic modelling[16]. This would no doubt lead to a more detailed quantification of the interactions that occur within communities as wealth is exchanged between individuals. From the perspective of a physicist this seems equivalent to obtaining the detail of the interatomic potential. However what is known from this latter work is that when considering the behaviour of large numbers of atoms, very few details of the interatomic potential are required in order to understand the existence of the Maxwell-Boltzmann distribution. That there are numerous molecular collisions and that the number of atoms within the system is large are the crucial attributes. Fine points of an inter-atomic potential determine details such as the precise values for the boiling point and freezing points of a liquid rather than the emergence of the distribution of velocities per se. To understand the gross features of assemblies of molecules, knowledge of the fine details of the molecular potential or exchange process is not necessary. One might assume that for assemblies of agents, the fine detail is similarly not essential.

The issue of wealth inequality has been taken up in a different but complementary manner by Mimkes who has shown how thermodynamics may be applied to economic problems and in particular the issue of wealth distributions[17]. Mimkes invoked the concept of a Carnot cycle as an idealized production process and identified the 'temperature' that features in physical system with 'mean price level' or mean income level' within the economic system. The production function is identified with entropy. In refrigerators, the Carnot cycle creates different temperature levels, the 'hot' side and 'cold' side. Mimkes argues that production systems create two different income levels, the 'rich' side and the 'poor' side. Using an entropy function calculated using the familiar mathematics of combinations this approach also leads to distributions for wealth distributions of the Maxwell Boltzmann type. This fits data for the average or moderately wealthy communities. It does not yield a Pareto tail characteristic of the super-rich.

Economists have used the Cobb Douglas function rather than an entropy function and it can be shown that using this function in the approach proposed by Mimkes does yields a Pareto law however it does beg the question: how does the Cobb Douglas function arise? Mimkes notes that the wealth of a super rich minority arises from the fact that they own the Carnot machines as exemplified by the numerous super rich who emerged in late Victorian England as a result of building their manufacturing businesses, or pop stars of today such as Paul McCartney who retained ownership of his music. Not only do the super rich then derive wages but they also own risky assets. The value of these then fluctuates as economies fluctuate and leads us back to a system where the total wealth is not conserved as economic processes evolve. Such a system may be modelled by imposing a slow fluctuation on the temperature difference or volatility of the economic process generated by the Carnot machine. For chi-squared distributed fluctuations, a Pareto tail in the overall distribution density is the outcome.

Networking Europe with COST

What became clear as we entered the 21st century was that there were a number of researchers across Europe developing interests in the application of physics to economic issues, but unlike other areas of physics, these researchers were relatively isolated. Mainstream areas of physics across Europe benefitted from networks and concerted actions which helped foster strong links between research groups. The networks for so-called 'econophysicists' that were available were mainly focussed on mathematical fundamentals and tools such as stochastic processes and non-linear dynamics. There seemed to be no multidisciplinary network that drew in for example economists and social scientists to discuss not just tools but also the problem areas. The APFA meetings provided one forum but this only meets once every one or two years and as everyone knows, large meetings are not always the best arena for intimate discussions. The EU was funding increasingly large research projects that allowed discussions between the participants but these networks were and for the most part continue to be increasingly top-down driven specific work packages and targets and the meeting not surprisingly tended to focus on targets rather than ideas. As we entered the 21st century, the European econophysics community was not ready for such activity. The way forward was with COST.

As the web site www.cost.esf.org states: ‘COST is an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally-funded research on a European level. COST contributes to reducing the fragmentation in European research investments and opening the European Research Area to cooperation worldwide making it possible for various national facilities, institutes, universities and private industry to work jointly on a wide range of Research and Development (R&D) activities. COST – together with EUREKA and the EU framework programmes – is one of the three pillars of joint European research initiatives......It has been successfully used to maximise European synergy and added value in research cooperation and is a useful tool to further European integration. Furthermore ease of access for institutions from nonmember countries makes COST a very interesting and successful tool for tackling topics of a truly global nature.

More discussions with Sorin Solomon together with Janusz Holyst in Warsaw finally led in 2003 to success with a new proposal for a COST concerted action with as its main objective: ‘to develop greater understanding and application of modern statistical physics, mathematics and computational physics in relation to problems associated with risk such as occur in quantitative finance, food safety, health, social science and other disciplines, where these tools can enhance and improve upon current approaches to these issues.’ The money associated with COST actions is not large. The funds are not for research per se, rather the money is for networking through small ‘working group meetings’ involving typically 10-20 researchers and one to one exchanges between members of the action. In addition support is now offered to action members for training schools.

The action was structured into three overlapping working groups. Working group I was concerned with empirical studies and the analysis of data for complex systems that revealed the underlying spatial and temporal dynamics together with the impact of shocks and other extreme activity. Working group II explored the use of agent models to understand social phenomena, market volatility, diffusion of innovation, technologies and convention and systemic risk. Working group III sought to uncover basic ingredients that determine network topology. A second objective was to investigate various dynamical rules on these networks and the interplay between these rules and geometry. The rules constrain attendance to two persons per country at these meetings ensuring not only large active countries are represented but also that smaller countries get a look in. The annual management committee meeting provides an opportunity for a larger scientific meeting to be held, typically 40-50 persons. This action proved to be extremely successful. Within less than 12 months we had over 20 European states from Finland and Lithuania in the north to Spain and Italy in the south, Portugal in the west to Romania and Bulgaria in the East signed up to the action. During the next 4 years we held 19 working group meetings across the EC. For example our four annual meetings were held in Nyborg Denmark, Toledo Spain, Vilnius Lithuania and Palermo Sicily. The annual meeting always attracted a number of eminent scientists not only from Europe but also the US and Australia. Some meetings were held within other international meetings such as APFA. The essential approach was to do what the members wanted to do within the constraints of the instruments available; there was no top down plan. The action was driven by what the members wanted to do!

Overall I believe we were successful in building the community of physicists interested in finance, economic and, as the action progressed, social issues. As a result of the discussions many new teams emerged that were subsequently successful in securing substantial new funds from both the EU Framework Programme and individual member states as the value of research in this multidisciplinary area became recognized. Equally we were able to support other initiatives from the member state funding agencies who were now thinking about developing strategies that might exploit the opportunities posed by research rooted in ‘complexity’. Two training schools were supported for young researchers. Over 70 short term scientific missions were sponsored between the member laboratories and over 150 scientific peer reviewed papers, review articles plus two books were published during the period of the action. All this for roughly 100KEUR per annum!

However, as the action was coming to an end, it was increasingly clear that the emphasis was broadening beyond the confines of financial and economic issues. The interest in financial systems had led to detailed studies of order books which capture the activity of the traders. But this data was not available to all and some members of the action, stimulated by the new and large data sets for email networks, mobile phone networks and traffic had begun to move their activity to look at these other social systems where data was more readily available. Opinion formation was another area of interest driven by French action member Serge Galam who by now had relocated from physics to social science.

At this point we were faced with a dilemma. Should we try to submit a new proposal to the social science COST domain or propose a new submission to the COST physics domain?[v] After some debate, we considered that our activity whilst being applied to social science issues was still firmly rooted within the physics domain and we went ahead to develop a new proposal - The Physics of Competition and Conflict - and submitted this to the physics domain. Success was not guaranteed but to our surprise, the proposal came through the assessment process and the new action began in September 2008. Once again we quickly built up membership from over 20 European member states and our scientific activity began in early 2009.

One development since the submission of the previous proposal was new support from the EC for coordinated actions such as GIACS and ONCE-CS, and our plan was, and continues to be, to ensure we coordinate our activity with these other actions. Our advantage as we have already remarked over all other actions is the flexible mode of operation offered by COST that optimizes the ability of participants to develop and share new ideas and evolve tailored partnerships that can then be the basis for more formal research applications to, for example, the EC Framework or Member State programmes covering both basic and strategic or applied aspects. A further significant benefit offered by COST is the ease with which new groups and institutions can become involved. The ability to involve both young researchers and eminent experts in a flexible way is another valuable feature of the COST programme.

The main objective of the new Action is to facilitate the development and application of modern statistical physics, mathematics and computational physics to problems associated with competition and conflicts which can of course include finance but now other social, political and economic areas, where the physics can enhance and improve upon current approaches to these issues. The action is constructed, as before, around working groups. One is concerned with the availability of information. Knowledge and learning dynamics is an important key to understanding relations within human groups and societies and the group seeks to explore available information within, for example, e-data bases and establish a forum for greater discussion between social, economic, and physics communities. The new information science at the crossing point between library science, information engineering & visualization offers a new field for physicists. A recent meeting in Amsterdam set within a wider meeting that brought together information scientists, artists and experts from the humanities as well as visitors from across the Atlantic included a discussion of Science maps not only for understanding our history but also for looking into the future. An early meeting was held in conjunction with historians within the International Medieval Congress, an annual event attended by medieval historians from all over the world. This led to a wide ranging discussion about the value of network theoretical approaches and more general statistical methods in the area using religious belief and the spreading of religion as the exemplar. Cyber-emotions which is exploring the content of blogs, for example offers a second line of exploration.

A second broad activity encompasses efforts to develop descriptions of social systems at the 'microscopic' level using, for example, game theory. The main feature is to strive towards explanations for and control of complex collective phenomena characterized by relatively long space-time scales in terms of elementary elements that operate at finer scales. A key issue is not only the juxtaposition of different disciplines but also the intimate fusion of complementary knowledge across these disciplines. Network structures and dynamics are fundamental to understanding many of these systems. A key challenge is development and understanding of co-evolution of agents on complex networks and, over the past two years we have facilitated a number of meetings that have brought together members of the physics community together with researchers from disciplines such as anthropology and history who are keen to work together. Some of the topics at a recent network meeting were concerned with: role of emotion in comments on Digg stories, Complex (social) networks and historical evidence: the case of Byzantium, Establishment of a large-scale "laboratory" for socioleconomic behaviour, Multi-scale dynamics and hierarchical structure in complex networks bringing together.

Both this and the previous action have provided a supportive environment for researchers who are keen to develop new research proposals and, at the time of writing, a new group has been formed specifically to support this activity. At the recent annual meeting in Bulgaria, the group stimulated discussion between members keen to build collaborative networks working on new flagship proposals that might fit key European research, in particular the development of new initiatives concerned with 'social' microscopes and the simulation of social phenomena.

The European community, as GIACS and ONCE-CS came to an end began support for a new concerted action ASSYST and we are working in complementary ways with this community who are also seeking to build complexity science across Europe and establish the European Complexity Community within ECCS. Simultaneously we are now seeing within Europe much more research investment in the area of complex systems targeted at application in the social sciences. The UK, Spain and the more recently the Netherlands have been especially prominent in this and what seems clear is that, whilst the new regime of austerity that looks set to spread across Europe, the initiatives already made will take root and continue. A new collaborative effort by the different European member state research councils was set in train with COMPLEXITY-NET. This led during 2009 to a call for research proposals from the community and some of these, despite the new financial constraints due to funding reductions, look set to be funded.

Overall then I think we can say that COST has played and can continue to play a solid role in helping build the multidisciplinary complex systems community across Europe and that we shall see much more activity and new insights into social, economic and financial issues in the future.

"If we define a religion to be a system of thought that contains unprovable statements, so it contains an element of faith, then Gödel has taught us that not only is mathematics a religion but it is the only religion able to prove itself to be one." John Barrow, Pi in the Sky, 1992

References

1. O Malcai, O Biham P Richmond and S Solomon, *Theoretical Analysis and Simulations of the Generalised Lotka Volterra Model Phys Rev* **E 66** 031-102 (2002).
2. S Solomon and P Richmond, Stable Power Laws in Variable Economies; *Lotka-Volterra implies Pareto-Zipf Eur Phys J* **B27** 257-261 (2002)
3. P Richmond and S Solomon, Power Laws are Disguised Boltzmann Laws *Int J Mod Phys C12* 333-343 (2001).
4. S Solomon and P Richmond, Power Laws of Wealth, market order and market returns *Physica* **A299** 188-197 (2001)
5. S Solomon and P Richmond, Stability of Pareto-Zipf Law in Non-stationary Economies. In Economics with heterogeneous interacting agents Springer Verlag, *Berlin Lecture notes in economics and mathematical systems* **503** 141-159 (2001)
6. P Richmond S Hutzler R Coelho and P Repetowicz, A review of empirical studies and modesl of income distribution in society In Econophysics and Sociophysics: Trends and perspectives. BK Chakrabarti and A Chakraborti (Eds) Wiley VCH Verlag GmbH & Co ISBN 3 527 40670 0
7. BB Mandelbrot, *J Political Economy* **71** 421-440 (1963).
8. J Angle, *The surplus theory of social stratification and the size distribution of personal wealth Social Forces* **65** 293-326 (1986).
9. J Angle, Deriving the size distribution of personal wealth from 'the rich get richer and the poor get poorer' *J Math Sociology* **18** 27-46 (1993).
10. J Angle, How the gamma law of income distributions appears invariant under aggregation, *J Math Sociology* **31** 325-358 1996
11. A Chakraborti and BK Chakrabarti, Statistical mechanics of money; How saving propensities affects its distribution *Eur Phys J* **B 17** 167-170 (2000)
12. A Chatterjee BK Chakrabarti and SS Manna, Pareto law in a kinetic model of market with random saving propensity *Physica A* **335** 155-163 (2004)
13. A Dragulescu and V Yakovenko, *Statistical mechanics of money Eur Phys J* **B 17** 723-729 2000
14. P Reptowicz S Hutzler and P Richmond, Dynamics of money and income distributions *Physica* **A 356** 641-654 (2005)
15. F Slanina, *Inelastically scattering particles and wealth distributions in an open economy Physi Rev* **E 69** 46102-1-7 (2004).
16. T Lux, Emergent statistical wealth distributions in simple monetary exchange models: a critical review In Econophysics of wealth distributions A Chaterjee, S Yarlagadda and BK Chakrabarti (Eds) Springer ISBN 10 88 470 0329 6 p. 51-60.
17. J Mimkes, A thermodynamic formulation of economies In Econophysics and Sociophysics, Trends and Perspectives BK Chakrabarti, A Chakraborti and A Chaterjee (Editors) Wiley VCH ISBN 13 978 3 527 40670 8 pages 1-33.