

Taking Causality Seriously: Propensity Score Methodology Applied to Estimate the Effects of Marketing Interventions

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Propensity score methods were proposed by Rosenbaum and Rubin (1983, *Biometrika*) as central tools to help assess the causal effects of interventions. Since their introduction two decades ago, they have found wide application in a variety of areas, including medical research, economics, epidemiology, and education, especially in those situations where randomized experiments are either difficult to perform, or raise ethical questions, or would require extensive delays before answers could be obtained. Rubin (1997, *Annals of Internal Medicine*) provides an introduction to some of the essential ideas. In the past few years, the number of published applications using propensity score methods to evaluate medical and epidemiological interventions has increased dramatically. Rubin (2003, Erlbaum) provides a summary, which is already out of date.

Nevertheless, thus far, there have been few applications of propensity score methods to evaluate marketing interventions (e.g., advertising, promotions), where the tradition is to use generally inappropriate techniques, which focus on the prediction of an outcome from an indicator for the intervention and background characteristics (such as least-squares regression, data mining, etc.). With these techniques, an estimated parameter in the model is used to estimate some global “causal” effect. This practice can generate grossly incorrect answers that can be self-perpetuating: polishing the Ferraris rather than the Jeeps “causes” them to continue to win more races than the Jeeps $j=i$, visiting the high-prescribing doctors rather than the low-prescribing doctors “causes” them to continue to write more prescriptions.

This presentation will take “causality” seriously, not just as a casual concept implying some predictive association in a data set, and will show why propensity score methods are superior in practice to the standard predictive approaches for estimating causal effects. The results of our approach are estimates of individual-level causal effects, which can be used as building blocks for more complex components, such as response curves. We will also show how the standard predictive approaches can have important supplemental roles to play, both for refining estimates of individual-level causal effect estimates and for assessing how these causal effects might vary as a function of background information, both important uses for situations when targeting an audience and/or allocating resources are critical objectives.

The first step in a propensity score analysis is to estimate the individual scores, and there are various ways to do this in practice, the most common

being logistic regression. However, other techniques, such as probit regression or discriminant analysis are also possible, as are the robust methods based on the t-family of long tailed distributions. Other possible methods include highly non-linear methods such as CART or neural nets. A critical feature of estimating propensity scores is that diagnosing the adequacy of the resulting fit is very straightforward, and in fact guides what the next steps in a full propensity score analysis should be. This diagnosing takes place without access to the outcome variables (e.g., sales, number of prescriptions) so that that objectivity of the analysis is maintained. In some cases, the conclusion of the diagnostic phase must be that inferring causality from the data set at hand is impossible without relying on heroic and implausible assumptions, and this can be very valuable information, information that is not directly available from traditional approaches.

Marketing applications from the practice of AnaBus, Inc. will also be presented. AnaBus currently has a Small Business Innovative Research Grant from the US NIH to implement essential software to allow the implementation of the full propensity score approach to estimating the effects of interventions. Other examples will also be presented if time permits, for instance, an application from the current litigation in the US on the effects of cigarette smoking (Rubin, 2002, Health Services Outcomes Research).

An extensive reference list from the author is included. These references are divided into five categories. First, general articles on inference for causal effects not having a focus on matching or propensity scores. Second, articles that focus on matching methods before the formulation of propensity score methods – some of these would now be characterized as examples of propensity score matching. Third, articles that address propensity score methods explicitly, either theoretically or through applications. Fourth, articles that document, by analysis and/or by simulation, the superiority of propensity-based methods, especially when used in combination with model-based adjustments, over model-based methods alone. And fifth, introductions and reviews of propensity score methods. The easiest place for a reader to start is with the last collection of articles.

Such a reference list is obviously very idiosyncratic and is not meant to imply that only the author has done good work in this area. Paul Rosenbaum, for example, has been an extremely active and creative contributor for many years, and his text book “Observational Studies” is truly excellent. As another example, Rajeev Dehejia and Sadek Wahba’s 1999 article in the *Journal of the American Statistical Association* had been very influential, especially in economics.

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