Economics: Applying Math to Real-World Problems
by Susan Athey

When I was in high school, thinking about my future, I had many plans: I thought I might be a psychiatrist, an entrepreneur, or maybe a computer scientist--but I never considered a career in economics. Sure, I read The Washington Post every morning, and I could repeat criticisms I had read of Ronald Reagan's "supply-side economics." But I couldn't have told you much about economics, other than that it had something to do with interest rates and recessions.

The Price of Televisions

When I entered college, I jumped right into computer science classes, taking an introductory economics course only because I thought I might someday work in a computer business. In that economics class, I learned the textbook definition of economics: the study of how "scarce resources"--land, energy, food, computers, or protection by military defense systems--get allocated to companies and consumers. One way these resources can be allocated is through markets that operate without too much day-to-day government interference. In such markets, firms are free to set their own prices, and consumers to choose what to buy.

So how do we figure out the price people will pay at the store for something like a television? The most basic model of a market needs two functions: supply and demand. We generally assume that demand decreases as price increases: the higher the price, the fewer people want TVs. Supply, on the other hand, increases as price increases: the higher the price, the more TVs companies are willing to sell. With these two functions, we can find the market equilibrium price, at which supply equals demand: the number of televisions companies are willing to sell at a given price equals the number of people who want televisions at that price.

Applying the Models

In class, we learned how to use our models of markets to answer questions about government policy, such as what happens when the government raises the minimum wage. By requiring employers to pay wages higher than they otherwise would, the government could upset the market equilibrium: the supply of workers might become greater than the demand for workers.

Of course, to know how many people would lose their jobs, we would need to know the actual numbers for the supply and demand functions. Some economists spend a lot of time trying to figure out exactly what real-world supply and demand curves look like. But since economists don't usually make use of highly controlled laboratories as biologists and chemists do, they have to use a lot of ingenuity and statistical analysis to draw conclusions from the data they gather.

Partly for this reason, economists don't always agree with each other as in the debate about raising the minimum wage. Some economists' research about supply and demand suggests that a lot of people would lose their jobs if the minimum wage were raised. Other economists have analyzed specific examples in the past in which the minimum wage did go up but the number of jobs stayed about the same. This second group of economists won the most recent debate in Washington: they convinced the president to increase the minimum wage, and Congress voted the increase into law.

The minimum wage question demonstrates the two main kinds of problems economists solve: empirical problems and theoretical problems. Empiricists spend most of their time working with data; they look for exact numbers that best match up with reality, like the economists who try to figure out the effect of raising the minimum wage. Theorists, on the other hand, write abstract mathematical models that capture only the most important parts of a real problem. An elegant theoretical model helps you understand the main ideas, as in the example of market equilibrium.

Although I was excited about the idea of using math to solve theoretical economic problems, the supply-and-demand models we studied in the introductory course seemed too simple. For example, the models did not allow for the possibility that firms might be able to charge different prices to different people, as when the local baseball stadium gives student discounts or when airlines charge less for the same flight when a Saturday night stayover is included. By using more complicated pricing structures, it seems that companies can charge low prices to people who don't want to spend a lot of money, but at the same time charge high prices to people who are willing to pay more.

To Fink or Not to Fink?

I might have given up on economics and stuck with computer science had I not taken a seminar on game theory and industrial organization, in which I learned that economic models could be much more powerful than I had previously imagined. These models could explain companies' strategic behaviors by formally analyzing the "games" that companies play.

Our education about game theory began with the famous "Prisoner's Dilemma," in which two criminals are brought into separate rooms for interrogation. The criminals have two choices: "fink" and implicate the other criminal, or stay silent. If neither finks, both will go to jail for one year. If one prisoner finks and the other is silent, the one who finks goes free and the other goes to jail for fifteen years. If both fink, both go to jail for ten years.

In game theory, you analyze games like this using the principle of Nash equilibrium, which is a set of strategies, one for each player. For the set to be a Nash equilibrium, each player's strategy must be a "best response" to the strategies of the other players. That is, each player makes the following calculation: Suppose I knew for sure that my opponents were going to follow a certain strategy. Then, is my strategy the best choice I can make in response?

In the Prisoner's Dilemma, the Nash equilibrium is for both players to fink. Why? Suppose you thought your opponent was going to stay silent. If you fink on him, you go free, while if you stay silent, you go to jail for a year. So your best response to an opponent staying silent is to fink. Now suppose that you thought your opponent was going to fink. If you remain silent, you go to jail for fifteen years, but if you fink, your sentence is only ten years. So your best response to an opponent finking is to fink. Thus, the Nash equilibrium is for both players to fink.

Game Theory in Real Life

The Prisoner's Dilemma has useful economic applications, such as in a trade war. Introductory economics teaches you that the best outcome for two countries results from free trade, with no tariffs. When both the U.S. and Japan have tariffs, cars and computers cost consumers more in both countries, fewer goods are produced, and both countries are worse off than with free trade.

But whether or not the Japanese decide to use tariffs, the short-term best response of the U.S. might be to place tariffs on some goods. The government profits from the taxes collected on each imported good, and American companies capture a larger market share when foreign imports are taxed. On the other hand, all consumers pay higher prices, and some even get priced out of the market. But if the U.S. is an important customer for Japanese firms, the Japanese might lower their prices in order to avoid losing all of their U.S. customers. If the Japanese lower their prices enough, the U.S. might do better by using a tariff. The "dilemma" is that Japan will make the same calculation, leaving both countries in the fink-fink Nash equilibrium of high tariffs all around.

We also learned in that class how to apply the tools of game theory to a wide variety of complicated problems, such as why gas stations tend to locate in clusters instead of isolating themselves; why beer companies sell almost the same product under different labels, a premium brand and a generic; and why companies might make more money by bundling several products together (a current example is Microsoft's attempt to bundle Internet Explorer with its operating system Windows). For each of these problems, we could write down a mathematical model and actually prove our answers. I never looked at a supermarket the same way again.

Making a Career of Applying Math

When I decided that I wanted to become an economics professor, I arranged to spend a summer doing research with an economist to gain experience. I was surprised when, after I asked him what classes I should take, he advised me to major in math! He told me that most undergraduate econ classes weren't as mathematically sophisticated as those I would soon encounter in graduate economics programs, and that lots of math is required to get into the top schools. So when I returned to math classes, it was with a new respect for math. I was no longer just plodding through problem after problem--I was learning tools that I would need to do my own research.

In graduate school, I became interested in the mathematical tools used to solve theoretical models. Before I knew it, I was discovering new ways to analyze models. I'll never forget my excitement and disbelief when I proved my first theorem.

When my classmates and I finished our Ph.D.s, we went looking for jobs. Some went to work for the government, while others went into research positions on Wall Street and in management consulting firms. Still others went to work for consulting firms that specialize entirely in legal cases involving economics. And many of us were hired by universities as professors.

Economics professors aren't always in their offices or the classroom, though. Companies and government officials frequently seek the advice of economists. Some of my colleagues serve on commissions to analyze particular policy problems, such as social security. Others go to Washington, D.C., for a few years to serve in presidential administrations; they might serve, for example, in the cabinet or on the Council of Economic Advisors. When they return to the university, their lectures are filled with real-world examples, and they have new ideas for research topics.

Careers in academia can take many directions, as professors spend some years focusing mainly on research, others on teaching, and others on shaping public policy. But no matter how they spend their time, it's a great way to make a career of applying mathematics to real-world problems.

Photo caption: Susan Athey is an assistant professor of economics at MIT, where she holds the Castle Krob Career Development Chair.