DISCUSSION

Richard Royall, The Johns Hopkins University

The simple unweighted ratio estimator (the "model 1" estimator) has been highlighted in many discussions of prediction models for two reasons:

(i) it is presented in practically every standard sampling text,

(ii) the probability sampling theory in these books is quite different from the theory produced under prediction models.

But to present this estimator as "what prediction theory recommends" is inaccurate. And to apply it in a badly unbalanced situation where prediction theory explicitly warns against its use, interpreting its poor performance as evidence that prediction theory is not trustworthy, is grossly misleading.

What does prediction theory say about the simple ratio estimator? For one thing, it is optimal under a certain zero-intercept linear regression model. But prediction theory has also shown that the ratio estimator is biased in unbalanced samples if the zero-intercept model fails, as it does in the artificial population created by HM&T. The ratio estimator is so sensitive to this model failure that serious bias can arise even in samples where the zero-intercept linear model would not be rejected by standard statistical tests. This sensitivity to model failure in unbalanced samples is a property of the ratio estimator not of prediction theory. Random sampling will not protect against this bias, as Cumberland and I showed in an extensive empirical study of real populations in our Chapel Hill paper.

Besides failing to point out prediction theory's warnings against using the ratio estimator in unbalanced samples, these authors failed to report what prediction models have to say in support of the weighted ratio estimator. They take this estimator's performance to somehow demonstrate the value of probability sampling. In fact the estimator is approximately unbiased and reasonably efficient under models considerably more general than the one they used to generate their artificial population. I think this reason, not the use of random sampling within the strata, explains why the combined ratio estimator performed well. They would have observed equally good performance from this estimator if they had foregone random sampling entirely and chosen a balanced systematic sample within each stratum.

The first few pages of this paper leave the distinct impression that stratification is a technique appreciated only within probability sampling theory. But Herson and I published a paper studying stratification under prediction models in 1973. We showed that stratification, with disproportionate allocation and balanced sampling within strata, had some advantages, in both efficiency and robustness, over simple overall balanced sampling.

The authors repeatedly fail to distinguish between the process of finding optimal strategies under simple models and the entirely different act of advocating the use of these strategies in complex real-world problems. One example is their reference to what I "advocated" in 1970 and 71. I only published two relevant papers in those years. The second one, Royall (1971), which is missing from their list of references, was published with discussion. There I said, not that one should rush out and draw a cut-off sample whenever overwhelming evidence against the zero-intercept linear model was lacking, but rather that

> "Many of the comments ... express reservations which I share ... The comments to which I refer are those of the form "Yes, but what if such-and-such conditions do not hold?" I enthusiastically agree that the questions of robustness are of utmost importance. They must be answered before one takes the important step from determination of theoretically optimal strategies under certain assumptions to recommendation of a particular strategy as being one which represents, for a specific application, a reasonable compromise between optimality under the most plausible assumptions and validity under departures from these assumptions. These questions have not yet received adequate attention."

My next publications were the work with Herson on robust estimation, balance and stratification.

REFERENCES

Royall, R. M. (1971) "Linear Regression Models in Finite Population Sampling Theory," in Foundations of Statistical Inference eds. V. P. Godambe and D. A. Sprott, Toronto: Holt, Rinehart and Winston of Canada, Ltd.