

Q&A: Hyejin Youn applies statistical physics to human behavior

The physicist examines crime, transportation, innovation, and more in the burgeoning field of computational social science.

How does a physicist end up on the faculty at a business school? Hyejin Youn says that for her, “one thing led to another.” While a graduate student working on complex systems in 2008, Youn and two colleagues published a paper in *Physical Review Letters* that looked at traffic. Using data and simulations, they found that the aggregate of individual choices about routes does not optimize traffic for all drivers in the area and that drivers end up wasting a “considerable amount” of time on the road. “Counterintuitively,” they wrote, “simply blocking certain streets can partially improve the traffic conditions.”

Their results were picked up by *The Economist*, and soon Youn was being invited to speak at workshops, conferences, and other events for business schools and economics departments. It turns out that the mathematical and computational models she used for energy optimization in physics map directly to those in economics. “These audiences asked questions I was never asked by physicists, things I had never thought about,” she says. “They wanted to know about humans. I became very curious about social systems.”

Youn earned her undergraduate, master’s, and doctoral degrees at the Korea Advanced Institute of Science and Technology in Daejeon. She spent a few years as a postdoc at the Santa Fe Institute and as a senior research fellow at Oxford University before joining the faculty of the Kellogg School of Management at Northwestern University in 2017. In September, she accepted a position in South Korea, at Seoul National



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Hyejin Youn

University, where she is a professor of strategy and international management in the business school.

In the past, Youn says, social science was based on observation in the field or small lab experiments, introspection, and judgment about how people behave. But with the developments of massive data collection, computational power, and AI, physicists and other STEM scientists are entering the emerging field of computational social science.

PT: Why did you go into physics?

YOUN: I felt that physics explains the world. And if a theory doesn’t work with empirical data, we are ready to leave the theory behind. I was fascinated by this intellectual framework that tries to be as logical as possible but at the same time doesn’t lose touch with the real world.

My parents didn’t like the idea of my studying physics—they thought I wouldn’t be able to get a good-paying job. I told them that physicists can go anywhere. I pointed to the quants on Wall Street. I didn’t care about the quants. That was a device to persuade my parents.

PT: How did you segue from statistical physics to computational social science?

YOUN: I didn’t intend to go into social sciences. I was just following my curiosity. As a graduate fellow and later a postdoc at the Santa Fe Institute, I learned about work that other physicists were doing. They included my PhD adviser, Hawoong Jeong, who worked on complex systems;

my postdoctoral adviser, Geoffrey West, who worked on scaling frameworks for physics, biology, and urban systems; Albert Barabási, who worked on network science; and Doyne Farmer, who tried to understand economics with an agent-based model. I was inspired.

As a statistical physicist, I studied Ising models. I looked at spins, at how a liquid becomes ice or a gas, how these phase transitions happen. I thought everything could be explained by the Ising model—even politics, because the voting system can be explained by a spin-glass model. So, when I entered social science, my mindset was that I could explain every social system with physics. Then I realized that is absolutely not true. Humans are more complicated than spin systems. They can’t be understood in terms of pure physics. I went down a rabbit hole about human systems.

PT: Describe some of your research.

YOUN: I’ve studied how cities scale their socioeconomic properties with population size. When a city doubles in population, what is the expected change in the number of crimes per capita? What about creativity, as measured by the number of patents? And productivity in terms of GDP? Remarkably, these factors scale superlinearly with population size, all sharing a similar power-law exponent of 1.15—meaning creativity and crime increase at a higher rate than the population expands.

Some inessential properties disappear when we aggregate the system, and some

essential properties survive. The method, known as coarse graining or renormalization, highlights that while humans are individually diverse and adaptable, cities collectively follow underlying principles that govern their behavior.

PT: Where do the data come from?

YOUN: For productivity, we look at GDP, income, and patents. For creativity, we look at patents. We search for hundreds of thousands of key words—things like autonomous vehicle and Google glass and technical codes for wireless communications. We analyze millions of patents using statistics. It's all automated.

PT: What are you working on now?

YOUN: I started to work with economists, sociologists, and biologists who were interested in technology and to look at technology in terms of network science. I was interested in how technology, or the creation of new ideas, can be understood in terms of combinations of existing ideas. We apply techniques that were developed in physics to identify clusters and examine how they evolve. We find that there have been periods of technologies merging and splitting over time. I want to understand why technological innovation happens, whether there is any phase transition in the innovation process, and what the fundamental unit of innovation is.

PT: What's a research topic that you are particularly excited about?

YOUN: Economists often think that innovation slowed down in the US after 1870. Before that, we had the technologies of the steam engine, the train, the toilet, the telephone. The common understanding was that there was little new technological invention after the late 19th century.

As a physicist, I was curious: Is it really true that there was a phase transition in innovation around 1870? I looked at how often new words appear in patent filings and found that it's true: The introduction of new key words slowed down around 1870. But, if invention is understood in terms of combining technologies, innovation appears to be invariant. The apparent phase transition disappears.

My model also explains why multiple

inventors often arrive at the same discovery at the same time. In the model, ideas are like particles in a network. It doesn't matter if it was Isaac Newton or Gottfried Leibniz who came up with calculus. Or Charles Darwin or Alfred Russel Wallace who developed the theory of evolution by natural selection. Connections are made stochastically and probabilistically, with human inventors acting as vehicles for these processes.

If the invention and the creation of new ideas is explained by this simple model, it seems like everything becomes physics. Then the question arises, Where is the human agency?

How do I reconcile the nonhuman model with the human model? I am still struggling with this.

PT: How is it different being in a business department than in a physics department?

YOUN: Physicists tend to think in a context-free way; businesspeople look at context. If you are trained as an innovation scholar, you understand the history of telecommunications and semiconductors, and you want to know the nitty-gritty details—about individuals, firms, strategies, and markets. As a physicist, I was trained to seek universal and invariant theories, and such details are often irrelevant to me. I just want to understand if a structure emerges and whether the structure can be modeled with a simple rule. My strengths are complementary to the strengths of my colleagues.

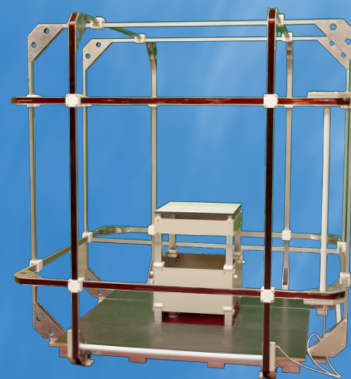
One of my roles is to integrate interdisciplinary into the business school. We want to bring more STEM people into business and train business school students to be more capable of dealing with data and mathematics.

PT: Is there anything else you'd like to mention?

YOUN: My lifetime goal is to explore whether certain human behaviors fall outside the laws of physics. Are questions such as why wars happen or why some people have more opportunities than others too complex for physics to answer? I don't know, but it's worth exploring. I think physicists can contribute to answering those questions.

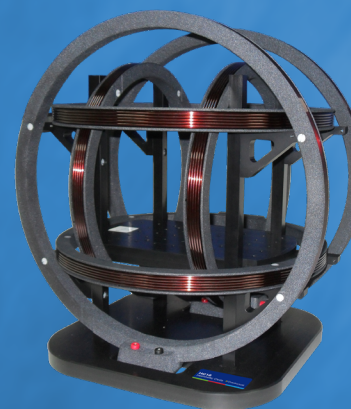
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