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Clarifying hierarchical age–period–cohort models: A rejoinder to Bell and Jones

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ABSTRACT

Previously, Reither et al. (2015) demonstrated that hierarchical age–period–cohort (HAPC) models perform well when basic assumptions are satisfied. To contest this finding, Bell and Jones (2015) invent a data generating process (DGP) that borrows age, period and cohort effects from different equations in Reither et al. (2015). When HAPC models applied to data simulated from this DGP fail to recover the patterning of APC effects, B&J reiterate their view that these models provide "misleading evidence dressed up as science." Despite such strong words, B&J show no curiosity about their own simulated data—and therefore once again misapply HAPC models to data that violate important assumptions. In this response, we illustrate how a careful analyst could have used simple descriptive plots and model selection statistics to verify that (a) period effects are not present in these data, and (b) age and cohort effects are conflated. By accounting for the characteristics of B&J's artificial data structure, we successfully recover the "true" DGP through an appropriately specified model. We conclude that B&Js main contribution to science is to remind analysts that APC models will fail in the presence of exact algebraic effects (i.e., effects with no random/stochastic components), and when collinear temporal dimensions are included without taking special care in the modeling process. The expanded list of coauthors on this commentary represents an emerging consensus among APC scholars that B&J's essential strategy—testing HAPC models with data simulated from contrived DGPs that violate important assumptions—is not a productive way to advance the discussion about innovative APC methods in epidemiology and the social sciences.

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We would like to thank Bell and Jones (henceforth B&J) for highlighting some areas of agreement in their commentary (2015) on our recent defense of innovative age–period–cohort (APC) methods (Reither et al., 2015). To our understanding, we have achieved consensus on the following points:

- APC data are generated by historical and social processes, not by algebraic functions invented in data laboratories.
- In the presence of exact linear effects, traditional specifications of APC models will fail.

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- From a conceptual standpoint, it is appropriate to treat birth cohorts and periods of observations as random effects.
- Although theory and speculation are useful, they cannot replace evidence in any field of scientific inquiry.
- Given patterns of BMI change in the U.S. population, it is unlikely that birth cohort effects are principally responsible for the obesity epidemic.

These areas of agreement could help narrow the divide between innovators and antagonists of APC research. However, we continue to have significant concerns with certain arguments and data structures advanced by B&J, and we thank the editors at *Social Science & Medicine* for granting us this opportunity to address them.

1. Another inappropriate data structure for APC models

In our recent assessment of B&J's critiques (Reither et al., 2015), we found that the purported failures of hierarchical APC (HAPC) models occur not because of inherent problems with the method, but rather because B&J subject them to unrealistic data structures that violate key assumptions. We concluded that "when more reasonable assumptions are employed – that is, when associational nonlinearities are permitted in a data structure that is truly three-dimensional – the HAPC-CCREM approach consistently performs well" (Reither et al., 2015, 9). Ostensibly to test our claim, B&J (2015) invent a data structure that borrows the period trend from our second equation and the age trend from our fourth equation. They also create a cohort trend that, curiously, is based on the pattern of period effects shown in Figure 4 of (Reither et al., 2015). The impression B&J may create for some readers is that, by borrowing age, period and cohort trends from our models, they have created a data structure that satisfies the assumptions of APC modeling, thereby providing an opportunity to "scrutinize" the HAPC method via the specification of a complete HAPC model.

But what kind of a data structure have they actually created? To address this question, we use the data generating process (DGP) provided by B&J to simulate 100 datasets, each with 20,000 observations. We then use simple tools (descriptive and model selection statistics) that are available to any analyst to help inform our modeling choices. To gather a preliminary sense of the data structure, we plot descriptive estimates of obesity prevalence by age, period and birth cohort for each dataset. As shown in Fig. 1, the age and cohort trends are mirror images of each other, and the period trends are flat, consistent with the second equation in Reither et al. (2015). The obvious similarity in age and cohort patterns is obfuscated in the way that B&J present the age DGP, which is centered at the grand mean (generally about age 49 in the simulated data) in their DGP equation but – for reasons that are obscure – at age 40 in their Fig. 1 (2015). When the quadratic age DGP is graphically represented in the same way that it is modeled

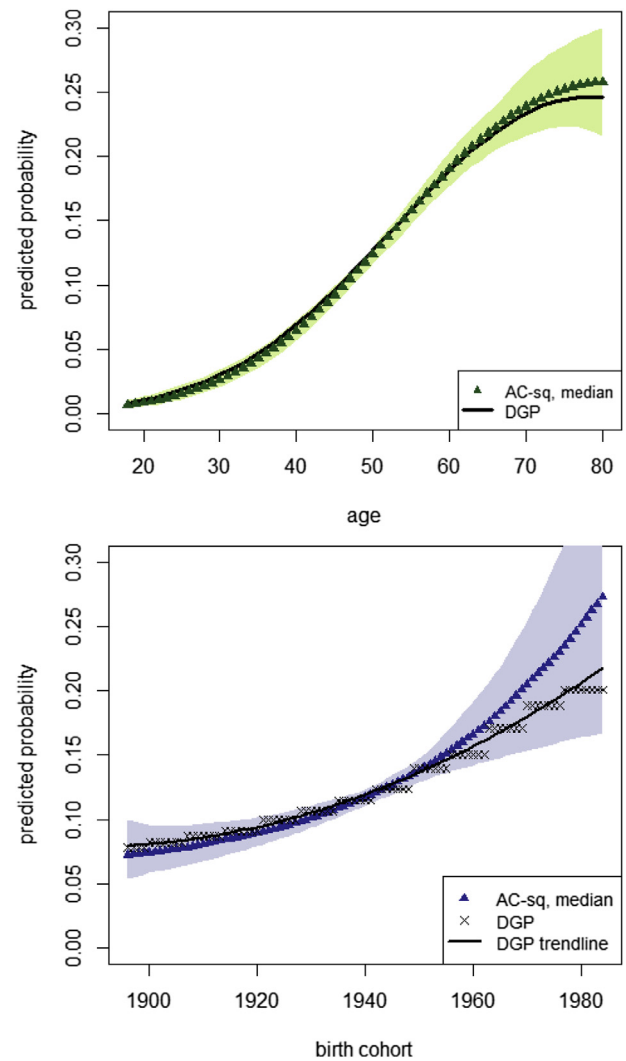

Fig. 2. Estimates from quadratic age–cohort models applied to data simulated from the DGP invented by B&J, with 95% point intervals in shaded areas.

(i.e., centered at the grand mean), it also resembles the cohort DGP that B&J invented (Fig. 2). Indeed, a quadratic equation explains 99.8% of the variation in the cohort DGP, further suggesting that the cohort effects may not be distinct from the age effects in this data structure. Therefore, given these features of the DGP, it is inappropriate to simply move forward and specify a HAPC model (or any APC model) with three operative temporal dimensions – and B&J's commentary (2015) rests upon a house of cards.

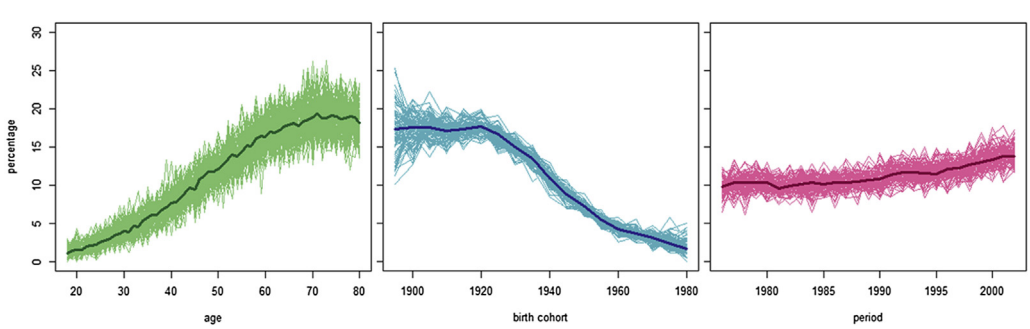

Fig. 1. Descriptive estimates of obesity prevalence by age, period and birth cohort in 100 datasets simulated from the DGP invented by B&J (median estimates in bold).

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