1 Equilibrium, Welfare, and Information

Kenneth Arrow

Kenneth Arrow passed away on February 21, 2017, before he could complete this paper, which is based on his lecture at the World Bank conference. In a phone conversation on February 17 with one of us, he said he expected to complete the manuscript within a month, but that was not to be. We are immensely grateful to Larry Summers, who worked on the transcript of Ken Arrow's lecture, editing it lightly, and made this publication possible. We, as editors of the volume, have subsequently added some minor edits. It was our conscious decision to do minimal work on Ken Arrow's transcript, even at the risk of the text reading somewhat colloquially. As a last statement from him, we expect this paper to be an important document and were keen to maintain the texture of his voice. It is also clear that during the lecture, he ran out of time and so in some sense, this paper is not complete. That must have been the reason that Ken Arrow was keen to work on it before submitting it for publication. We do not have that choice now. But, as editors, we expect that his fascinating reflections on how modern economics came to be what it is, and his assessment of the weaknesses and strengths of modern economics, as well as his views on various historical figures in economics, will be of wide interest.

—Editors

I was asked to talk today about equilibrium and welfare. The word "information" was not in my suggested title, but as I shall argue, issues regarding information are fundamental to understanding the problem. I won't go into technical questions of existence theorems. What I really want to do is to remark on what exactly the point of equilibrium theory is. What question are we asking? How does it contribute to our economic knowledge, to our understanding of the economy? Inevitably, given the many aspects of these questions, my remarks will be a bit scattershot.

One of the questions is: Why do people talk in equilibrium terms? What is the purpose of relying on the notion of equilibrium? Well, knowing about

the economy is a little different from knowing about astronomy, because it's part of our daily life. Astronomy is something you have to study. You have to stop and look at the stars. You have to watch what's going on. Whereas we are part of the economy.

It reminds me of the story of an astronomer who used to take summer vacations hiking. He went to the Pyrenees, France, and ran across a shepherd. They decided to walk together for a while and have dinner together. The astronomer was trying to explain what it was he did. He pointed at the stars and said, "Well tomorrow they're going to be in this different position." The shepherd listened. "Marvelous," he said, "I see the point. Since I follow my sheep and I know where they are, I know if I'm missing one, he probably went down that valley. So, I can see if you spend enough time, you'll begin to know where the stars are. But the one thing I can't understand is how do you know their names?" The story captures some of what we think about when we think of the difference in the positions of astronomers and economists.

We are part of the economy. For us, the economy is not like the stars are to the astronomer. The economy is a part of our everyday life; we observe it from the perspective of a participant. This creates advantages of proximity. But there is the disadvantage that we are too close in many ways. So, we are likely to see only one aspect, and even that aspect we do not see in a very unbiased fashion.

One thing, however, every day observation tells you is that somehow, I'm provided goods; I don't really worry that they won't be there. They're usually there when I want to buy them. My house is there, rented or whatever. When I go to the store, there's butter. Or, if you're up to date, there is some healthier kind of spread for you. But whatever it is, it's there.

Early History

Goods and services are available in a straightforward way. I may look at the price I have to pay, but that's all I ever have to know. I don't know how they make this stuff. I don't know where it comes from. This aspect of economic life goes back a long time. In the great days of Athens, the most traveled and most knowledgeable person about the world was Herodotus. And when he was writing his history of the Persian wars, he actually went all around the known world or the eastern Mediterranean, as we'd look at it today. He

writes on the subject of bronze. You make bronze by mixing copper and tin. Well, copper comes from a lot of places, but tin comes from very few. In fact, if you look at what we know about the ancient world, tin either came from Iran or it came from Cornwall. Cornwall is a long way from the eastern Mediterranean.

Tin from Cornwall, as we now know, was brought to what we now call Marseille. The Gaelic merchants rafted it down to Rome and sold it. The Greeks had no idea where it came from. They didn't even know—at least at the time of Herodotus—they didn't even know there was an island now called "Britain." They didn't know it existed. All they knew was they paid their price to the Gaelic merchants and bought their tin, and that was the tin that was used for making bronzeware. And of course, the modern world has these transactions multiplied *n*-fold.

So, we see a relatively smooth operating mechanism. We see it's regulated by prices, and prices, for the most part, aren't arbitrary. Firms, when they sell things, don't make 500% profit. They make—most of the time—some normal level of profit. So there seem to be some rules, and it's these observations that motivate the development of economic theory dating from the time of Adam Smith or even earlier. In fact, some people ascribe quite a bit of the development of economic theory to the medieval commentators who were concerned with the concept of profit and worried about excessive profit. A vast literature seeks to interpret Smith, but it was this mechanism and the "normal" level of prices that he had in mind when he famously spoke of the invisible hand.

This leads naturally to the question of how prices affect behavior, a topic that really did not come up at the time of Adam Smith or immediately after. But one thing that was already stressed in Smith, and I suppose, some of his predecessors, was the importance of competition. The idea that you really cannot make supernormal profits because somebody will see a profit opportunity. Now they didn't spell out how this works. Presumably, if you have high profits, other people enter, and of course, other people can cut the price a little bit to take the trade. The implication in Smith is that it's more about entry than about firms explicitly moving prices. So, a demand function must be implicit in the story. Yet you have no explicit notion of a demand function in Smith, his immediate successors, or Ricardo.

It was implicit and became explicit in the post-Jevons era that there's a circular flow element. Somehow, there are primary factors that enter into

production. Production then goes on, and the goods are delivered, and they are bought by other producers or consumers. So the prices paid for the primary factors are the purchasing power. They ultimately determine the demand functions.

Now, it was the production side rather than the consumption side that was most emphasized in the Classical period. Returns to scale played and continue to play a major role in equilibrium theory. One natural assumption is that returns to scale are constant, and so firms can enter an industry at any scale with equal efficiency. But that poses a constraint, because if the price of the product is a little too high compared to the prices of the inputs, then with constant returns to scale, it pays to increase your scale of operations indefinitely. The question is then: What is it that restricts prices and the levels of output?

And so the demand function was invented. Cournot certainly uses it and indeed was an inventor of it. As an observation about how economic science developed, it is noteworthy that Cournot published his book in 1838, yet the first known review is somewhere around 1877. It was completely ignored, and it was reviewed because Walras's book came out, and people began to go back. And Walras does pay some credit to Cournot, but Cournot, by this time a rather old man, going blind, was very bitter that he did not get the credit he deserved. And there was a very famous review by an astronomer named Bertrand, which is where the concept of Bertrand Competition is introduced.

But there was another introduction of demand functions besides in Cournot, and that is in John Stuart Mill. One of Ricardo's greatest innovations was the idea of comparative advantage as a determining factor in foreign trade. But without demand functions, you don't really have an explanation of quantities, you have theories about prices. So, Ricardo was taking the prices as cost driven and therefore given. There are a lot of ambiguities in that, which I won't go into now, but that's the way he saw it. Mill wanted to know something about quantities. So, he produced the idea of demand curves. For example, Germany had a demand curve for English cotton. And England had a demand curve for German linen. I think that was the example he gave. This was Mills's first paper and probably one of the most brilliant things he wrote.

The next step in the development of equilibrium theory was the attempt to provide foundations for thinking about the idea of profit. One of the

questions you get into is: Why are there profits at all? Why aren't there zero profits? Presumably, it's a cost-driven thing, but in the simplest economic model, there is just one primary factor, labor, and then everything essentially is priced based on how much labor is embodied in it. That doesn't give you any profits at all. This is what Marx, of course, took up. The rates of profit are equal, but why do they have to equal zero? Nassau Senior, who was a professor of political economy at Oxford at the time, said, "well, there's a cost to waiting." That's a subjective cost. That's not a cost in any literal sense. If goods are produced, they take time. I'm going to come back to that as one of my main themes. There were also important contributions by Gossen, Jevons, and Menger that clarified these matters further.

Externalities

So general equilibrium theory seems to have something to say about a good part of the economy. Does it say everything? Well, no. We're now accustomed, I'm sure the World Bank especially, to talk about externalities. We find that the markets somehow don't work properly.

And that realization took quite a while. Although you see it recognized: Walras, for example, has some statements that are pretty clear, not in his book but in some of his essays, on the subject. Jules Dupuit in 1844 was concerned with some ideas along these lines: Why the criteria for public works? When should you build a road? When should you build a railroad? How do you price railroads? And so forth. He was an inspector of bridges and highways for the French government.

It was really quite a bit later that Pigou gave us a really clear statement on externalities. But Pigou's original formulation was pretty faulty, and it was reviewed by an economist—I don't know how many have heard of him—Allyn Young. Allyn Young wrote a book review of the first edition of Pigou's famous work—first called *Wealth and Welfare*, and the later editions called *The Economics of Welfare*. Pigou didn't get it quite right, but in the review, Young explained very clearly and correctly what an externality was. And later there was, in the 1930s (the one I learned it from) a paper by Jacob Viner, distinguishing pecuniary from technological externalities. Technological externalities are the ones we think of as the welfare implications. I don't want to go into that, because there's hardly any advanced country with less than 30 percent of its national income going through

the government. Those are the externalities we attempt to take care of, but they are not the only ones. Externalities, public goods, whatever you want to call it. I didn't want to elaborate, except to mention it now; I'll come back to it later.

General equilibrium is useful here. It doesn't explain the externalities, it doesn't explain what's done to meet the externalities, but it does essentially, at least for many economists, have some effect on real life. When analyzing policies, we ask: What would general equilibrium say if it were operative? And that's the criterion we have. In almost all our analysis, policy analysis, in situations where externalities govern, we ask: What would general equilibrium say, if it even were applicable? And that is in a way the main theme I want to present in the end. Of course, there's another aspect, namely, the failure of effective demand. When I was a graduate student, an infinite period of time ago, we'd talk about business cycles. That was the big macro issue—at least around places like the National Bureau of Economic Research. I personally took macro from Arthur Frank Burns in the 1940s.

The Influence on Early Econometric Models

The idea of pursuing systematic empirical work (not just collecting numbers but putting them into models—the econometric movement) is the product of the creation of the Econometric Society around 1932. It was kind of a movement, perhaps a little more European than American, but international. One of its first examples in practice was a business cycle model of the Netherlands by Jan Tinbergen, who subsequently led a much bigger study sponsored by the League of Nations in Geneva. One thing that Tinbergen picked up from general equilibrium theory is the idea of a complete system. If you're going to forecast the future, you've got to have a complete system. Or if you're going to ask what the effect is of a policy, you have to have a complete system. And we see today at least one tendency is to essentially take a general equilibrium system, say, the prices don't immediately move in a right direction (they're sticky).

So now we have I guess what you would call the "New Keynesian" models. I don't know if they do any better, but anyway, they're complete systems. And they deal with motivation as to individual relations from the same basis but put in layers trying to say it's costly to change your prices all the time, or something along these lines.

Goods as Complements and Substitutes

A lot of the early literature on the production side assumed fixed coefficients. In other words, to produce good A, you just need so much of good B. So you can have intermediate goods, but ultimately, directly or indirectly, you're drawing on the primary factors. And the idea that you're going to have substitution in alternative kinds of production was elaborated by John Bates Clark in the late nineteenth century. Walras in his work—not in his first edition but in his later editions—has production functions. What Walras introduced really was the idea that (and he did this more elaborately, I think, than Jevons did) the demand for one commodity might depend not only on the price of that commodity but also on the prices of other commodities. Now once you say it's an allocation problem (and this is certainly there in Jevons), the idea of demand then becomes more complex, and we have the standard notion that these commodities are in some sense substitutes for each other. The fact that they are all competing for a limited purchasing power means that, in some sense, substitution is bigger than complementarity. But complementarity is still there: The price of butter may affect the demand for bread. Once you bring in production functions, you have a similar idea in production. So the idea that something that happens in one part of the system can then work its way through and affect seemingly remote parts of the system is the big lesson to be learned from general equilibrium. If you think of someone like Alfred Marshall, he clearly saw this. In fact, his initial review of Jevons wasn't terribly friendly. He was angry at Jevons (as he himself said in his memoirs), because Jevons was so contemptuous of Ricardo. Marshall said in his memoirs that he would write very angry comments, then cut them out, but they would "reappear" again. This was a very interesting discussion of the subconscious!

"Complementary Slackness"

Let me make two additional points. The first is an issue that sounds a little technical, but it really is not. This is what mainly drove the discussion on existence, which began in the 1930s and was completed in the 1960s. It's what the people who have a linear programming background would say: "complementary slackness." Menger made this observation. There are some goods that are free, but they are free only because they are very abundant.

In other words, if they were not so abundant, they wouldn't be free. What are the examples? Air is free. In many parts of the world, water is free. In a region with a lot of rain, water is free: I mean rainwater for agriculture. Of course, water for drinking has got to be processed. It's not the water that is scarce, it is the processing. So the idea that a good is free or not depends on economic circumstances. Well, this means that supply is not necessarily equal to demand. Of course, supply can't be less than demand in equilibrium. You can't meet the demand then. But supply could be greater than demand, and then the price would be zero. That's recognized by Menger.

What happened was that several German authors (and two in particular, Hans Neisser and Heinrich von Stackelberg) in the 1930s had different arguments—I won't try to reproduce them now—as to why the equations of general equilibrium could be inconsistent. Actually, even though the arguments were very easy, it would still take a few minutes, and I'm told I have less than that! A private banker named Karl Schlesinger fled Hungary, which was then under a communist threat, to Vienna and set himself up as a private banker there, but he kept his interest in economics as an amateur. (He had earlier received a PhD in economics.) Schlesinger pursued the existence controversy and grasped the idea that the existence problem was simply not recognizing complementary slackness. It was insisting that supply equals demand when you might have supply greater than demand.

Well, he was no mathematician. So he went to Oskar Morgenstern, who was running a business cycle research institute, financed by Rockefeller. Morgenstern had hired a graduate student in mathematics to do some work—mainly some statistical work—a fellow named Abraham Wald. Wald was Romanian. He was actually born in Hungary, but the boundary had been moved, so he was now a Romanian after World War I. And so there's Wald, who, using Schlesinger's insight about the importance of complementary slackness, came up with a proof of existence. The assumptions were absurdly strong. It clearly left an open problem, and I won't go into the history of that.

The Essential Role of Time

Now, though time is running short, let me turn briefly to the second issue, that is, the big question that comes up, sort of right at the beginning—even in Smith—but is usually skated over: Production takes time. It's not for nothing that the word "capitalism" starts with "capital," which means

production taking time. Well, it can take time in an indirect form. You buy durable goods, like your plant and your equipment, which last and are gradually used up in the process. So, one way or another, literally it just simply takes time—or it may use machines that are durable and so are used over time. That means, if I look at a production process, to do it properly, you put in goods at time zero, you put in more goods at time one, and the good comes out at time two, or some such process. So, a production process involves not only different goods but different goods at different times. So, we can say, okay, no problem, we'll just think of the same good at different times as different goods.

The first person, as far as I know, who made this simple observation was Eric Lindahl, a Swedish economist. It was picked up by Hicks. I got it from Hicks. To the young theorists of my generation, Hicks was god. His book, *Value and Capital*, was the most important thing in the world.

Prior to Hicks, the problem was that you read all this discussion about capital theory by Frank Knight and other things like that, and it was all mystical. You didn't know what they were talking about. Pigou was a little bit clearer, but he confined himself to simple questions. Hayek was impenetrable. But when you read Hicks and then went back to Hayek, you could see that's what Hayek was saying. I would never have understood Hayek. I did read Hayek, *Theory of Capital*. It was incomprehensible. But as I say, when you read Hicks, then it's "oh, now I understand Hayek." And I think part of it is that Hicks got something from Hayek. He gives credit in the footnotes but in a very general sort of way.

So, to this question of time. Now, when Gerard (Debreu) and I wrote, for example, our proofs weren't really any different from McKenzie's, or anything like that, but I think we set out—we carried the Walrasian program out—more thoroughly than anybody else did. That was the advantage of what we did. And so, we modernized it. We had utility functions, we had preference orderings, we recognized the ordinalist revolution, things of that kind, and we stated the need for concavity. It was a modernized version of Walras. And we wrote just automatically, but we both thought the same way without even discussing it. We treated goods at different times as though they were just different commodities.

But what does that mean? It means we're talking about a world in which there are markets for everything. In particular, a market for goods tomorrow and goods 10 years from now and 20 years from now. Well, you could

wave away a little bit of that, but you need goods markets for everything. Look at the world. What do we see? There are goods for things tomorrow. Agricultural goods, minerals, that's about it. You can't typically buy a car in the future. I mean, obviously, if I'm setting up an automobile plant, it'd be very nice to sell forward the car, a futures market, and credit. Well, the problem is that I don't know what the car is going to be like. I do know it's going to be different. Something's going to happen. Maybe nothing important, maybe just, you know, different styles or something trivial. But maybe it will be significantly better in fuel economy or safety or some other way that is important. So we have this problem. And that's where general equilibrium runs into limits. Somehow you can't carry through the program. And Hicks knew this, and he said, you have expectations of prices. But he's not very good at explaining how you form the expectations.

I'm sorry: I'll wrap up in a minute.

Expectations and the Role of Information

There had been a literature, in the nascent econometric movement, about price expectations. What people were really showing was that price expectations might give rise to trouble. And this is static expectations. Let's say the price tomorrow is going to be the same as the price today. And then they had this famous "corn-hog" cycle. Well, similar versions of this is when you plant your crop, you look at the price prevailing and say that's the price I'm going to sell it for. In fact, the result is, let's say, if the price is high, today you plant a lot, but then the resulting effect is that the price is low tomorrow. So you can wind up with a cyclical movement in people's expectations; of course, they're already being dashed all the time, and people began to develop more and more sophisticated kinds of expectations. But this is the trouble.

The same thing could be extended to uncertainty, but that brings in the question being asked of why information is key. (I don't have time to get to my main theme, but all right). Once you start out on the idea that we're ensuring there's uncertainty, there comes the problem that people know different things. There's asymmetric information. And of course, we've had an enormous development of the theory of asymmetric information, but it tends to be static. You have to laugh at the fact that there's going to be a realization.

So let me conclude by saying that where I find general equilibrium theory most used is as a basis for models. Climate change illustrates it. What have we got there? We have dynamic models, like Nordhaus and others have developed. That is, you have models of the future, and we make it clear that they are price clearing models. In fact, they are optimal, so they clear with full anticipation of what's going to happen in the future. So these models are fully specified. They're used for predictive purposes, and they're used for policy formation purposes. And that's where I think equilibrium theory is having its biggest use now. Thank you.

The State of Economics, the State of the World

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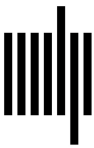

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