Economics at the Center of the Mathematical Universe

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"Small events at times can have large consequences," write Milton Friedman and Anna Schwartz in *A Monetary History of the United States* (1963), paraphrasing Shakespeare in *Richard III*. At one point, they trace the greatest economic calamity in the last century, the Great Depression, to the untimely death of a single individual. "Because no great strength would be required to hold back the rock that starts a landslide," they argue, "it does not follow that the landslide will not be of major proportions."

Friedman and Schwartz's study set off an intellectual avalanche that ultimately altered the landscape of economic thinking—just as the authors intended. So, in fact, did a half dozen or so other books published by Princeton in the 1940s, 1950s, and 1960s that have since attained the status of classics. That's an impressive record for a press that ignored economics entirely before World War II, dedicated just 1 percent of its titles to the topic for the next forty years, and acquired an actual economics *list* only in the last fifteen—all while MIT, Harvard, and McGraw-Hill dominated the market. As Paul Samuelson, sitting in his MIT office in Cambridge, Massachusetts, said the other day, "Princeton had the mathematicians; *we* had the economists."

But Princeton's tilt toward mathematics actually helps explain some of Princeton's biggest successes. A little history will show why: By the time World War II started, Princeton had become the world capital of mathematics. Intellectuals from Russia and from eastern and central Europe—including top mathematicians and physicists—had been flocking to the United States to escape revolution, war, economic collapse, and anti-Semitism since the 1920s. Princeton had opened its arms (and wallets) to the newcomers, going so far as to establish the Institute for Advanced Study, an Olympus comprising equal parts German university and Vienna café, to make them feel at home. Inside the Princeton town line, the belief that "the human mind could accomplish anything with mathematical ideas"—specifically, that mathematics could do for the social sciences what it had done for the natural ones—seemed no more far-fetched than expecting to bump into Albert Einstein or Kurt Gödel on Mercer Street.

By the end of the war, economists had adopted mathematics as their new lingua franca. As Roger Backhouse reports in his superb history of economics, *The Ordinary Business of Life* (Princeton, 2002), so many mathematically sophisticated émigrés went into economics that nearly half the contributors to the *American Economic Review* in 1945 were European-born. What's more, the war had given scores of young economists the opportunity to work shoulder-to-shoulder with mathematicians, physicists, engineers, and the like. Milton Friedman, who had been at the Department of Treasury during the New Deal, spent most of the war at the top secret Statistical Research Group at Columbia; Paul Samuelson's day job was at MIT's Radiation Lab; and Kenneth Arrow, who had joined the army, produced weather forecasts for the D-Day invasion.

The success of economists in advising the military on how to inflict maximum damage at minimum cost or, at the very least, how to move millions of men and cargoes by the cheapest route, convinced many of them of the applicability and effectiveness of mathematical methods. At least one, Wassily Leontief, used a computer to construct a giant economic model. Within a few years, some universities decided to allow Ph.D. candidates to substitute fluency in mathematics for a reading knowledge of French or German. One observer complained, circa 1952, "These days you can hardly tell a mathematical economist from an ordinary economist."

The point is that, having specialized in mathematics, Princeton had a comparative advantage when economists decided they wanted to use more math. Put another way, Princeton University Press didn't need a long list of economics titles to have a large impact—just enough of the right ones. *Theory of Games and Economic Behavior* (1944) is such a book. A reflection of the zeitgeist, the book was the product of a collaboration between a mathematician from Budapest and an economist from Vienna. John von Neumann practically invented the branch of mathematics called game theory, but a book about its potential uses in economics was Oskar Morgenstern's idea. According to historian Robert Leonard, who is working on an intellectual biography of von Neumann, Morgenstern knew about as much mathematics as von Neumann knew economics. But ignorance of the other's discipline was an incentive to collaborate. Ultimately, the coauthors were forced to do their readers the favor of spelling out their thoughts doubly, once in symbols, a second time in English.

Theory of Games is a pitch for using new mathematics to make economics more useful. The authors point to a gaping hole in existing theory—it can't handle situations where one outcome depends on another—and then outline a strategy for fixing it. Any economic outcome involving interdependence can be defined as the solution to a game between two or more players, they write, and therefore can be analyzed through game theory. Along the way, they develop the first coherent theory of how rational individuals choose among different options that are more or less likely.

One British reviewer couldn't decide whether *Theory of Games* was "a great classic" or a "mere complicated mathematical puzzle void of practical relevance." That was a fairly typical reaction, since it looked for a while as if the mathematics would scare away most economists and the economics would turn off most mathematicians. The authors' haughty disdain for existing economic theory didn't endear them to readers either. They, and the Press, were saved by a front-page *New York Times* story depicting game theory as a weapon in the Cold War.

Ironically, the book owes its publication less to editorial vision than to an anonymous donor. The war was in its third year, paper was costly, and the manuscript was "mammoth," having ballooned from a "pamphlet" of 100 or so pages into a doorstop of 1,200. The trustees of the Press balked, demanding that the university, or the Institute for Advanced Study, or some other donor contribute $3,000 (the equivalent of $32,000 today). Things looked bleak for a month or two, but finally a telegram reached von Neumann in Atlantic City in late September: "Delighted to inform you publication of your book assured." Relieved, he returned to Los Alamos, where he told Robert Oppenheimer, chief of the Manhattan Project, that he could now devote his spare time to the physics of implosion.

Paul Samuelson wasn't so lucky. In *The Foundations of Economic Analysis* (Harvard, 1947) Samuelson recast virtually the whole of economic theory in the precise language of mathematics and showed that many seemingly disparate situations could be treated as optimization problems. Samuelson submitted a first draft as his Ph.D. thesis in 1941 at age twenty-five and finished the entire manuscript while working on lasers in 1944. But *Foundations* didn't appear for another three years. What's more, when it finally was published, the chairman of Harvard's economics department insisted that Harvard University Press destroy the metal plates after the five hundredth copy had been printed. Cambridge may have had the economists, but Princeton had the advantage of being less hostile to their use of mathematics.

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It must be said that Princeton failed to exploit its first-mover advantage—quite possibly because Princeton's pure mathematicians had no more appreciation of economics as a discipline than the Institute had for the MANIAC, von Neumann's mainframe computer. Still, there were some important exceptions. In 1962, with the information technology revolution still embryonic, the Press published the first-ever attempt to describe and measure the *information* economy, *The Production and Distribution of Knowledge* (1962) by Fritz Machlup. Machlup, who had worked with Morgenstern in Vienna, drew on the theories of Ludwig von Mises and Friedrich Hayek about how markets generate and employ information. George Dantzig's *Linear Programming* (1963) introduces a method for solving problems like one that Dantzig actually solved during the war: how to supply American GIs with the necessary vitamins and minerals during World War II at the lowest possible cost. In the book, Dantzig describes how he and his team spent a total of 130 man-days with desk calculators to solve a system of 9 equations and 27 unknowns. His method, inspired by Leontief's input-output model, has become standard for solving transportation, scheduling, and allocation problems involving hundreds of thousands of variables; it helped start a field dedicated to finding new ways to economize on computation time.

Princeton also published one of the first books to apply high-powered mathematics to finance, *Spectral Analysis* (1964) by Clive Granger. Last year, Granger won a Nobel for that work which has proved particularly valuable in forecasting economic variables. Interestingly, Oskar Morgenstern, who founded Mathematica—a consulting firm staffed by Princeton professors that used cutting-edge mathematical techniques—was present at the creation in this case as well. The pitfalls and drawbacks of commonly used methods for analyzing time series constituted another of Morgenstern's pet peeves. In the 1960s, he and Granger applied spectrum analysis—a technique for separating noise in the data from trends—to stock data.

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No twentieth-century work of economic history has had the impact on economic *policy* of Friedman and Schwartz's monumental study. What on earth was Princeton doing, anyway, publishing one of the pillars of the so-called Chicago School? It was just part of a deal that Princeton had with the National Bureau of Economic Research, which sponsored the study. Arthur Burns, the legendary Fed chairman and head of the NBER in the 1950s, suggested that Friedman and Schwartz would make a perfect team despite the fact that one lived in Chicago, the other in New York. For half a dozen years they were. "Chapters went back and forth," recalled Anna Schwartz recently. "Statistical tables went back and forth. Of course there were disagreements."

The result had the heft and narrative sweep of a three-decker by Trollope, Schwartz's favorite author. It was also a wide-ranging attack, backed by a mass of minutely detailed statistics rather than fancy econometric techniques, on the prevailing Keynesian consensus. Instead of agreeing that markets were inherently unstable and that monetary policy was of little help in preventing depressions, the authors blamed the Great Depression on fatal errors by the Federal Reserve and tried to show that better monetary policy would have prevented the global slump. Not surprisingly, given that it was published the year that the Kennedy tax cut was proposed, the *Monetary History* was greeted with skepticism or else ignored. The Federal Reserve, which had supplied the data, maintained a dignified silence, but Chairman William McChesney Martin secretly commissioned a rival scholar to produce a rebuttal.

Just as the 1919 eclipse validated Einstein's theory of relativity, the failure of fiscal policies to end the 1970s stagflation eventually made the *Monetary History*—especially its chapter on the Great Depression—required reading. The effect on the profession is reflected in Samuelson's best-selling textbook, *Economics*. In the 1948 edition, as a study of successive editions notes, Samuelson maintains that "few economists regard Federal Reserve monetary policy as a panacea for controlling the business cycle." By 1985, Samuelson and coauthor William Nordhaus insist, "Money is the most powerful and useful tool that macroeconomic policymakers have."

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When Princeton University Press finally decided to make economics a priority, it returned to its roots in mathematics. In the interval since 1944, econometrics—mathematical and statistical tools for testing economic hypotheses—had become standard equipment. In fact, the very first and the latest Nobel Prizes were given for contributions in econometrics. James Hamilton's *Time Series Analysis* (1994) is an important handbook for researchers trying to understand the uses and pitfalls of the enormous array of techniques developed for coping with the very problems that Clive Granger began to focus on in the early 1960s. Similarly, John Campbell, Andrew Lo, and Craig MacKinlay's *Econometrics of Financial Markets* (1997) is another highly regarded compendium of problems and techniques for researchers in finance, the area where the growth of mathematical applications has been most explosive. *Irrational Exuberance* (2000) by Robert Shiller, on the other hand, was aimed at investors, not researchers. Warning that the nineties' stock bubble was about to burst, the book landed on the *New York Times* best-seller list.

These days Princeton's list is especially strong in game theory. Modern corporations engage in life-and-death competition to make new products by new means, but they also cooperate by licensing proprietary knowledge to competitors. Von Neumann and Morgenstern offered no methods for analyzing such complex cases. By contrast, *A Course in Microeconomic Theory* (1990) by David Kreps, which reflects the contributions of John Nash, John Harsanyi, Reinhardt Selten, and many others since the 1940s, is a milestone marking the transition from an exotic novelty to the closest thing to a unified field theory of economics. It's somehow quite fitting that one of last year's additions to the now crowded economics list was the sixtieth anniversary edition of von Neumann and Morgenstern's *Theory of Games*.

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