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Book review

Causality: Models, Reasoning, and Inference
by Judea Pearl (Cambridge University Press, 2000)

Pearl's *Causality* is an impressive work, covering a wide spectrum of interdisciplinary approaches toward understanding, identifying, and measuring "causality." It addresses philosophical issues on occasion, and provides useful examples of applications of causal inference and related areas of inquiry to resolving problems in epidemiology, law, economics, and other disciplines. However, though it provides numerous practical methods for analyzing causality, the book might also be described as heavily axiomatic, in the style and spirit of a graduate-level mathematics textbook, making it most appropriate for graduate students, instructors, and advanced practitioners who would already be familiar with the basic principles of mathematical statistics.

In the order they appear in the book, the major topics addressed are: probability theory and Bayesian approaches; inferred causation; causal diagrams; actions, plans and direct effects; structural models; confounding and collapsibility; the logic of counterfactuals; imperfect experiments; probability of causation; the concept of "actual cause"; and an epilogue about the history of thought on causality. Pearl's handling of these topics is quite well done. His command of the subject matter and the relevant literature is excellent, clearly capturing the "high ground" of understanding.

The book does have certain flaws, however. The greatest of these is the author's harsh critique of the social sciences, and economics in particular, in which he implies in various ways that these areas of inquiry have virtually ignored issues of causality. In particular, he vehemently attacks structural equation modeling (SEM), as in the passage:

> Today the enterprise known as structural equation modeling is increasingly under fire. The founding fathers have retired, their teachings are forgotten, and the practitioners, teachers, and researchers currently find the methodology they inherited difficult to either defend or supplant. Modern SEM textbooks are preoccupied with parameter estimation and rarely explicate the role that those parameters play in causal explanations or in policy analysis; examples dealing with the effects of interventions are conspicuously absent, ... issues pertaining to the meaning and usage of SEM's models are subjects of confusion and controversy. ... I am thoroughly convinced that the contemporary crisis in SEM originates in the lack of a mathematical language for handling the causal information embedded in structural models.

There are three problems with this assessment. The first, and most obvious from the author's discussions, is that he has focused primarily on the statistical literature within the

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fields that he has examined — that is, in his investigation of economics, his perspective has apparently been built upon a familiarity with the literature in econometrics alone.

It is true that SEM in econometric literature does not devote much attention to issues of causality. To conclude, from there, that economic thought, itself, lacks proper attention to causality, or, as he mentions on page 149, "the users of SEM should concentrate on examining the implicit theoretical premises that enter into a model," is completely unfounded. Causality and the "theoretical premises that enter into a model" are not addressed very much in econometrics because they are already addressed extensively in the subject matter of economics itself. Econometrics is not economics, nor does it ever purport to be — it is simply a specialized tool of economic analysis. Every introductory economics textbook since Paul Samuelson's earliest editions decades ago, usually by page 20 in the first or second chapter, makes mention of fallacies in economic thinking, among them being the "fallacy that association is causation," the "fallacy of composition," and others. Though these ideas are not expressed in formal axiomatic language (as introductory students would not understand them in that context), the fact remains that the direction of causal factors is an integral part of all economic thought — it is, in fact, what the subject of economics is all about. Therefore, criticizing econometrics for ignoring causality is analogous to criticizing the owner's manual of a car for ignoring safe driving practices. Just as safe driving habits are an integral part of learning how to drive, but not an integral part of maintaining a car, consideration of causality is an integral part of economic thought and the initial creation of structural models, but not an integral part of the econometric estimation of those structural models.

Similarly, in promoting the use of structural diagrams on causality (a central theme of the book), Pearl is overly critical (in Chapter 5 especially) of standard mathematical notation, like the equation $Y=a+bX$, which he claims ignores causality. The equation $Y=a+bX$ may, or may not, ignore causality, depending on how the subject matter is treated. In many contexts, that equation is, in fact, taken to mean that X causes Y, even though it is not explicitly designated as such by a special symbol, like the arrows that Pearl uses in his causal diagrams. Every economics paper, for example, tells a "story," and if that story, in written words, explains how and why "X causes Y," then the relevant information is already conveyed, and special symbols are simply extraneous artifacts. Yet, Pearl generally interprets the superficial absence of special symbols as necessarily reflecting a lack of interest in causality. He appears to be overly enveloped in a diagrammatic and axiomatic universe in which all that matters are the properties of explicitly stated equations, as though those equations alone are responsible for capturing completely the background knowledge of the topic at hand. (Perhaps in physics that assumption might be applicable, but in most other fields, especially in the social sciences, it is not.) This limited perspective is not adequate for judging the degree of attention that is truly paid to causality in disciplines that utilize structural equation models, no more than one might accuse historians for a lack of interest in causality due to their use of written words as opposed to causal diagrams.

Researchers in the sciences and social sciences have a different objective than to formally outline all causal assumptions as if they were writing a textbook that assumed zero background knowledge. That does not necessarily mean that they pay too little attention to causality. The true test of whether there is enough interest in causality should be based on whether the quality and usefulness of their discourse would be improved through greater

interest in causality, and should not be based on the shallow absence of causal diagrams in their published documents.

A third and final problem with Pearl's critique of SEMs is that, in spite of his book's title, he should properly acknowledge that causality is not "everything." Structural models may be used to answer questions about associations among variables, rather than questions about causal influences, especially when the variables of interest are known to have a circular influence over each other. For instance, a nation's level of research and development (R&D) expenditures surely affects its gross domestic product (GDP), as R&D leads to improved products and processes, and thus to economic growth. The greater the GDP, on the other hand, the more R&D there will be, since R&D must be financed from the earnings of the nation's institutions. Each variable surely has a causal effect on the other, but a structural model that incorporates both, without ironing out all the causal details, might still be useful for forecasting next year's levels of R&D and GDP, even though the causal relationships are ambiguous. Forecasting literature, in general, often downplays the importance of understanding true causal relations, as such knowledge may be peripheral to accurate forecasting as an end in itself. Much of his book, in its critique of SEMs and other methods, however, appears at times to implicitly assume that causal knowledge is the only form of useful knowledge.

One other significant limitation of the book is with regard to its style and organization. Most of the chapters appear to have been independent papers at one time, which were partially rewritten and bound together into a single volume. The book, in other words, is not unlike books that compile the proceedings of a workshop, though in this case, each paper is by the same author. Though the book could easily serve as a textbook for a course, it could be better organized for that purpose. For example, introductory material is often repeated: Markovian and semi-Markovian models are first explained in Chapter 3 on pages 68–69, and explained again in Chapter 5 on pages 140–41 in very similar language; the "d-separation criterion" is first explained in Chapter 1 on pages 16–17, and repeated in Chapter 5 on pages 146–47; etc. In addition, the level of difficulty varies considerably from introductory material to cutting-edge theory in mathematical discourse. If causality, as an interdisciplinary subfield in its own right, eventually takes off, then we may one day see Pearl's *Causality* re-worked into a more student-friendly textbook, with smoother transitions between difficult concepts, richer diagrams and real-world examples, and problem sets in the back of chapters. At present, such student-friendliness is not quite there, though it is certainly achievable.

The book's style as essentially a collection of related works is revealed most by its epilogue at the end, which is identified as "a public lecture delivered November 1996 as part of the UCLA Faculty Research Lectureship Program." In that section of the book, for instance, Pearl writes, "My colleagues from Boelter Hall are surely wondering why I stand here before you blathering about an engineering triviality ... " leaving most readers to speculate that Boelter Hall might be the location of UCLA's School of Engineering. That lecture, itself, is quite interesting, though it is propagandistic regarding the importance of causal diagrams, i.e., suggesting that they are necessary for the existence of "deep understanding." In essence, the book goes a bit too far in promoting the cause of causal diagrams, especially in its occasional criticism of other research methods like structural equation models.

Nonetheless, within the subject matter for which Pearl is truly a leading expert — causality as studied through models, reasoning, and inference — the book is well grounded, thorough, and highly valuable. Pearl demonstrates how principles of causality, along with causal diagrams and associated equations in probability analysis, are essential for proper analysis of real-world problems. Examples of problems that he analyzes include legal cases involving liability suits, investigations in epidemiology, and clinical trials in medical research. He also lays out the groundwork for the creation of rules that may eventually (if not already) enable artificial intelligence programs to identify cause and effect.

Pearl's *Causality* offers a great deal of clarity, which is manifested through contributions in causal diagrams and mathematical language. His introduction and utilization of the "do operator," which is offered within the language of probability theory, is first introduced in Chapter 3. As a concept, the "do operator" is particularly helpful for understanding the distinction between "intervention" (as in a controlled experiment) and confounding (association not attributable to causation). Likewise, his discussion and analysis of counterfactuals in Chapter 7, and bounded causal effects in Chapter 8, are quite extensive and have a wide range of useful applications in nearly all areas of scientific research. Overall, the book covers the topic of causality in a serious, intense manner, and at the highest level of detail and complexity that one might ever find in any book of its kind. Pearl's *Causality* truly expands the envelope.

For those people who are genuinely interested in the topic of causality, the book will be intriguing. Consider, for example, the "desert traveler" problem that Pearl poses in Chapter 10: A person traveling in the desert has two enemies trying to kill him. One finds a way to mix deadly poison into the water of his canteen, but before the traveler could drink the poison, the other enemy empties the canteen by shooting a hole in it. The traveler dies of dehydration, but which enemy could be said to have "caused" his death? If you do not know the answer, you need to buy Pearl's *Causality* and find out for yourself. It is a "must buy" for anyone who is responsible in their professional work for answering serious questions about causality, regardless of what that work might entail. If "causality" ever becomes a field of study in its own right, analogous to statistics, physics, or economics — an idea that the book certainly promotes — then Pearl's *Causality* might some day be recognized as a major cause of that effect.

Steven Payson
Virginia Polytechnic Institute
Northern Virginia Center Falls Church, VA 22043
E-mail address: SvPayson@aol.com