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ABSTRACT

This paper discusses four criteria for selecting covariates when utilizing the analysis of covariance in quasiexperimental research: completeness, causation, independence, and fallibility. Completeness is the extent to which the known or suspected sources of bias are accounted for by covariates used in an experiment. Causation is the requirement that covariates used in nonrandom research designs are causally related to the dependent variable of a study. Independence is the requirement that there is no treatment/covariate interaction. Fallibility refers to the reliability of the covariate measure. Ways of determining to what degree these criteria are met are suggested. (Author)

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Criteria for the Selection of Covariates in Nonrandomized Designs

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University of Pittsburgh, 1983

ABSTRACT

This paper discusses four criteria for selecting covariates when utilizing the analysis of covariance in quasi-experimental research: Completeness, Causation, Independence, and Fallibility. Completeness is the extent to which the known or suspected sources of bias are accounted for by covariates used in an experiment. Causation is the requirement that covariates used in nonrandom research designs are causally related to the dependent variable of a study. Independence is the requirement that there is no treatment/covariate interaction. Fallibility refers to the reliability of the covariate measure. Ways of determining to what degree these criteria are met are suggested.

Keywords: Analysis of Covariance (ANCOVA): Quasi-Experiment; Nonrandomized Design; Covariate Selection.

I like to classify the criteria for the selection of covariates in quasi-experimental research using the analysis of covariance into four categories: Completeness, Causation, Independence, and Falibility. The first two criteria concern the association of a covariate with the dependent variable. The third criterion, Independence, concerns the relation of the covariate with the treatment of an experiment. The fourth criterion, Falibility, concerns the accuracy of measurement of the covariate.

The purpose of the use of ANCOVA in quasi-experimental research is to remove bias from a study, to statistically adjust for pre-treatment differences between treatment groups in order to eliminate rival hypotheses that post-treatment differences in a study are functions of factors other than treatment. To accomplish this, covariates utilized in a research study must be causally related to the dependent variable. This is the criterion of causation. In other words, to make adjustment for bias, the covariates used must be sources of bias. This is an essential difference between the use of ANCOVA in quasi-experimental research and in true experimental research. In true experimentation using ANCOVA, as H. F. Smith (1957) has argued, it does not matter whether the covariate is causally related to the dependent variable. What does matter is the strength of the relation between the dependent variable and the covariate. The works of Cox (1957) and Feldt (1958) address the importance of the degree of this strength of relation for the use of ANCOVA in true experimentation.

In order to remove bias and eliminate rival hypotheses, the researcher must identify the known sources of bias and utilize these sources as covariates in an analysis. This is the criterion of completeness. It is only when these sources of bias are adjusted in the analysis that a study may be considered to be unbiased. In the words of Cook and Campbell,

> When it appears that all plausible biases have been taken into account and a treatment emerges in spite of them all, conclusions can be made with reasonable confidence. (Cook & Campbell, 1979,p.201)

The emphasis of this criterion is on known and plausible sources of bias. When research involves human subjects, the possible sources of bias may be many. For this reason, a researcher planning to use ANCOVA in quasi-experimentation must be well-versed in previous research on the experiment of interest and in both the subjects and treatments to be used. It is with this dual knowledge that known and plausible sources of bias can be accounted for and utilized, and, in this manner, the conclusions of a study may be considered to be relatively unbiased.

The criterion of causation is met by incorporating as covariates only those variables that derive from a convincing causal model for the dependent variable. The researcher should report that the results of a study are conditional upon the sources of bias that were removed, and, therefore, the conclusions of a study are also conditional upon this adjustment.

The third criterion, Independence, refers to a lack of interaction between the covariates and the treatment of a study. The importance of this criterion is not so much for its effect on the ANCOVA model and statistical technique, but rather for its effects on the feasibility of conclusions of a study using ANCOVA. That is, "...the covariate being unaffected by the treatment is of great importance ... if the interpretation of the adjusted treatment means is to be meaningful." (Baker, 1972, p.32). When there is covariate/treatment interaction, the regression adjustment on the dependent variable, "...may remove part of the treatment affect or produce spurious treatment affect." (Elashoff, 1969, p.388)

A way to test this independence was proposed by Huitema in 1980. He suggests that an analysis of variance be performed on covariates across groups under study. His rationale for this is that,

> If treatments have not been applied but the ANOVA F is significant this is a warning that the ANCOVA F and adjusted means are almost certain to be biased as reflects the treatment effects. If the ANOVA on the covariates is not significant, the ANCOVA F and adjusted means are still subject to problems of bias but the degree of bias, although unknown, may not be large. (Huitema, 1980,p.109)

Although this test does not provide a definitive answer to whether or not the covariates and treatment are independent, it does provide useful information about this criterion. It is recommended that this test be routinely performed as part of an analysis of covariance.

Another way to test this, particularly when a researcher wishes to test the feasibility of the use of a variable measured either during or after the application of treatment, ie. a cross-sectional covariate, is to analyze a post-treatment covariate by a pre-treatment covariate. Because a cross-sectional covariate is assumed to be independent of treatment, it seems reasonable that two measures of this covariate, one pre-treatment, one post-treatment, would not show a significant difference from one another. A possible way to test this is to perform an analysis of covariance on the post-treatment variable covarying on the pre-treatment or longitudinal measure of the same variable. It would be expected that the ANCOVA F will not be significant. If this was not the case, it would indicate that the cross-sectional covariate, which was assumed to be statistically independent of treatment, was affected by treatment and that the results of a study using this covariate would be biased. This is a test of assumed independence of covariates which are measured during or after the application of treatment and may prove useful to researchers who are considering the utilization of a cross-sectional covariate in their research. To be sure, it requires extra time and work, but it may be of value as a justification for the use of a covariate which is measured during or after the application of treatment.

The fourth criterion, Falibility, refers to how well the covariate utilized in a study is measured without error; the reliability of the covariate measure. This criterion comes from the assumption of the ANCOVA model that, "...the covariate is a fixed mathematical variable measured without error, not a stochastic variable." (Wildt & Ahtola, 1978, p.89) In quasi-experimental designs where subjects are not randomly assigned to treatment, the falibility of the covariate measure can be of particular importance because, "...if the covariate means are not equal, the difference between the adjusted means is partly a function of the reliability of the covariate." (Huitema, 1980,p.113). While in randomized designs the affect of unreliability is to lower the precision of the F test, in nonrandomized or quasi-experimental designs, the degree of falibility of the covariate may affect the meaning and interpretability of the results of an analysis. That is, adjusted mean differences could be a reflection of the reliability of the covariate measure rather than adjustments for bias, and consequently the results of the analysis could be misrepresentations. There are two suggestions regarding this criterion. First, a researcher should utilize the most reliable available apparati in the measurement of covariates. Second, a researcher should check the reliability of the instrument after its use in a study. Although this latter point adds a burden to a quasi-experimental study using ANCOVA, with the present availability of statistical computer packages, and considering the importance of this criterion on the meaning of results, the slight inconvenience of this procedure is well worth the time it takes to conduct.

As Glass, Peckham, and Sanders pointed out, the assumptions of a statistical model, "...are always false to a greater or lesser degree."(1972,p.237) This is also true for meeting these criteria for covariate selection in quasi-experimental designs; the criteria are never entirely met, they are only collectively achieved by degree. Researchers should strive to meet all of these criteria but, in lieu of that, they should report the degree to which criteria are met and take this into account when interpreting and reporting results and meaning of a study.

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