complete. Einstein and Rosen published another, earlier paper, "The Particle Problem in the General Theory of Relativity."[1]

Reference

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Rui-Hua Xie
(jrxie@yahoo.com)
Texas A&M University
College Station

On the merits of mathematical models

I offer a few comments regarding "Is Economics the Next Physical Science?" by J. Doyne Farmer, Martin Shubik, and Eric Smith in the September 2005 issue of PHYSICS TODAY (page 37). Physicists have deployed mathematical models of interacting entities for two purposes: to establish the existence and properties of such entities—for example, quarks and other subatomic particles—by comparing precise calculations with precise measurements; and to predict and understand the properties of systems, such as doped semiconductors comprising known entities. To imagine an analogous research program for econophysics is to see at once how little can be expected from this field.

Human beings are unique, purposeful individuals whose properties cannot be captured in a few numerical parameters the way one specifies the properties of atoms and particles. It is implausible that we will add to our understanding either of human nature or of market economies by treating people as mathematical Tinkertoys. Yet that is precisely what econophysics appears to have in common with mainstream neoclassical economics.

There exists an older, more modest economic tradition, one that explores the implications of individual human choice in the pursuit of individual goals. The focus is not on solving equations but on reasoning directly about the actions of human beings as we know them through introspection and common experience. This approach offers a rich and fruitful insight that extends beyond the problems ordinarily regarded as "economic." As I have demonstrated elsewhere,[1] it can explain much about the conduct and dissemination of scientific research itself.

Farmer and coauthors seem puzzled by the weakness of price predictability, given that there are long-memory correlations among closely related data in the stock market. May I suggest an explanation? Price predictability offers profit opportunities, which people are likely to discover and exploit. In general, however, to exploit profit opportunities is to eliminate them. We can expect, therefore, that price predictability will be limited by profit-taking market speculators to a level at which only the most astute of them earn enough to stay in the game. There is no particular reason to expect other correlations in market data to be so limited, if they do not offer direct profit opportunities.

I had a look at the University of Fribourg website recommended by the authors. Some econophysicists seem to think that by criticizing mainstream economics, or by referring dismissively to "Adam Smith's invisible hand," they are also undermining the case for free markets. On the contrary, the mainstream's preoccupation with mathematical models of equilibrium obscures the market's dynamism and underlies counterproductive anti-trust legislation. At one time, uncritical faith in mathematical modeling lent false plausibility to the notion that one might in fact measure the parameters, solve the equations, and thereby centrally control an economy. Mainstream economists eventually shook off that pipe dream. Econophysicists would do well to avoid it.

Reference

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Allan Walstad
(awalstad@pitt.edu)
University of Pittsburgh at Johnstown
Johnstown, Pennsylvania

The article on economics and physics by Doyne Farmer, Martin Shubik, and Eric Smith reviews several interesting studies for senior- or graduate-level physics students who are well grounded in statistics. A much simpler study, one that I think would be informative and suitable for freshman physics and economics students, would be a measure of the operational efficiency of a country.

Other economic systems might also offer appeal, such as a comparison of the operational efficiencies of farms. Selecting a study on countries, however, has the advantage that the data for the total annual input energy consumed in a country are readily available from government websites.

The output energy required for calculating a country's operating efficiency would be more difficult to assemble. Instead, a simple measure of the total output is the country's gross domestic product. The resulting ratio of GDP to annual input-energy consumption would not be an efficiency, but it would offer a measure of how well a country utilizes its energy for generating wealth. The ratio could be called an efficiency index and is conveniently expressed in terms of dollars per megajoule. The ratio would be valuable in examining long-term trends, if one corrects for inflation, and would also be useful for comparing the operational efficiencies of different countries.

John D. Knapton
(john@knapton.com)
Churchville, Maryland

Farmer, Shubik, and Smith reply: We titled our article "Is Economics the Next Physical Science?" because we are interested in the wide variety of questions of organization that have traditionally concerned economists, but that might also be well formulated as physics problems. The existence of such interesting problems does not presume that human behavior is mechanical. Our article emphasized two major observations that we think provide opportunities for a physical point of view.

First, we live in an institutional world. Without regard to the degree of mechanism in people's behavior, institutions are by their nature mechanistic, and their mechanism can be treated even with relatively modest conceptual advancement from what physics already does well. Much of current econophysics, including some of our own work, is based on explicit models of institutional dynamics that have been omitted from more mainstream economic research, but that can be shown to predict strong regularities in price formation or other economic processes.

Second, the assertion that people are too irregular to be treated mathematically does not follow from the failure of past attempts to do so. The modeling of institutional process is as interesting for its limitations as for its successes, precisely because the regularities left unexplained by pure process models (which we have characterized as "zero-intelligence" models) are potential mathematical regularities of behavior. Readers will judge whether they prefer quantitative, predictive, falsifiable theories to the 19th-century narrative mode of description, but scientific description clearly provides modes of belief change that narrative does not.

J. Doyne Farmer
Santa Fe Institute
Santa Fe, New Mexico
Martin Shubik
Yale University
New Haven, Connecticut
Eric Smith
Santa Fe Institute
Santa Fe, New Mexico

One thing Einstein didn't do in 1905

As we look back on 2005, the 100th anniversary of Einstein's most creative year, it is worthwhile to remember what he didn't discover—or at least what he didn't tell us he discovered—in 1905. Among the items is the photon.

A "photon"—the name was coined by the physical chemist Gilbert Lewis in 1926—is an elementary particle with energy $h\nu$, momentum $h\nu/c$, and mass zero. In 1905, Einstein discussed an energy quantum only. He did not discuss the quantum's momentum until 1916. On the question of the mass, his 1905 paper contains an odd calculation. He noted that the average kinetic energy for a Maxwell–Boltzmann particle in a distribution at a temperature T is given by $3kT/2$ (in our present notation, not his). He assumed that the Wien spectrum, which he used for high frequencies to exhibit the entropy of the radiation, is valid for all frequencies. He then calculated, in his notation

$$\int_0^\infty \alpha\nu^3 e^{-\beta\nu/T}\,d\nu \Big/ \int_0^\infty \frac{N}{R\beta\nu}\,\alpha\nu^3 e^{-\beta\nu/T}\,d\nu = 3\frac{R}{N}T = 3kT$$

Wilhelm Wien found his distribution using the analogy to the Maxwell–Boltzmann distribution, although it did not occur to him to ask why that particle analogy might be valid for radiation. The above result is what you would get if you replaced the classical kinetic energy by pc, which would be appropriate for a massless particle. Einstein never explained why he did this calculation or what its significance was.

Jeremy Bernstein
Stevens Institute of Technology
Aspen, Colorado

Proper performance prediction for ITER

In his letter in the February 2006 issue of PHYSICS TODAY (page 10), David