Physicomathematical Aspirations

The Invisible Hand. Economic Equilibrium in the History of Science. BRUNO INGRAO and GIORGIO ISRAEL. MIT Press, Cambridge, MA, 1990. xvi, 491 pp., illus. $47.50. Translated from the Italian edition (Roma-Bari, Italy, 1987) by Ian McGilvray.

Modern general economic equilibrium theory owes its origins to ideas that were developed between 1870 and 1911 by Léon Walras and Vilfredo Pareto, as successive occupants of an economics chair at the Academy of Lausanne, Switzerland. Chief among these ideas is the notion of an economy as a system of interdependent markets in which supply of and demand for any good depend not only on its own price but also on the prices of other goods.

The Invisible Hand is a history of general economic equilibrium theory in two stages. The work of Walras arises from precursors and that of Pareto extends it. Then in 1950 separate papers by Kenneth Arrow and Gérard Debreu emerge from work by mathematicians and economists in the 1930s and lead to research that continues today. Ingrao and Israel (an economist and a mathematician respectively) view the first stage primarily as an attempt to develop economics in analogy with 19th-century mechanics. They see the second as an effort to shape economics in analogy with 20th-century axiomatic mathematics, which largely abandons first-stage hopes for a theory capable of verification by real market phenomena.

Ingrao and Israel focus on cultural milieu and training as sources of economic thought. An opening scene of Newton's ideas diffusing as a philosophy of knowledge in French Enlightenment culture sets the stage. Montesquieu, the Physiocrats, Turgot, and Condorcet call for a mathematical social science, in some cases akin to physics. From 1781 through the mid-1850s Isnard, Canard, Dupuit, and Cournot—all trained in mathematics, physics, or engineering—make contributions to putting economics on a mathematical footing like mechanics. So by the time Walras makes his appearance he has many Newtonian shoulders to stand on.

Walras sees his project as the creation of a "physicomathematical" economic science. He studies mechanics at an early age, and a famous statics text of the day (Poinsot's *Eléments de statique*) influences him. His concept of general equilibrium, a set of prices, one for each good, is the centerpiece of his theory. For those prices all persons, constrained by their budgets, can consume amounts of goods that give them maximum satisfaction, and supply equals demand simultaneously in all markets. The second condition resembles the static equilibrium condition for a system of masses, with prices of goods replacing positions of masses and demand minus supply replacing net force.

Walras sought acknowledgment from mathematicians and scientists that he had created a mathematical science on a par with physics. Ingrao and Israel focus on the reaction of mathematicians in letters exchanged by Walras and Poincaré and in papers written by Volterra, Picard, and Painlevé, between 1901 and 1909. The authors of these appraisals are open to the idea of mathematical economics but doubt that the Lausanne school has an empirical economic science yet. Pareto, better trained in mathematics than Walras, consolidated the theory in his *Manuale di economia politica* of 1906, putting it on an ordinal rather than a cardinal utility basis. Later he sought unsuccessfully to make the theory more empirical with sociology.

After a period of dormancy, general equilibrium research reemerges in 1935 from the Vienna Circle, which champions axiomatization of the social and natural sciences. Walras erred in assuming that an equilibrium exists because a set of n simultaneous equations with n unknowns always has a solution. Stimulated by economists, two mathematicians close to the Circle—Abrahám Wald and John von Neumann—state axiom sets on market supply and demand functions. These imply that there is a price for each good for which supply equals demand simultaneously in all markets. In 1939 and 1941, John Hicks and Paul Samuelson suggest how to integrate time into the previously static theory.

A 1954 paper by Arrow and Debreu gives axioms on consumers and producers that imply that an equilibrium exists. In 1959 Debreu, trained in the Bourbaki school of axiomatic mathematics, publishes a monograph, *Theory of Value*, from which three streams of research branch out. One gradually weakens the Debreu axioms that imply the existence of equilibrium. The other two seek axioms that imply that an equilibrium is unique and stable and find some on market supply and demand functions. Ingrao and Israel argue, however, that these axioms contradict the Debreu existence axioms on consumers and producers.

The Invisible Hand considers the ideas of each thinker carefully, relating them to those of precursors and successors. It relies on both primary and secondary sources, supporting its interpretations with frequent quotations and weaving a rich and detailed narrative history. Mathematical sections on the contents of general equilibrium theory may intimidate some readers, but those who struggle with them will improve their grasp of the theory. Those who skip them will lose little in understanding the history.

A weakness of the book is its imbalanced consideration of the precursors of Walras. In addition to the French thinkers discussed Walras read Adam Smith and John Stuart Mill, whose influences the authors decide to ignore. Both Smith and Mill have a price for which supply of a good equals demand, though no idea that supply of and demand for a good depend on prices of other goods. That idea follows from the maximum satisfaction condition, which originates with Jeremy Bentham. So Walras also mathematically consolidated the ideas of English economic predecessors. The analogy between his theory and statics is largely mathematical, that is, the two theories contain similar forms of equations.

The book also does not adequately explain the nonempirical nature of Walras's theory. If statics is empirical and Walras's theory is similar to statics, then why is it not also empirical? The answer is that Walras's theory is only similar to a *part* of statics. Walras defended his theory on the grounds that it was like a mechanics without friction, which applied economists, like applied physicists, could use in real situations. However, his theory lacks analogs of Newton's gravitational law and Hooke's law, which make statics empirical, that is, imply how equilibrium positions are related.

Finally, the authors exaggerate the extent to which modern research abandons the goal of an empirical theory. There are no obvious universal laws that make Walras's theory empirical like statics. So axiomatic approaches clarify the assumptions that imply that an equilibrium exists and seek to weaken them into plausible descriptions of real economies. Debreu, regarding Walras's original assumptions as too strong, weakened them in the 1950s, believing that such weakening makes the theory more useful. Though the weakest axioms now available are not yet plausible, there is little reason to doubt that researchers aim at more empirically descriptive axioms.

The Invisible Hand pioneers as the first book-length history of general economic equilibrium theory and one of the first to explore the relation of economics and physics. Does Walrasian theory resemble a mechanics without laws that make its propositions empirical? Are the assumptions of modern theory plausible for real economic agents? Are they consistent? Do applied economists particularize modern theory's conclusions and check them against real economies? Is general economic equilibrium a scientific theory yet? Many economists, physicists, and historians and philosophers of economics and science will want to ponder these questions. *The Invisible Hand* is excellent food for such thought.

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A Southward Endeavor

The Creation of the Anglo-Australian Observatory. S. C. B. GASCOIGNE, K. M. PROUST, and M. O. ROBINS. Cambridge University Press, New York, 1991. xiv, 301 pp., illus. $59.50.

Nearly all large optical telescopes have, until fairly recently, been sited in the Northern Hemisphere. Astronomers in Britain as elsewhere have long pressed for better views of the southern heavens. In the 1830s, for example, John Herschel transported a big reflecting telescope from England to the Cape of Good Hope. There he extended the surveys of nebulae and star clusters that his father, William, had begun in the late 18th century. In 1869, a 48-inch reflector—probably the first large telescope that a committee played a key role in planning—was shipped from Britain and put into service at Melbourne in Australia. It was a failure.

The Anglo-Australian Observatory is a far more recent example of an astronomical enterprise involving Britain and Australia. The result of many years of lobbying and politicking by astronomers, civil servants, and politicians in Australia and Britain, the observatory was in effect established in 1970 with the Anglo-Australian Telescope Agreement. The observatory is now most famous for the Anglo-Australian Telescope (AAT), a powerful reflector with a primary mirror 3.9 meters in diameter sited at Siding Spring in Australia. Regular observations with this instrument commenced in 1975. It has won a reputation among astronomers as a very successful and cost-effective telescope.

The Creation of the Anglo-Australian Observatory describes the events leading up to the founding, as well as the early years, of the observatory, most particularly the planning for and construction of the AAT. There is much here for those interested not just in the scientific and technical aspects of the observatory but also in its managerial and political history. The authors also make a good case that to understand the observatory's history all these factors have to be taken into account. In so doing, the authors shift easily between the discussions at the working levels of engineers and scientists to those that took place at high political levels, occasionally involving government ministers in both Australia and Britain. A long and acrimonious debate over the role the Australian National University would play in running the observatory is also well treated.

The book, however, has some problems. All three authors have participated to various degrees in the observatory's history. Though this has provided them with inside information, it has had two unfortunate consequences. First, long slabs of text seem simply to be personal recollections and opinions, and not the products of careful historical research and synthesis. Whether or not this is truly the case is hard to judge because of the small number of footnotes. Those included are not always of much help. To be informed, for instance, that "correspondence quoted in this chapter is found in the archives of the Australian Government agency" is useless. The authors are also inclined on occasion to write text that is overburdened with details or resembles official minutes. Sometimes when we are told of a particular decision, for example, we are given no clear sense of the process that brought it about. Nor have the authors made much of an attempt to connect issues and themes in the text to a broader literature. Early in the book there are a few references to big science, yet this potential theme is promptly dropped, and there are also several other themes implicit in the text that are never fully probed or connected with each other.

The Creation of the Anglo-Australian Observatory will be of interest to those who worked to create, and who have worked at, the observatory. It will also doubtless provide policymakers and future historians with material and pointers, but it is some way from a properly documented and well-rounded work of history.

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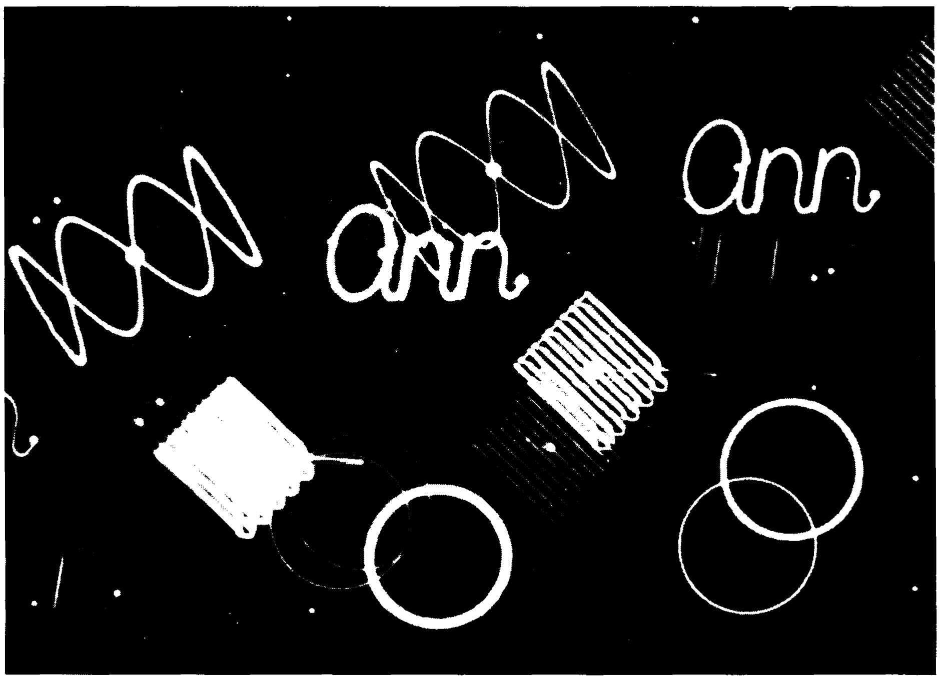
Music Producers

The Physics of Musical Instruments. NEVILLE H. FLETCHER and THOMAS D. ROSSING. Springer-Verlag, New York, 1990. xviii, 620 pp., illus. $69.

A well-built musical instrument is a thing of great beauty, and not only in the obvious sense of producing exquisite sounds. It is also a piece of visual art, sometimes explicitly in its elaborate decorations but always in its marriage of form with function. Put this together with the intimate relationship a great performer achieves with the instrument, and you may well be discouraged from performing an analytic dissection to



"The Ann plate. This was taken to demonstrate the variety of patterns which the computer can cause the [Anglo-Australian Telescope] to trace on the sky. Stars which happen to be in the field mark out the patterns made by the moving telescope. The lines in the raster scans are separated by 10 arc seconds." [From *The Creation of the Anglo-Australian Observatory*]