Science

www.sciencemag.org
Science 23 May 2014:
Vol. 344 no. 6186 p. 828
DOI: 10.1126/science.344.6186.828

- NEWS

THE SCIENCE OF INEQUALITY

Physicists say it's simple

Adrian Cho

If the poor will always be with us, an analogy to the second law of thermodynamics may explain why

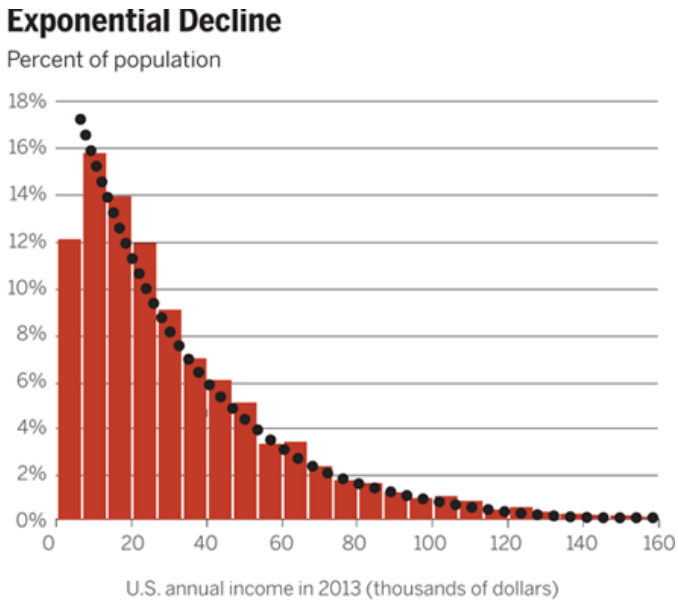
The basic inequality that plagues economies the world over may have a simple explanation—at least, according to physicists who've turned to economics. Pick a country, they claim, and you'll find multitudes of people who earn next to nothing, a few who rake in plenty, and a distribution between the extremes that falls exponentially as income increases (see figure). That distribution applies to all but the very rich, they say, and it arises from an analogy to the concept of entropy, a measure of disorder in a physical system such as a gas. Just as a gas evolves to a state of maximum entropy, they argue, random churning in the economy ensures that the income distribution naturally tends to this inequitable form.

The argument suggests that although social and economic policy can help individuals edge ahead or perhaps boost everybody's fortunes, nothing short of radical intervention can overcome the forces of randomness and transform the lopsided distribution. An equal sharing of income, in this view, is as likely as the air in your office collapsing into your empty coffee cup. The reasoning is “not very close to the thinking of economists, but it's pretty persuasive,” says Thomas Lux, an economist at the University of Kiel in Germany. But Frank Cowell of the London School of Economics and Political Science says “I'm extremely skeptical” that the argument provides any insight into the economy.

The argument builds on the century-old kinetic theory of gases, in which physicists asked: What is the most probable distribution of the energies of the molecules in a gas? That might seem impossible to determine without tracking exactly how the molecules ping off one another. But the puzzle can be solved by simply counting the ways the gas's overall energy can be divvied among the molecules—a number that defines the gas's entropy. The most likely energy distribution is the one that can be achieved by the most combinations of individual molecular energies. That turns out to be essentially an exponential distribution, with lots of molecules of low energy and a few with high energy.

Victor Yakovenko, a theoretical physicist at the University of Maryland, College Park, applies the same reasoning to income. Suppose you randomly divide $500 million in income among 10,000 people. There's only one way to give everyone an equal, $50,000 share. So if you're doling out earnings randomly, equality is extremely unlikely. But there are countless ways to give a few people a lot of cash and many people a little

or nothing. In fact, given all the ways you could divvy out income, most of them produce an exponential distribution of income. So that's what you end up with, even if you start with a different pattern and let random economic activity take over, Yakovenko and a colleague argued in 2000 in *The European Physical Journal B.* "The exponential distribution is what you would call natural inequality—what you would get from entropy," Yakovenko says.



Data: U.S. Census Bureau, Survey of Income and Program Participation
Source: Scott Lawrence and Victor Yakovenko/U. Maryland
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Natural inequality. Econophysicists say the income distribution is, inevitably, a decreasing exponential with few winners and lots of losers.

In 2001, Yakovenko and a colleague argued using tax data that income in the United States and both income and wealth in the United Kingdom follow exponential curves, as they reported in *Physica A.* Such curves also fit income data from Japan, Sweden, and the European Union, others have shown. "I don't know any other place in economics where the theory is so close to reality," says Mauro Gallegati, an economist at the Polytechnic University of Marche in Ancona, Italy.

Some economists are unimpressed. Economists gave up explaining the exact shape of the income distribution decades ago, Cowell says. Now, he says, economists estimate inequality using only raw data, and don't depend on knowing the distribution's precise mathematical form.

An exponential distribution also predicts fewer super-rich people than are found in most economies, and the entropy argument does not explain the balance of wealth between the handful of super-rich and the masses, says James Foster, an economist at George Washington University in Washington, D.C. The idea also fails to account for well-established correlations between income and education, race, and other factors, Foster says, and so is unhelpful in making policy.

Such criticism misses the point, Lux says. An individual's income can be highly correlated with other factors, he says, even as the distribution of income in a population as a whole appears random—just as the trajectory of a molecule in a gas is in principle predictable even as the motion of all the molecules as a group appears random. "That this is not a contradiction is something that we have to communicate to [traditional] economists," Lux says.

Even the theory's supporters say it must be fleshed out. It assumes that, at least over short times, the total amount of income is fixed, notes Duncan Foley, an economist at the New School for Social Research in New York City. If that's true, economists need to explain how that constraint arises. Still, Foley says he finds the physicists' perspective compelling, if bleak. In trying to achieve a more equal income distribution, "you're kind of fighting against the second law of thermodynamics," he says, "which as we know is generally a losing battle."

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