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Should age-period-cohort studies return to the methodologies of the 1970s?

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A B S T R A C T

Social scientists have recognized the importance of age-period-cohort (APC) models for half a century, but have spent much of this time mired in debates about the feasibility of APC methods. Recently, a new class of APC methods based on modern statistical knowledge has emerged, offering potential solutions. In 2009, Reither, Hauser and Yang used one of these new methods – hierarchical APC (HAPC) modeling – to study how birth cohorts may have contributed to the U.S. obesity epidemic. They found that recent birth cohorts experience higher odds of obesity than their predecessors, but that ubiquitous period-based changes are primarily responsible for the rising prevalence of obesity. Although these findings have been replicated elsewhere, recent commentaries by Bell and Jones call them into question – along with the new class of APC methods. Specifically, Bell and Jones claim that new APC methods do not adequately address model identification and suggest that "solid theory" is often sufficient to remove one of the three temporal dimensions from empirical consideration. They also present a series of simulation models that purportedly show how the HAPC models estimated by Reither et al. (2009) could have produced misleading results. However, these simulation models rest on assumptions that there were no period effects, and associations between period and cohort variables and the outcome were perfectly linear. Those are conditions under which APC models should never be used. Under more tenable assumptions, our own simulations show that HAPC methods perform well, both in recovering the main findings presented by Reither et al. (2009) and the results reported by Bell and Jones. We also respond to critiques about model identification and theoretically-imposed constraints, finding little pragmatic support for such arguments. We conclude by encouraging social scientists to move beyond the debates of the 1970s and toward a deeper appreciation for modern APC methodologies.

1. Introduction

Shortly after Norman Ryder's classic treatise about the influence of birth cohorts on social change (Ryder, 1965), debates emerged over the simultaneous estimation of age, period and cohort (APC) effects in the social sciences. Some scholars argued that confounding between APC effects (the so-called identification problem) was intractable (Glenn, 1976), requiring the elimination of one of three temporal dimensions in APC analyses (Baltes, 1968). Other scholars challenged such views, contending that identification problems could be reasonably addressed (Pullum, 1980), and that it was not only possible to estimate APC models, but necessary in many instances to avoid erroneous conclusions (K. O. Mason et al., 1973).

These debates persisted with little resolution for over thirty years. But over the past decade, scholars have taken note of the

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fact that the concepts and tools of statistics have evolved since the 1970s and, by applying these, have developed several innovative methodologies in APC research (Yang and Land, 2013a) that could deliver more reliable tools of discovery to social scientists. Capitalizing on these developments, Reither et al. (2009) examined the separate contributions of secular change (periods of observation), biological age, and birth cohort membership to the U.S. obesity epidemic. Using a methodology called hierarchical APC estimation with cross-classified random effects modeling (HAPC-CCREM), the study found that younger birth cohorts were generally at higher risk for obesity than their predecessors, even after accounting for age and period of observation. However, recent increases in obesity prevalence were primarily attributable to sweeping, period-based secular changes that have affected virtually all Americans. In a commentary on this study, Harding remarked that new APC approaches like HAPC-CCREM "have the potential to re-invigorate research investigating age, period, and cohort effects and increase our confidence in APC analyses" but also cautioned that such techniques "have yet to be widely adopted or evaluated by other researchers or methodologists" (Harding, 2009, 1451).

In a recent issue of *Social Science & Medicine*, Bell and Jones (hereafter, B&J) challenge the widespread adoption of new APC techniques (2014b) through a critical evaluation of the HAPC-CCREM approach used by Reither et al. (2009) in their study of obesity. Specifically, B&J argue that (1) Reither et al. did not adequately address the identification problem, (2) it is plausible that the U.S. obesity epidemic is rooted in cohort-based changes that occurred throughout the 20th century, and (3) the HAPC models estimated by Reither et al. could have generated misleading results – although they stop short of asserting that this is actually the case.

Through the following discussion, we address each of these critiques in turn. The arguments and simulation models in our study have important implications, not only for the findings reported by Reither et al. (2009) and the challenges raised by B&J, but also for the future of HAPC modeling and innovative APC methods in general.

2. The identification problem

Discussing the identification problem in APC models, B&J (2013; 2014b, 177) cite the identity: Age = Period – Cohort, and state: "As such, if we know the value of two of the terms, we will always know the value of the third." This reflects the common confusion of the nature and origin of the "identification problem" in APC analysis. It was clearly exposited in the early works of Mason et al. (1973) that this problem occurs only when both of two conditions are simultaneously met: 1) age, period, and cohort variables are linearly related to each other (Age = Period – Cohort); and 2) each variable is postulated to be linearly related to the outcome (Y). A major deficiency of prior studies is the exclusive focus on condition 1 (as is the case in B&J) and the avoidance of condition 2. That is, in the absence of the latter, the former would not induce the problem by itself. The problem is inevitable only when the three linearly related variables are treated as independent and additive factors in a linear model. Therefore, a critical insight into this old problem is that it is not data specific, but model specific (Fu, 2008).

In the context of the classical single-equation APC accounting/regression model of Mason et al. (1973), conditions 1 and 2 are both satisfied and hence the problem ensues. In this conventional APC research design where population level data in terms of rates or proportions are tabulated in an age-by-time period table, widths of the Age and Period intervals are fixed and equal and Cohorts are then arrayed along the diagonals as linear combinations of Period – Age. It is important to note that there is only one observation per age-by-period cell. Condition 1 is certainly true in this data structure. And the specification of linear models to such data leads to the identification problem by also providing condition 2.

As Yang and Land (2006, 2013a) have emphasized, however, the repeated cross-section sample survey research design is not the same as the classical age-by-time period table of rates and offers opportunities to address both conditions 1 and 2. Specifically, the repeated cross-section survey design allows for the flexibility of defining temporal widths of the time periods and birth cohorts to be not identical to the ages of the individual sample respondents and hence facilitates the loss of the exact algebraic identity stated in condition 1. In addition, the presence of multiple observations instead of one observation in each period-by-cohort cell makes it more transparent that the data follow a multilevel structure that includes individual-level observations on the ages (typically recorded in sample surveys as age in single years at last birthday at the time of the survey) of the sample respondents that are then nested in higher-level units or contexts such as historical periods and birth cohort memberships. Accordingly, the statement from B&J quoted above need not apply to the APC analysis of repeated cross-section surveys if full advantage of this flexible data structure is utilized.

B&J (2014b, 177) next assert that: "Yang and Land's proposed solution is to use a cross-classified multilevel model, which treats age as a fixed effect and periods and cohort groups as random effects – contexts in which individuals reside." That is certainly an approach that Yang and Land (2006, 2013a) have taken in developing the HAPC-CCREM class of models. In the context of the above introduction, this new family of models is employed to address condition 2 based on the characteristics of the multilevel data using sample surveys.

Bell and Jones (2014b, 177) go on to say "it has been shown elsewhere that this methodological advance in fact amounts to another constraint" citing as authority an unpublished paper (Luo and Hodges, 2013) that incorrectly assumes that the statistical model for HAPC-CCREM analysis is that of the classical single-equation APC accounting model, and that also tests the HAPC approach by assuming exact linear algebraic (i.e., no stochastic/random component) period- and cohort-based trends in the model.[1] In fact, and as clearly stated by Yang and Land (2006, 2013a), HAPC-CCREMs, as with any class of statistical models, are based on statistical assumptions. In any specific empirical application, these assumptions should be evaluated. For instance, the HAPC-CCREM, as with any mixed (fixed and random) effects model, assumes zero correlation between the individual-level regressors and the random period and cohort effects. As noted by Yang and Land (2008, 2013a), this assumption can be assessed by application of a Hausman-type chi-square test. If the zero correlation assumption is rejected, then the model specification can be modified by treating either the time period or cohort effects (or both) as fixed.

3. A perspective on time periods and cohorts as contexts and as random variables

In the classical APC accounting/linear regression model – which evidently is assumed by B&J (2013, 2014a, b) to be the only proper

[1] B&J (2013, 1) also cite an article (Luo, 2013) as "… questioning the capabilities of … other methodological innovations to disentangle APC effects." They do not cite the response of Yang and Land (2013b) to Luo (2013), which shows that the Luo application is incorrectly applied and misleading.