How can physics help economics?

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The crisis put classical economics under pressure. In theory, deregulated markets should be efficient, with rational agents quickly correcting any mispricing or forecasting error. Prices should reflect the underlying reality and ensure optimal allocation of resources. These "equilibrated" markets should be stable: crises can only be triggered by acute exogenous disturbances not the market itself. This is in stark contrast with most financial crashes.

The crisis might offer an occasion for a paradigm change, to which physics could contribute, through so-called econophysics. Econophysics has tended to concentrate on financial markets, and these represent an ideal laboratory for testing economics concepts using the terabytes of data generated every day by financial markets to compare theories with observations.

In financial markets, physicists are intrigued by a number of phenomena described by power-laws. For example, the distribution of price changes, of company sizes, of individual wealth all have a power-law tail, to a large extent universal. The activity and volatility of markets have a power-law correlation in time, reflecting their intermittent nature, obvious to the naked eye. Many complex physical systems display very similar intermittent dynamics, for example velocity fluctuations in turbulent flows. While the exogenous driving force is regular and steady, the resulting endogenous dynamics is complex and jittery. In these cases, the non-trivial (physicists say "critical") nature of the dynamics comes from collective effects: individual components have a relatively simple behaviour, but interactions lead to new, emergent phenomena. The whole is fundamentally different from any of its sub-parts. The dynamics of financial markets, and more generally of economic systems, may reflect the same underlying mechanisms.

Several economically-inspired models exhibit these critical features. One (a transposition of the Random Field Ising Model, RFIM) describes situations where there is a conflict between personal opinions, public information, and social pressure. Traders are influenced by some slowly varying global factors, for example interest rates or dividend forecasts. Assume no shocks in the dynamics of these exogenous factors, but that each trader is influenced by the opinion of the majority. If all agents made up their mind in isolation (zero herding tendency) then the aggregate opinion would faithfully track the external influences and, by assumption, evolve smoothly.

But if the herding tendency exceeds some finite threshold, the evolution of the aggregate opinion jumps discontinuously from optimistic to pessimistic, while global factors only deteriorate slowly and smoothly. Furthermore, some hysteresis appears. Like supersaturated vapour refusing to turn into liquid, optimism is self-consistently maintained. To trigger the crash, global factors have to degrade far beyond the point where pessimism should prevail. Likewise, these factors must improve much beyond the crash tipping point for global optimism to be reinstalled.

The representative agent theory amounts to replacing an ensemble of heterogeneous and interacting agents by a unique representative one, but in the RFIM, this is impossible: the behaviour of the crowd is fundamentally different from that of any single individual.

Minority Games define another, much richer, family of models in which agents learn to compete for scarce resources. A crucial aspect here is that the decisions of these agents impact the market: the price does not evolve exogenously but moves as a result of these decisions. A remarkable result here is the existence of a phase transition as the number of speculators increases, between a predictable market where agents can make some profit from their strategies, and an over-crowded market, where these profits vanish or become too risky.

There are other examples in physics and computer science where competition and heterogeneities lead to interesting phenomena, for example cases where even if an equilibrium state exists in theory, it may be totally irrelevant in practice, because the equilibration time is far too long.

As models become more realistic, analytics often has to give way to numerical simulations. This is well-accepted in physics, but many economists are still reluctant to recognise that numerical investigation of a model, although very far from theorem proving, is a valid way to do science. It is surprising how easily numerical experiments allow one to qualify an agent-based model (ABM) as potentially realistic or completely off the mark. What makes this expeditious diagnosis possible is the fact that for large systems details do not matter much – only a few microscopic features end up surviving at the macro scale.

The attraction of ABM is that they can put together simple elements that produce rich behaviours. The instability mechanisms in the complex systems they are used to study show common features. Phase diagrams are a core element of this approach, allowing the study of places where behaviour can change suddenly and radically. In ABM, macro observables such as output are not smooth functions of the parameters. The interest rate for example can induce a transition between a good and a bad phase.

The notion of emergence is important in ABM. Equilibrium output level is usually exogenous in traditional, models, but in an ABM it is the result of the ability of agents (or firms) to cooperate, so it is an emergent property that can appear or disappear suddenly. This is one way to think about crises.

ABM also allow for the notion of hysteresis. Different states of the economy can coexist in the same region of parameter space. The economy can be stuck in a good or a bad state, while the system could have chosen another outcome if the history had been different or some anecdotal event occurred.

ABM can allow policy experiments, even if they still require a lot of work as policy tools. They show that policies that would be stabilising if you assume infinitely rational, forward-looking agents can actually be destabilising when you remove that assumption. This makes it intrinsically difficult to design hybrid models incorporating some elements of ABM. If you abandon infinitely forward-looking agents, things happen that would not happen with them. In addition, there is the "curse of complexity". Optimised complex systems are often on the verge of instability – optimality and instability go hand in hand.

Other empirical results, useful analytical methods and numerical tricks have been established by econophysics, which I have no space to review here, but the most valuable contribution may be methodological nature. Physics constructs models of reality based on a subtle mixture of intuition, analogies and mathematical spin, where the ill-defined concept of plausibility can be more relevant than the accuracy of the prediction. Kepler’s ellipses and Newton’s gravitation were more plausible than Ptolemy’s epicycles, even when the latter theory, after centuries of fixes and stitches, was initially more accurate to describe observations. Physicists definitely want to know what an equation means in intuitive terms, and believe that assumptions ought to be both plausible and compatible with observations. This is probably the most urgently needed paradigm shift in economics.

Sources

NAEC seminar with Olivier Blanchard

The (unfortunate) complexity of the economy, Jean-Philippe Bouchaud, Physics World, April 2009, p.28-32 https://arxiv.org/abs/0904.0805v1