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CULTURE CRASH

Some economists had hoped that physicists might shake up the rigid theories typical of mainstream economics. But so far, they're unimpressed by physicists' handling of the markets. **Philip Ball** reports.

For the past two decades, some physicists have been trying to apply their ideas and tools to an area that seems a long way from traditional physics. They are exploring the notion that there might be a kind of physics of the economy — an 'econophysics', as it has been dubbed[1]. Last year, some of these econophysicists even went as far as to suggest that economics might be "the next physical science"[2].

But now this unlikely marriage is showing signs of turning sour. Even those economists who at first welcomed econophysics are starting to wonder whether it is ever going to deliver on its initial promise. Early successes in modelling financial markets have not led to insights elsewhere, some complain. Matters came to a head at the Econophysics Colloquium, held at the Australian National University in Canberra last November. A group of economists attending the meeting were so dismayed with what they saw many physicists doing that they penned a forthcoming paper entitled 'Worrying trends in econophysics'[3].

In their critique, economist Paul Ormerod of the London-based consultancy Volterra and his co-authors accuse econophysicists of a litany of sins: applying inappropriate assumptions to economic systems, failing to do their homework properly, getting fixated on a small corner of the subject, and being sloppy with their statistics. At face value it is a damning indictment, and raises the question of whether econophysics will ever make a genuine contribution to economic theory, or whether it is doomed to remain a fringe interest.

Claim to blame

Some econophysicists admit that there are problems. "Econophysics is a field with very uneven quality," says Doyne Farmer, a physicist at the Santa Fe Institute in New Mexico, who made pioneering contributions to the study of chaos before moving into economics. Yi-Cheng Zhang of the University of Fribourg in Switzerland is even more ready with a *mea culpa*. "My economist friends are right. The literature is often littered with garbage. We can find gauge-field theories of finance, quantum options and so on. In short, anything goes."

But others reject the accusations. In response to the Canberra critique, Joe McCauley, a physicist at the University of Houston, Texas, who now works mostly on economic problems, says, "Would one write an essay called 'Worrying trends in physics' simply because a few minor researchers put out bad papers? Bad papers, even wrong papers, appear in every issue of every scientific journal."

It is tempting to interpret this as a mere academic turf war. But Ormerod and colleagues are among the few people in economics who have taken econophysics seriously. Most economists don't know the discipline exists — and if they did, they would probably heap derision on it.

The idea that physics might have something useful to contribute to economics arises because both fields are concerned with systems of many interacting components that obey specific rules. Statistical physics describes the behaviour of bulk matter based on the forces acting between atoms and molecules. Economics studies the interactions between economic

"Econophysics is a field with very uneven quality." — Doyne Farmer

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Econophysicists have focused on the financial market because it offers a lot of good-quality data.

'agents' — market traders, say, or businesses.

Arguably, deriving microeconomic principles from the behaviour of individual agents should pose similar problems to deriving thermodynamic laws from interatomic forces. The rules dictating how interactions play out between economic agents are admittedly more complex than the forces between atoms, but in conventional economics the rules have always been grossly simplified to make the models workable.

For example, the core theory of mainstream economics, the neoclassical model, argues that agents always act with perfect rationality to maximize their 'utility' (for example, profit), based on complete information about the state of the market as a whole. In this picture, an economic market quickly reaches an equilibrium state, in which commodities find the price that perfectly balances supply and demand.

Model world

Economists recognize that real human agents do not always act in such a coldly rational way, and that they generally have to manage with incomplete information. But although Nobel prizes in economics were awarded in 2001 and 2002 for work that recognizes these limitations, neoclassical theories — and particularly the idea of equilibrium — remain central to mainstream economics.

Ormerod and his colleagues, and other physics-friendly economists, had hoped that econophysics would help them create a new economics that is free from some of the dogmatic assumptions characterizing the mainstream discipline today. "Economics desperately needs econophysics," claims Ormerod's co-author Steve Keen, an economist at the University of Western Sydney in Australia. Keen had hoped in particular that econophysics might break his fellow economists' misconceived obsession with equilibrium. "Equilibrium thinking still has them in its unshakeable thrall," he says.

A glance at almost any plot of commodity prices over time belies the idea of market equilibrium: the values fluctuate wildly. But in neoclassical theory, these fluctuations are regarded as background 'noise' caused by unpredictable 'shocks' from outside the economic system, to which the market constantly and quickly adjusts. An attempt to explain such fluctuations using statistical physics was made as early as 1900 by Louis Bachelier; he proposed an explanation that introduced the theory of random walks, which was later developed independently by Einstein to explain brownian motion.

Bachelier's theory was deemed too strange to be taken seriously by economists. But the issue was revisited in the early 1960s, when mathematician Benoit Mandelbrot showed that fluctuations in cotton prices have a statistical distribution that differs from that expected of a typical gaussian process — where each event happens randomly and independently of all others. There were more large fluctuations than a gaussian distribution predicts[4]. This has significant implications for economic theories that assume market 'noise' to be gaussian — but more importantly, it suggests that big fluctuations, perhaps even market crashes, are not rare anomalies but intrinsic to normal market behaviour. Mandelbrot's 1963 paper on price fluctuations is now regarded as one of the key precursors to modern econophysics.

"Physicists suffer from a belief that there must be universal rules." — Paul Ormerod

Out of equilibrium

But it wasn't until the early 1980s, when an unusual mix of researchers got together at the Sante Fe Institute, that economists showed much interest in scientific ideas related to complex systems. They were helped by advances in computing. "Once we got desktop computers, we could model systems of many agents and allow them rules of behaviour and see how they evolved," says economist Brian Arthur, who worked at Santa Fe alongside physicists and evolutionary biologists to develop non-traditional approaches to economics[5]. Such computer simulations of the economy led to models of 'interacting agents'[6] that were influenced as much by work on cognition and evolutionary biology as by physics.

In these models, researchers could give the interacting agents any decision-making strategy they desired, and therefore study markets with different underlying behaviours. "What we found was quite surprising," recalls Arthur. "Under some restrictive conditions, you get market equilibrium, but under other conditions you get much more complicated outcomes." It seemed there was no good reason to believe that microeconomics always operates at equilibrium. "The economy is out of kilter most of the time," says Arthur. That, he says, accounts for one of the virtues of econophysics. "The core of economic theory is still built around equilibrium models, but most models in econophysics are non-equilibrium ones."

But those economists who have adopted new approaches such as agent-based modelling have become increasingly frustrated with the intransigence of mainstream economics. Some have even resorted to starting their own publication, the *Journal of Economic Interaction and Coordination*, the first issue of which appeared online in May. Zhang says that three of the four authors of the Canberra critique are victims of the intellectual exclusion imposed by mainstream economists. "That's why they had such high hopes when physicists offered what

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IS ECONOPHYSICS REALLY NEW?

Although the idea of economists borrowing concepts from physics might seem unlikely, it has been a feature of economic theory ever since its inception. Adam Smith (pictured) wrote his *Wealth of Nations*, which laid the foundations of economic thought in 1776, in an intellectual climate that was infused with newtonian ideas about causative forces. Indeed, some of his contemporaries compared the circulation of commerce to the circulation of the planets.

Pierre-Simon Laplace and the Belgian astronomer Adolphe Quetelet helped to establish the idea that there are natural laws, akin to Newton's laws of motion, that govern human social systems such as the economy. And nineteenth-century economic thinkers such as John Stuart Mill and Karl Marx frequently alluded to scientific ideas and analogies.

CLASSIC IMAGE/ALAMY

Microeconomic theory, which strives to understand economic phenomena by building them up from the behaviour of individual 'agents' in the economy, was established in the late nineteenth century — just as James Clerk Maxwell and Ludwig Boltzmann were laying the foundations of statistical physics. The early microeconomists Francis Edgeworth and Alfred Mashall drew on some of the ideas of these physicists, in particular the notion that the economy achieves an equilibrium state like that described for gases by Maxwell and Boltzmann. Edgeworth and Marshall's microeconomics led to the neoclassical theory of economics that defines the mainstream today. **P.B.**

seemed to be an alternative."

So why have some of these physics-friendly economists become fed up? Although Ormerod and colleagues are highly critical of mainstream economic theory, they point out that "economics is not at all an empty box." The Canberra critique accuses econophysicists of ignoring the existing literature — a charge also levelled at physicists when they began to dabble seriously in biology.

Zhang agrees this is a fair complaint. "Most econophysicists don't care about the underlying idea, history and cultural background to the problem. All they want is to get a lot of data, crunch the numbers better than anybody else, and publish a lot of papers." But he admits that doing the job properly is very daunting: "Compared to anything I've done in physics, the requisite reading is enormous. I get a pile of books delivered every month, and I'm just overwhelmed."

Another criticism raised by Ormerod and colleagues is that econophysics has too narrow a focus. Physicists have made important contributions to finance and industrial economics, Ormerod acknowledges, but he wants them to bring an open mind to other areas of the economy. "I think they fail to appreciate that financial markets as such are not terribly important in economic theory," he says. "They are just a special case of a more general theory of markets."

Why are physicists so finance-centred? Ormerod suspects that they feel more comfortable with the generally high-quality and long-term data from financial markets. Most other economic data exist in small, noisy data sets. Some econophysicists defend the focus on finance precisely for these reasons: "Finance data are strong enough to falsify specific classes of models," says McCauley. Farmer adds that physics has often been successful by tackling problems that could be solved with the data and the tools to hand.

Perhaps more damning, Ormerod and colleagues worry that some econophysicists have imported concepts from physics that just don't belong in economics. For one thing, they say, some have tried to apply conservation laws to quantities, such as money, that the economy doesn't actually conserve. "Conservation of money is too far from the truth in a credit economy like ours," McCauley agrees. But he says that such mistakes are rare.

More broadly, claim the Canberra authors, physicists fail to appreciate how diverse and changeable the economy is in practice. "Physicists suffer from a belief that there must be universal rules," says Ormerod. "This is not a handicap in the physical world, but it is in economics, where the behaviour of agents may differ across time and place." But Farmer thinks that looking for generalities can still be useful: "The typical view among social scientists is that one should focus on documenting and explaining differences. Physicists have jumped in and said, 'Before we do that, let's spend some energy on first trying to understand if there is any way in which everything is the same'."

Out on a limb

Economist John Sutton at the London School of Economics agrees that physicists can help to identify relationships within economics that are driven by, say, elementary statistics, irrespective of any assumptions about agent behaviour. He says he welcomes outsiders to economics "who may look in different places for interesting relationships".

Sutton is, however, a rare example of a mainstream economist who is aware of the econophysics literature. Arthur believes that some shortcomings of econophysicists may be caused by their enforced isolation: "They tried to publish in mainstream economics journals, but were rebutted. It's a shame and a scandal that the journals haven't opened their pages to them." Consequently, econophysicists set up their own journals. This means they don't get the contact with economists that would have "rounded off their rough corners", Arthur says.

Perhaps not surprisingly, some econophysicists reject the Canberra critique outright. "The problem is not with econophysics," McCauley says. "The problem is within the economics profession." He argues that the neoclassical model, which is still taught in all economics classes, was falsified in the 1970s by M. F. M. Osborne of the Naval Research Laboratory in Washington DC, who he regards as the first econophysicist (see 'Is econophysics really new?'). "Economists are overwhelmingly unaware of this contribution. Worse, the majority have no interest in anything that physicists write."

Arthur counters that economics has a long history of assimilating ideas from outside the field. But he explains that while economics tolerates some 'unorthodoxy', it also isolates it from the core theory that is taught to students and practised by academics. There is an attitude of "fine, but not in my journal," he says.

Despite their concerns, the authors of the Canberra critique still hold out hope for econophysics. "It's just that we don't want it going off the rails," says Ormerod. Yet for McCauley, the goal of econophysics is not to batter its way into the citadel, but to raze and rebuild it. "Econophysics will displace economics in both the universities and boardrooms," he says, "simply because what is taught in economics classes doesn't work."

> **"Econophysics will displace economics in both the universities and boardrooms."** — Joe McCauley

Still, if econophysics is to survive and prosper, it needs support from somewhere, says Farmer. "It is clear that this is not going to come from economists." Turning to the physics community for help has not been the answer either. Rosario Mantegna, an econophysicist at the University of Palermo in Sicily, says that in academia physicists cannot pursue econophysics as their main research. "There is no one in the United States who has gotten tenure based on work in econophysics," Farmer agrees. "This is a real pity for physics." ■

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