Preface: A Short Introduction to the Textbook and this Course

I. Organization of the Class

The class website is the main source of the class materials, which is for the most part a draft of a textbook in advanced microeconomics. The website also links to classic articles that extended or fleshed out microeconomic analysis during the second half of the twentieth century. The class website provides a web-syllabus (and a pdf syllabus) and approximate timing of all the blocks of materials covered in the class. It also includes "due dates" for the 8 homework assignments that are each due roughly a week after a block of material is finished in class. It also provides the exam dates. The homework assignments are on the class Ecampus site. No homeworks are accepted after their due date without a note from a doctor or hospital. They are online and so can be done anywhere in the world with internet access and at any time before they are due.

Your grades are based on the 8 homework assignments, 2 exams, and a final paper, plus a bit of extra credit for helpful class participation.

The course is based on the web notes, but the class lectures are not simply me reading my lecture notes. The class lectures are shorter somewhat more focused versions of the notes with the mathematics worked out and more examples. The lectures are also an excellent time to ask questions. The optimal textbooks are sources of alternative explanations for the material covered in class and also provide various extensions beyond what is covered in the class. All questions in class are welcome—and usually benefit most students in the class! So, please ask questions.

II. Focus of this Textbook

Most mainstream microeconomic courses focus narrowly on the mathematics of price determination in what may be regarded as "normal" markets. That is to say, they focus on models that help to explain the prices observed in well-functioning commercial societies. They neglect the underpinnings of such societies such as entrepreneurship, relatively honest promise keeping individuals, effective law enforcement, and public policies that do not greatly inhibit market activities. However, such underpinnings cannot always be taken for granted. Markets that lack some or all of these features will be less effective as a means of satisfying consumer wants than ones in which such features are ubiquitous.

Although the effects of illegal activities, market inhibiting regulation, and corruption have been examined by microeconomists, moat are simply ignored in typical micro-economics textbooks.

This textbook (and course) differs from most such textbooks by devoting more attention to the effects of uncertainty and also by considering how markets operate when some or all of the features of "well-functioning" markets are absent. These differences allow micro-economics to explain why some societies have more productive markets than others, and why their effectiveness changes through time. These differences are simply a matter of technology or capital stocks. Technology and capital are both quite portable and thus can be used anywhere in the world. Possible explanations for some of these differences are taken up in Part III of the textbook and course.

Although price theory has been the "home territory" of contemporary economics since the marginal revolution of the late nineteenth century, it is not the only important part of microeconomics. In the second half of the twentieth century, new models were developed that provide insights into how Law, Political Science, Sociology, Psychology, and Philosophy affect market outcomes. The pioneers of these extensions were often awarded Nobel prizes in economics. Thus, although such contributions are still left outside of "normal" texts in advanced microeconomics—they clearly deserve significant space in any text that claims to review the foundations and major implications of micro-economics.

The text also differs from most mainstream microeconomic textbooks in that it is for the most part narrowly "calculus based" and stresses the fact that models are models. Models are simplified characterizations of the world that make it easier to understand important causal linkages. Economic models characterize both individuals and circumstances and use mathematical deduction (implications) as a heir basis for making claims about how markets operate, given those models. The models reveal tendencies in the choices of individuals and in market outcomes that emerge when individuals are forward looking, generally right about the consequences associated with their actions, and institutions are broadly supportive of market activities. When these assumptions are unrealistic, the implications of the models developed will be less useful and accurate than when they are.

The text as a whole is intended to be an introduction to the fields of economics covered rather than a complete in-depth overview. The entire field of micro-economics is enormous, and no single text can cover everything that might be usefully known by all advanced students in economics. More could be said about every topic covered—but by providing an overview of core findings in a broader range of topics than other books, students will have a deeper understanding of the power and limits of microeconomics and be better prepared for further study. (Limits are rarely mentioned in other textbooks.) The references at the end of each chapter provide additional material that is either deeper or broader than that provided in the individual chapters.

This is not a difficult book for students who have a solid understanding of the geometry of intermediate micro-economics, have mastered the basics of calculus, and who have enough discipline to carefully read the text, think about it critically, and work homework problems on their own. Although the book presumes that students have such abilities, it provides short reviews of most of the "tools" drawn on in the text. However, in spite of that review, it will be a challenging book for those who do not understand basic economic models, have never taken derivatives, and lack the discipline and free time to read and think about the subjects covered.

The book is calculus based. It uses the calculus of optimization to understand the main implication of rational decisionmaking in a variety of market-relevant choice settings. Most of the choice settings are economic ones. Part I focuses on the core models of neoclassical price theory. Part II focuses on the effects of uncertainty and information limitations on market outcomes. Part III focuses on the legal, political, and social foundations of well-functioning markets.

The choice settings are modelled with calculus—not because calculus is always the best way to do so, but because very similar and quite general models can be developed for all of the settings examined using that approach. This frees students from having to master a broader variety of useful mathematical tools such as matrix algebra, differential equations, and real analysis. This, in turn, allows the book to focus more on the economics (logic of choices and their outcomes), and less on applied mathematics.

Because the website provides links to the "first draft" of the textbook, each chapter will be improved a bit as we approach the lectures in which a chapter is reviewed. The syllabus, likewise, will be subject to minor revisions.

In the end, understanding and internalizing the models and their implications takes place in the minds of each student. The book makes this process easier, but each student has to take the material seriously, by which it is meant to do more than simply memorize results. Instead, they must strive to fully understand them and incorporate them into their world views—a project most began in their undergraduate studies, and most will continue after graduate school. The text, lectures, assignments, and exams can only help a student to focus on important puzzles and possible solutions to those puzzles.

III. The Methodology of Microeconomics

Microeconomics is based on an approach to social phenomena referred to as methodological individualism. Methodological individualism regards all social outcomes to be consequences of individual decisions and thus the best way to understand social phenomena is to understand the individual choices that gave rise to those phenomena. From this perspective, a club, firm, community, market, or government is nothing more—nor less—than a group of individuals whose choices jointly determine various outcomes. Such decisions do not take place in a vacuum. The circumstances of each individual matter. These are partly consequences of economic conditions (wealth and prices) and partly of legal and social conditions (organizational rules, laws, regulations, and norms). The most important part of most of the models is characterizing relevant choice settings. These (partly) characterize the legitimate (and illegitimate) choice that an individual can make. For example, laws governing ownership determine who controls particular resources and how ownership rights can be transferred from one person or organization to another. Such laws along with market prices, largely determine a consumer's and firm's economic opportunity set.

Firms operate within a broader set of formal rules (its society's civil legal code and regulatory codes), which together with the technology of its era, determine the legitimate actions that it can undertake. A society's laws and public policies constrain each firm's behavior insofar as it engages in legal strategies for making profits. The laws, in turn, are largely products of past political decisions. All these rules affect economic outcomes through effects on economic opportunities and tradeoffs among them. Prices and technology are important, but they are not the only factors that affect economic outcomes.

Firms and other voluntary organizations have their own rules, rules that apply only to a subset of individuals in the society of interest. A firm is a group of individuals that are all members of an organization that attempts to profitably produce and sell particular goods and services. Its members agree to follow rules about various work-duties which allow a variety of coordination and free-riding problems to be overcome (or at least mitigated). Decision making procedures within firms are often quite complex with managers and employees each being delegated non-trivial, but constrained, authority to make various kinds of decisions using particular procedures. Each type of relationship inside the firm (owner, manager, employee etc.) can be analyzed using rational choice models—but the rules that characterize their authority within the firm vary and so do their opportunity sets.

If we assume that a firm is well-organized and well-led and that its main purpose is to produce income for firm owners, we can also assume that the "firm" attempts to maximize its profits by producing particular things for sale and selling them. These assumptions simplify the analysis of how such commercial organizations adjust to changes in prices and technology. They are implicit parts of most models of the supply of goods and services provided in well-functioning markets.

This is where the microeconomics of the firm begins—but it does not end there because not all firms are well-organized in this sense. The conventional assumptions, for example, neglect the existence of a variety of principal-agent problems inside the firm, which may not be entirely solved by every (or any) commercial organization.

These non-price effects on firm decisions and market outcomes are analyzed in Parts II and III of the book. Part I covers the core neoclassical theory of prices in settings where all such problems have been solved and only voluntary well-informed purchases and production take place.

Chapter 1: On the Usefulness of Imperfect Models

I. Less than Perfect Models

Many advanced economic texts give student the impression that economics is a field of applied mathematics and that its conclusions and predictions are as precise those associated with pure logic and mathematics are. They forget to mention that there is a difference between pure mathematics—which does not make claims about the world beyond the intangible sphere of that field of study—and science which make claims about the world. Mathematical results are true in the logical sense of being generated by the rules of logic. Some propositions have relevance for the quantifiable parts of the real world, but many do not. Economists use models that are believed to reflect essential features of real-world choice settings as an aide to better understanding how well-functioning markets operate. If the models used are "perfectly realistic," then the inferences drawn from them will all be present in the real world. However, if the models are less than perfectly realistic—but nonetheless characterize important features of the choices being made—then many, but not all, of the inferences drawn will be evident in the world.

In both cases, the inferences drawn, if they have been carefully undertaken without mistakes, are true in the logical or mathematical sense, but economic deductions may or may not be true in terms in the real world. The models used are never perfect. They are not features of the world, they are models of the world.

As models, it is generally understood that many features of the world have been left out. Thus, the results are often said to hold ceteris paribus—other things being unchanged. That caveat, however, covers a lot of ground that is rarely discussed in economic classes. Most models intentionally leave out many details so that particular aspects of the phenomena of interest (as with market prices) can be better understood. However, some factors are unintentionally left out because the theorist does not know all the factors that might influence choices in the settings modeled—some of which change rather frequently. The latter implies that all models are imperfect. It also imply that the "other things being equal" part of many economic conclusions is untestable, a dodge rather than an analytical result. The universe is always in motion.

Nonetheless imperfect models can be very useful. Even imperfect models can increase our understanding of economic and other relationships, and also of their consequences for larger scale phenomena such as a solar system or well-functioning market. The degree to which a model is "good" or not or "useful" is partly an empirical question (how well does it explain the phenomena of interest) and partly a matter of judgement (does it increase are understanding of fundamental relationships). With respect to markets, a good model's implications should accord well with what is already known about the phenomena of interest (such as the purchase and production of goods and services). It should also have implications that are a bit novel—which imply previously unnoticed or unknown relationships. A useful model may simply make it easier to understand the phenomena of interest, even if its implications are not always borne out. It may point out important relationships that might have been missed given the complexities of many real-world settings.

Indeed, insofar as models are known to be less than perfect, one expects differences between their logical implications and the real world—the phenomena being modelled. Thus, differences, per se, cannot be used to reject a model, unless it also fails to advance our other interests in clarifying underlying processes and increasing our understanding.

The inferences drawn from mathematical models may be logically correct, but less than perfectly true, without being worthless. For example, a model may account for half of the variation (in prices, outputs, rates of innovation, etc.), rather than all of it—a common result for statistical estimates of the core neoclassical models. However, that relatively simple models of consumer and firm choices can account for even half of the variation in prices through time is actually remarkable, and often quite useful—especially when no more accurate or general models are available. "Useful" models shed useful light on the phenomena of interest.

The understandings generated often facilitate the development of better models—models with logical and mathematical implications that better accord with the real world. They may also be used to make decisions in settings where even greater uncertainty would exist about the consequences of a long-term financial commitments or public policies. A good model might, for example, account for the average or typical result rather than all the unusual ones. Simplified models are also useful as a method of getting general ideas across to students—because if the assumptions and reasoning is clear, students can get a rough understanding of a broad range of phenomena far more easily than possible with a catalog of special cases. Having mastered a relatively straightforward model, often facilitates the next step in their learning--mastering more sophisticated models.

All the models developed in this text are "good" in the above senses. They are engines of analysis, whose logical implications are reasonably faithful to the phenomena modeled. They provide relatively clear understandings of the choices and processes that generate market outcomes, without being perfectly accurate in all cases. They are not trivial. They are products of hard work by hundreds of talented persons over the past three centuries who were interested in improving our understanding of the most important factors that determine how markets operate.

The models and their implications should be taken seriously by economics students not because they are perfect or will never be improved, but because they increase their understanding of markets, provide points of departure for more sophisticated models, and also provide logical foundations for empirical tests of economic propositions and predictions. They also provide the logic behind the most commonplace intuitions of economists who are not themselves actively engage in theoretical research—e.g. not themselves model builders.

II. Science as Model Building

It bears noting that the use of models is not exclusively a feature of economics or social science, but of all sciences. Specialization within the various scientific fields of knowledge implies that all models are somewhat incomplete, because the possible influences of research in other fields is normally left out of their models. And, perhaps naturally, experience has shown that they are all imperfect in their ability to perfectly account for the past or perfectly predict the future course of events. Anomalies always exist and their predictions may be accurate, but nonetheless remain imperfect. Models are models, and even the best of today's models are likely to be improved in the future—indeed some of the readers of this textbook will be engaged in doings so for much of their careers.

Scientific work attempts to determine general properties of the world or universe. To do so, both individual scientists and teams of scientists use combinations of models, logic, and empirical evidence to determine what is (approximately) true. Because the real world is complex and interconnected in many ways, all scientists abstract from many features of the world in order to focus on the subset of characteristics and relationships thought to be most important for the aspects of the universe that they are most interested in. Physicists, biologists, and economists, for example, focus on completely different aspects of the world and universe. They create quite different models of the relationships of interest to their own groups of specialists, which they believe help us to better understand particular subsets of the phenomena of our universe. They largely ignore any interdependencies with fields other than their own that might exist.

The existence of separate fields of research, astronomy, physics, chemistry, geology, biology, economics, political science and so forth imply that every model is a bit incomplete—because work in other fields is not fully taken into account. Thus, unless the problems addressed are truly independent of one another, all sciences have developed models that are incomplete. For example, astronomers do not take account of features of human nature (as with the senses) that partly determine how the universe is perceived and measured. They neglect other aspects of human evolution and society that influence their astronomical observations. Economists, likewise, generally neglect the effects of astronomy and geology on the nature and distribution of the Earth's resources. Clearly, these phenomena affect the location of many natural resources, and thereby the demands and supplies of goods and services, which in turn affect the types of market networks that have emerged through time. Biologists, arguably do a bit better on integrating such effects into their theories after Darwin's theory of biological evolution was proposed and refined, but relatively few biologists focus on the vary long run, and those that do not also tend to neglect the effects of astro-physics and economics on the distribution and nature of the species that exist today. As every economic student should know, there are advantages to specialization, but also costs.

It is far easier to think about subsets of relationships than to simultaneously take all possible factors into account. (Indeed, the later may be impossible.) Which is, of course, one of the reasons that science has become so specialized and why imperfect models are commonplace.

Limitations of Simple Causal Models

Models rarely, if ever, account for everything of interest. For example, the simple theory of gravity attemptd to explain why and how objects fall. In many cases, this is fairly easy, and models that ignore everything except gravity can explain quite accurately how an object such as an iron ball or rock falls. However, there are cases in which other factors, such as wind, air resistance, and aerodynamics matter. It is much easier to predict how a rock falls than how a leaf falls. Although both fall because of gravity, a leaf's path is often quite complex because of wind and its own aerodynamics. The "average" leaf may fall straight down, but leaves will be distributed widely around that spot because of the interactions of air and aerodynamics that the simple gravity theory of falling ignores.

That does not make the simple theory of gravity useless, rather, it means that it does not and cannot account for the path of every object on earth. It is more generally applicable in a vacuum and thus does a better job of accounting for the movements of planets in their orbits than in predicting the path of a leaf falling from a tree in autumn. On Earth, it is a model rather than reality. Fortunately, even models that only partially account for some phenomenon can be very useful. Gravity accounts for much of the phenomenon of interest (falling) and also provide a basis for developing more inclusive theories (ones that include the effects of air, wind, and aerodynamics).

Trying to explain the path of a volitional, self-propelled object such as an insect, bird or person is even more challenging. Clearly, more than physics will be required to account for where a bird or person goes after leaving a high branch of a particular tree. In a few cases, they may fall straight down, but that is not most common cases. Neither a bird nor person is likely to wind up motionless at a place more or less below the branch they initially resided on until another external force acts on them. When a bird leaves a branch, it does not immediately fall to the ground—because they can fly and make choices about where to go—unlike a rock or leaf. Birds may fly off to their nests in other trees or to another place where food is available. Similarly, a person may descend to the ground in a manner that avoids the worst effect of gravity (falling and hurting oneself), but rather than staying where he or she lands, he or she may reclimb the tree (despite gravity) or "simply" walk home for lunch and reflection about the nature of trees, apples, and falling, as Isaac Newton is reputed to have done. Such paths are influenced by gravity, but not fully determined by it. Humans climb down from trees and walk, rather than fly, but gravity has a relatively small effect on the paths followed. Gravity remains part of the causality behind such phenomena, but it does not account for the most important features of the path of animals (beings that are "animated," e.g. self-propelled).

Entirely different and more sophisticated models are required to account for the effects of volition. For example, the nature of volition itself has to be modelled. In theories of volition, gravity may be ignored by the models developed rather than given centrality.

Modeling Volition

The simplest models of volition assume that the being in question has a unified goal that try to advance through their actions. A geneticist might, for example, argue that all living beings try to maximize the probability that their genes are transferred to the next generation. Those that do so, have genes that appear in success generations, those that do not, do not. It is only instances of the species do so that we observe in the long run. So, this simple model fits the long-term data about the nature of living things very well—even those that lack volition.

However, the genetic theory does not do as well at explaining exactly how a given member of a species maximizes the probability its genes will be passed on to the next generation, but it does provide a persuasive model of successful biological beings.

This model, like the gravity model, has some relevance for humans. If humans are to survive as a species, the genes of individual homo sapiens have to be transmitted to future generations of humans, which requires individuals to procreate and nurture their children. That model implies that individuals would all attempt to maximize the number of their descendants.

However, that universal prediction conflicts with a variety of behaviors that humans engage in that reduce the likelihood that a particular person's genes will be passed on to the next generation. Examples include vows of chastity and other sexual lifestyles that make procreation unlikely, choosing to have very small families, youthful suicides, engaging in risky activity such as reckless driving and drinking, participation in warfare, and many others. Although procreation is necessary for human survival and together with child rearing do take up a good deal of adult time and attention, they are not the only activities that contemporary humans devote their time and attention to—and maximizing family size is not always, or perhaps even usually, their main focus.

A more general model is required to model human volition. The one that most economists have adopted has utilitarian roots going back to Jeremy Bentham's writings in the late eighteenth century, which in turn has roots that go back at least as far as Aristotle writing in 350 B. C.. This line of reasoning argues that all persons have a single unified goal that they pursue, namely they attempt to maximize happiness.

> **So far as the name goes**, **there is a pretty general agreement**: for happiness both the multitude and the refined few call it, and "living well" and "doing well" they **conceive to be the same with "being happy;"** but about the nature of this happiness, men dispute, and the multitude do not in their account of it agree with the wise. (*Nicomachean Ethics*, p. 26)

> Happiness is manifestly something final and self-sufficient, being the end of all things which are and may be done. (*Nicomachean Ethics*, p. 34) … As for the life of money-making, it is one of constraint, and **wealth manifestly is not the good we are seeking, because it is for use, that is, for the sake of something further.** (*Nicomachean Ethics*, p. 29)

> **Nature has placed mankind under the governance of two sovereign masters, pain and pleasure.** It is for them alone to point out what we ought to do, as well as to determine what we shall do. On the one hand, the standard of right and wrong, on the other the chain of causes and effects, are fastened to their throne. **They govern us in all we do, in all we say, in all we think: every effort** we can make to throw off our subjection, will serve but to demonstrate and confirm it. *(An Introduction to the Principles of Morals and Legislation*, KL: 3474–78)

Bentham and other utilitarians replaced the word "happiness" with the word "utility" in the early nineteenth century. This accounts for the name of their school of philosophy, which remains and important one. Utilitarians were among the leading economists of the nineteenth century, which accounts for the use of the term utility in economics. The utility-maximizing model is the dominant analytical model of human volition used in economics. All human decisions and actions are represented as attempts to maximize utility. (The same model is used in game theory and in "rational choice" strands of political science, sociology, and anthropology.)

This model of human volition, however, had critiques that challenged the utilitarian model of human nature and decision making. In response to such critiques, Paul Samuelson (1948) developed the revealed preference theory of utility. He demonstrated that if individual make decisions that were internally consistent (e.g. if A is preferred to B and B is preferred to C then A is preferred to C, etc.) then one could assign numbers to A, B, and C such that A gets a number higher than that for B and B higher than C. After doing so, one can use this pattern of "revealed preferences" in the same manner as utility numbers and model individuals "as if" they maximized utility.

One does not have to assume that all people pursue happiness or satisfaction to use the utility maximizing model in areas of life where individuals make consistent choices. However, the more intuitive assumption that most folks do so is consistent with a good deal of experience. Nonetheless, for most economic models, what matters most is that decisions are (mostly) internally consistent within the class of decisions being modeled (or estimated).

III. Improving Models (and Theories)

In economics and most other areas of active research there are often two or more models that provide roughly equally accurate and informative explanations of the phenomena of interest. This make choosing among the models challenging, because one cannot always simply pick the model that provides the most accurate account of the phenomena of interest. In some of these cases, there are also a somewhat less accurate model that is far easier to communicate with others, or to use for as a basis for estimation. For example, models taught in principles of economics clearly differ from those taught in intermediate microeconomics and advanced microeconomics courses, although they are not entirely different. Similarly, within empirical research, single market estimates may be followed by models that take better account of inter-interdependencies among markets or the effects of government policies.

All "useful" models account for well-known relationships and most also point towards unknown or ignored relationships that are not intuitively obvious. That is to say, they serve as frameworks or points of departure that help scientists and other experts determine previously unknown relationships and facts. Many of such relationships would not have been predicted or imagined without the relatively simple first models that allowed core relationships to be understood. Exceptions to the predictions of such models, in turn, often stimulate the development of more inclusive models. In some cases, refinements in one of the existing models will cause it to become "the" model of choice. In other cases, entirely new theories may be required to achieve a consensus among experts.

As noted above, Newton's theory of gravity provides a good approximation of how inanimate objects behave when falling, but for some objects, such as leaves, the effects of wind and aerodynamic shape are also important. Relatively few analyses of falling or rocketry would neglect aerodynamics these days.

Similarly, models of perfect competition that were developed in the late nineteenth and early twentieth centuries, that were subsequently extended to take account of less than perfectly competitive circumstances, as with competition among a few firms selling identical goods (oligopoly) or many firms selling similar but somewhat variated goods and services (monopolistic competition). These models, in turn, were extended to take account of the effects of informational problems, government policies, and culture.

The evolution of models in every field of science is a joint exercise in logic (model building), observation (empirical testing), and reflection about the results, and subsequent refinements. There is a nearly endless cycle of model building (hypothesizing), empirical testing, refinement, retesting, and so forth in every active area of science (a process is sometimes call boot strapping). Ideas that look obvious in retrospect, often take a century or more to be worked out and accepted.

Through this process our understanding of the world gradually improves and is, in a sense, gradually perfected. Even after several thousand years of efforts to understand the universe, some aspects of the world and universe are understood far better than others. Thus, some models are better than others—more precise, more encompassing, or better at facilitating one's understanding of key relationships.

Even somewhat imprecise models (mathematical representation of a principle or relationship) often allow one to discover and understand relationships among phenomena far better than human intuition alone can. And, they serve as a source of hypotheses about the world that can be tested and refined.

IV. The Often Very Slow Progress of Science

In contrast to the fields of logic and mathematics, all fields of science have "truths" that they pass on to their students and expect others in the field to have mastered, but which they also acknowledge may change in the future. These "truths" or "facts of nature" should be regarded as "relatively absolute absolutes." Which is to say that they are taken to be true or accurate for many purposes—even though many experts anticipate that future refinements will improve on the models or theories considered "truths" today.[1]

Past truths are sometimes discarded—as when Newtonian physics replaced Aristotelian physics in the seventeenth century—but more often models are simply adjusted in various ways to take account of new ideas, data, and results. Newton's theories are still used for most day-to-day physics and engineering today, but they are replaced by Einstein's theories in cases in which the objects of interest travel very rapidly (approach the speed of light) and with both Einstein's and other theories when the phenomena involve

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[1] This terminology is one developed by Frank Knightand extended by his student, James Buchanan. See Emmett (2009) for an overview of this idea in Knight's work. See Buchanan (1962) for an early use of this expression by Buchanan or Boettke and King (2024) for an overview of its influence on Buchanan's research.

changes in atomic structure. Similarly, the core neoclassical models of micro-economics worked out in the late nineteenth and early twentieth centuries continue to be applied in the twenty-first century, but they have been modified in various ways to address issues neglected in the original models such as the importance of information problems and innovation.

Such refinements often take decades or centuries to be worked out. One can see evidence of this in the language that we use to describe some common events. For example, an example of a current model that most educated persons accept is that all sunrises on Earth are caused by the Earth's daily rotation in combination with light generated by its nearest star—the sun. After Copernicus introduced the heliocentric model of the solar system in the sixteenth century and was refined induced by Newton's theories and Galileo's observations in the seventeenth century, this explanation for our daily cycle of light and darkness has been the model accepted by all educated persons. Nonetheless, our normal English expressions for the point at which the earth spins around enough so that the sun becomes visible is called sunrise, rather than sun approach or the beginning of sun sight. Similarly, the end of that period of direct illumination by the sun is called sunset rather than the end of sun sight or the beginning of shadow time. Our language is still based on the earlier and more intuitive flat-earth theories of daylight. The sun does not move (much) relative to the Earth, it is the Earth that moves relative to the sun.

Note that there is some ambiguity about the meaning of sunrise and some measurement error in measuring the exact moment of sunrise or sunset at a given place on earth. Perhaps surprisingly, although we have lots of data about sunrise, the exact moment is more difficult to determine than one might expect. Is sunrise when the light of the sun first appears or is it when the transition to lightness is first complete. What factors cause the observed variation in the time at which lightness occurs? Does it matter whether one is on top of a mountain, on an ocean, or in a deep valley? In practice, the first light and sunrise numbers published on meteorological websites tend to neglect the effects of mountains and weather on the times when first light and last light occur. They are, in a sense, approximations—numbers that would be accurate if the world was a level plane and the sky always clear and cloudless—even though they are not.

Nonetheless, exact times for sunrise and sunset are widely published and useful for planning purposes, although they are rarely exactly correct. Refinements that include all the "ifs" are possible and many have been worked out, but the approximations are easier to remember and have clearer (if often slightly wrong) implications than their more precise counterparts.

The models developed in Part I of this book can be thought of as the economic counterparts to the simple theory of sunrise and sunset. They are useful and provide many insights that are relevant for planning and public policy, but are not always, or perhaps even often, perfectly precise. The models developed in parts II and III cover (or at least introduce) some of the most important refinements of the neoclassical model of price determination covered in part I. Most were worked out during the second half of the twentieth century. Some, but not all, were associated with the mathematization of the older models. Others were models that incorporated factors that were neglected in the original verbal and geometric models.

V. A Short History of the Use of Mathematical Models in Social Science

Economics has a long history, it is essentially as old as trade is, because trading always involves coming to terms about how much of this will be traded for how much of that—and theories about a "good deal" or "bad deal" must have emerged at basically the same time. The logic of supply and demand in their own markets would have been "intuitive" to most firm owners for thousands of years before general models of price determination were worked out.

Theoretical explanations of equilibrium prices go back at least as far as Aristotle, who proposed a theory of the origins and property of money that remains largely in place today (as an index and store of value that can nonetheless decline in value through inflation). Aristotle also developed a theory of equilibrium fair prices that was worked out to illustrate his theory of proportional justice. The first truly encompassing work on economics is that by Adam Smith—the *Wealth of Nations*, written just before the time of the American Revolutionary War—who supported his theory with many illustrations and a significant amount of numerical data. He noted the advantages of specialization, considerations that tend to push various prices and exchange rates toward long run equilibrium values, and also the factors that might induce them to depart from those values.

The use of mathematics for modelling human behavior arguably started in political science at roughly the same time as Smith was writing, just before the French Revolution when Condorcet and Borda used rational choice models to analyze the properties of different voting rules. Many of their results are still of interest today. Condorcet's analysis of majority rule identified the ideal of a dominant option (now referred to as a Condorcet winner) that is majority preferred to every other and Borda's suggested alternative for voting (the Borda count method) remains of interest to scholars of voting processes. The economic department at WVU has used the Borda count method to select among job candidate finalists for many years. However, very few political scientists adopted their analytical approach to understanding the effects of elections on public policies.

Mathematical models of economic decisionmaking and their consequences were developed in the late nineteenth century and extended throughout the twentieth and twenty-first centuries. Many of the first persons to do so were members of the philosophical school referred to as utilitarians. Their notion of "utility" turned out to be a very useful way of thinking about choices, gains to trade, and the normative area of economics called welfare economics. It also turned out to be a useful foundation for mathematizing economic models and reasoning, as mentioned above.

At first, this mathematical strand of economic research was a minor part of the overall research program of the group of scholars and practitioners who studied how markets operate, but about fifty years ago it fairly rapidly became the main method used to model equilibrium prices and networks of exchange and production. Prose, geometric representations, and tables of numbers were commonplace in economic journals until around 1970.

By the 1970s, models that used calculus (and to a lesser extent differential equations and more advanced mathematics from real analysis) to analyze economic relationships had become the most common methodology for "theory" papers published in leading mainstream economic journals such as the *American Economic Review* (AER), *Quarterly Journal of Economics* (QJE), and *Journal of Political Economy* (JPE). Other more mathematically demanding approaches were often published in more specialized journals such as *Econometrica* and the *Journal of Economic Theory* (JET). Very few prose or geometric based theory papers were published in leading economic journals after 1980.

Most mathematical and geometric models imply that results worked out for a particular product or market generalize to essentially all markets. That is to say, there are commonplace relationships that exist among all markets, and these have implications about both existing prices, how they change through time, and their effects on behavior. This allows the inferences drawn from models of single markets to be applied to many other markets and also to phenomena that resemble a market and choices that appear to be instances of constrained optimization. It is for this reason that microeconomics provides a very broad understanding of social phenomena.

Without those commonalities, the best that economists could be accomplished would be a catalog of special case results. This is not to say that such catalogs would not be useful, but it would imply that little about market and other social phenomena could be anticipated using the various models developed.

The mathematization of economic research is one of many reasons for the mathematization of graduate economic programs. Some background in mathematical model building (and it limitations) is necessary if one is to be able to read contemporary research. The book begins with an overview of some of the main results of neoclassical price theory (part I) then examines extensions and other applications of rational choice-based models to settings where information constraints are important (part II), and lastly models the influence of neglected framing institutions such as law and economics, political economy, and socioeconomics. The final chapter is on welfare economics. There is a mix of ideas and mathematics in all chapters, rather than simply a series of mathematical exercises.

VI. Rational Choice and Methodological Individuals as Foundations for Microeconomics

What distinguishes microeconomics from macroeconomics is both the widespread use of partial equilibrium models and an approach to social science referred to as **methodological individualism**. Microeconomics also tends to be less directly public policy oriented than most macroeconomic research tend to be.

Methodological individualism regards all social phenomena to be consequences of individual decision making . This includes such phenomena as markets, politics, norms, and social networks. Given this, it argues that must be analyzed in terms of the individuals in the networks, institutions, or societies of interest, and the choices they confront. The latter includes consumer choices, production choices, investment choices, choices of political candidates during elections, decisions to engage in criminal behavior or not, to marry or not, to have children or not, and so forth. This approach maintains that individuals are the prime movers, the choosing agents, through which all social phenomena emerge.

"Networks," "groups," and "societies" are all composed of individuals making independent decisions in particular choice settings. The properties of "networks," "groups," and "societies" emerge from the choices of the individuals in those networks, groups, and societies and the constraints associate with those networks, groups, and societies. In lean models, the decisions reached by individuals are determined jointly by each individual's particular circumstances (constraints) and partly by their aims in life (often characterized as maximizing utility).

Most lean models assume that individuals make their choices without taking account of the effects of their actions on others. The choices are simple self-interested choices, ones that maximize their own utility. However, in more complex models, that assumption may be modified to take account of sympathy and hostility among individuals and groups that may exist. Such models may also explicitly take account of various rules and norms that an individual has internalized, some of which may have to be followed to maintain membership within a firm, group, or society.

Lean models of economic decision making also implicitly assume that the decisions made are inhibited by a well-functioning system of laws, by personal inhibitions or by combinations of both that are sufficient to largely rule out non-market transactions. The individuals modeled do not steal or use threats of violence to gain what he or she wants—rather they engage in various forms of voluntary exchange. That is one of the fundamental "rules" or constraining principle of market networks. More general approaches include possibilities for theft and violence, and so must take explicit account of how such possibilities affect the scope of trade and innovation. Such approaches may also take account of why some institutions and internalized norms can promote economic development.

Rationality as Forward-Looking Internally Consistent Behavior

Microeconomic models use "rational choice" models to characterize the kinds of choices made by individuals in wide domain of possible circumstances. It is such models that allow methodological individualism to serve as the foundation for micro-economics. A wide variety of tastes and circumstances can be included in such analyses. In many economic settings, market level activities such as demand or supply are simply sums of individual consumer or firm decisions. In others, more complex, less linear effects emerge from the choices of individuals as with respect to externality and commons problems.

However, it bears keeping in mind that economists use the word "rational" in a manner that is quite different from its ordinary use in English. In normal usage, "rational" means "based on or in accordance with well-informed reason or logic" This in turn suggests that individuals who are rational are dispassionate, well-informed, analytically competent, and sane. Economists would regard such persons to be rational, but also include other types of individuals as long as their choices or rankings of alternatives are internally consistent. If A is preferred to B and C is preferred to B, then C must also be preferred to A for all possible A, B, and Cs. Individuals are locally rational is this is true for specific subsets of the possibilities confronted. Note that even insane or completely myopic persons may behave in a manner that is internally consistent and thus would be regarded to be rational in the economic sense, although their behavior would not be considered well-reasoned or reasonable.

For most purposes, local rationality is sufficient for the purposes of economic models, because such models normally characterize only a subset of the choice settings that individuals confront Individuals that are rational in this sense tend to advance through aims through a long sequence of actions. It is, of course, the ability to characterize preferences with numbers that allows geometry and calculus to be used to characterize choices. Once "mathematized," mathematical deduction can be used to infer the effects of changes in constraints or preferences on the actions that a rational individual will undertake. Other aspects of choice settings determine the joint consequences of the choice made by groups of interdependent individuals.

The models used by economists, game theorists, and the rational choice strands of research in political science, sociology, and anthropology are all very similar to one another in spirit, in that they nearly all assume that people are basically rational—at least in the circumstances of interest. Microeconomics tends to focus most of its attention on the various choice settings that individuals confront, although occasionally it examines the various factors that influence the decision making process, itself. For example, a model may explore the effects of whether expectations are accurate or not, the processes used to evaluate the consequences of the choices that can be made, and the extent to which human computational power and informational limits affect the decision making process used.

VII. Organization of this Book

The book is organized into three parts. Part I reviews the basic logic of neoclassical price theory. The first three chapters of Part I use geometry, concrete functional forms, and abstract functional to model the choices of consumers, the output choices of firms and the production methods used to produce their goods and services. These provide the foundations for the neoclassical theory of price determination explore in Chapter 5. Part II reviews extensions of the competitive model to settings where time and uncertainties exist. Among the topics reviewed are entrepreneurship, the nature of the goods sold, and intra-firm decisionmaking and incentive structures. Part III reviews extensions of the rational choice model to non-market settings that are relevant for economics and other social sciences. Law, politics, and prevalent norms within a given society all have effects on the extent of markets within those societies.

Although the book may appear to focus for the most part on mathematical representations using tools from calculus, its main aim is to expose students to broad subset of the most well-known ideas, models, and results that emerged from rational-choice-based research in economics and related fields during the postwar period.

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Appendix I: Axiomatic Choice: Some Fundamental Concepts and Definitions from Mathematics used in Microeconomic Theory

A. When the rules of logic are applied to numbers the result is mathematics.

i. Most of the mathematics we have been taught can be deduced from a few fundamental assumptions using the laws of logic.

- (See the postulates of Peano, an Italian mathematician (1850 - 1932).)

ii. Some mathematical economists are very attracted to the axiomatic approach (See Debreu's book for an early example), and we will spend a bit of time today seeing who that approach can be used to model human choices.

B. Some fundamental properties of preference orderings:

i. DEF: Relationship R is **reflexive** in set X, if and only if aRa whenever a is an element of X.

ii. DEF: Relationship R is **symmetric** in set X if and only if aRb then bRa whenever a and b are elements of set X.

iii. DEF: Relationship R is **transitive** in set X if and only if aRb and bRc then aRc when a, b, and c are elements of set X.

iv. Recall that within the set of real numbers, there are relationships which are symmetric (equality),reflexive (equality) and transitive (equality, greater than, less than, greater than or equal than, less than or equal than).

v. In economics there are also several relationships which possess all three properties, and some that exhibit only transitivity.

vi. In general, economists assume that "rational" preference orderings satisfy all three of these properties. Strong and weak preference orderings are transitive, while indifference is transitive, symmetric and reflexive.

- Indeed, rationality in microeconomics is often defined as transitive preferences.

C. Note that the indifference relationship, I, can be defined in terms of the weak preference relationship R.

- The weak preference relationship R means "at least as good as."
- Note that if aRc and cRa, then aIc.

a. Similarly, the strong preference relationship, P, can be defined in terms of the weak preference relationship. The strong preference relationship means "better than."

- Note that if aRb but b~Ra then aPb.

D. On the Essential Mathematics of Utility Functions

i. DEF: A **function** from set X to (or into) set Y is a rule which assigns to each x in X a unique element, f(x), in Y. Set X is called the domain of function f and set Y its range.

- On most diagrams from math classes, the domain is the horizontal axis (X) and the range is the vertical axis (Y).
- However, most textbook diagram in economics have the domain of the function on the vertical axis (P) and the range of the function on the horizontal axis (Q). For example, demand functions go from P (prices) into Q (quantities a consumer is prepared to purchase).
- This is evidently Marshall's fault, who decided that the diagrams were easier to draw this way—possibly because of the use of blackboards back in the 1890s.

ii. DEF: A **utility function** is a function from set X into the real numbers such that iff aPb then U(a) > U(b) and if aIc then U(a)=U(c) for elements of the set X.

Note that when a utility function is defined in this way it does not necessarily characterize satisfaction, but rather choices based on transitive preferences. However, if you think of utility as "satisfaction" or closeness to some "goal" you intuition will be correct. In diagrams, indifference curves are simply graphs (plots) of all combinations of two goods that generate the same utility.

iii. Note that the assumption that a utility function exists, is equivalent to the assumption that individual preferences are transitive (within the domain of interest).

- Real numbers are transitive with respect to equality (indifference) and greater than (strict preference).
- The assumption that all combinations of the goods can be evaluated with the function implies that preferences are **complete**: each bundle (combination of goods and/or "bads") has a unique rank. a. Every bundle of goods generates either more or less or the same utility level as other goods.
- (Some theorists make a distinction between complete and incomplete utility mappings from X to R, but this distinction is not important for "routine" decisions, because of constraints on the domain of possibilities. Completeness is only important within those domains.)

E. Some important definitions and concepts from Set Theory.

i. DEF: An infinite series, x_1, x_2, ... x_n is said to have a **limit** at x* whenever for any d >0, the interval x* d, x* + d contains an infinite number of points from the series. (That is to say, x* is a limit point of a series in any case where there are an infinite number of elements of the series arbitrarily close to x*.)

ii. DEF: A set is **closed** if it contains all of its limit points.

iii. Def: A set is **bounded** if every point in A is less than some finite distance, D, from other elements of A.

iv. Def: A set is **compact** if it is closed and bounded.

- Most opportunity sets in economics are assumed to be closed and bounded.
- Def: A set is **convex** if for any elements X_1 and X_2 contained in the set, the point described as $(1-d)X_1 + dX_2$ is also a member of the set, where $0<d<1$.

v. Essentially a convex set includes all the points directly between any two points in the set.

- That is to say, any convex (linear) combination of two points from the set will also be a point in the set.
- Thus, a solid circle, sphere, or square shaped set is a convex set but not a V-shaped or U-shaped set.
- To see this, draw one of these figures, pick serve representative pairs of points and connect them with a line interval (cord). The line interval will lie entirely in the set.
- What other common geometric forms are convex?
- (Why does a series of convex combinations trace out a cord? Because as d varies from 0 to 1, the "point" characterizes moved along a line from one point (X_1) to the other (X_2.)

vi. Example from economics: "better sets" are usually assumed to be convex sets. That is to say, the set of all bundles which are deemed better than bundle "a" is generally assumed to be a convex set.

- Another example is the budget set, the set of all affordable commodities give a fixed wealth and fixed prices for all goods that might be purchased.

vii. **Convexity and compactness assumptions are widely used calculus and graphical models** of human decisionmaking, because they make smooth continuous functions (and lines) possible.

- Opportunity sets and production possibility sets are nearly always assumed to be convex and compact.