Use of Heckman-type selection models to account for selective non-participation in HIV testing surveys

Recommendations from a meeting of the UNAIDS Reference Group on Estimates, Modelling and Projections held in Boston, MA, USA, 3 April 2012

RECOMMENDATIONS

The meeting of the UNAIDS Reference Group on Estimates, Modelling and Projections (the 'Epidemiology Reference Group') was organised for UNAIDS by the UK secretariat of the Reference Group (www.epidem.org) based at Imperial College London. Participants of the meeting are listed at the end of this document. The recommendations in this document were arrived at through discussion and review by meeting participants and drafted at the meeting.

Kelsey Case, May 2012

Introduction

The Joint United Nations Programme on HIV/AIDS (UNAIDS) *Reference Group on Estimates, Modelling and Projections* exists to provide impartial scientific advice to UNAIDS, the World Health Organization (WHO) and other partner organisations on global estimates and projections of the prevalence, incidence and impact of HIV/AIDS. The Reference Group acts as an 'open cohort' of epidemiologists, demographers, statisticians, and public health experts. It is able to provide timely advice and also address ongoing concerns through both *ad hoc* and regular meetings. The group is co-ordinated by a secretariat based in the Department of Infectious Disease Epidemiology, Imperial College London.

Aim of the meeting

The aim of this meeting was to review and discuss results from Heckman-type selection models used to account for selective non-participation in HIV testing surveys and to identify whether adjustments need to routinely be made to the HIV surveillance data obtained from household surveys.

Approach

The meeting featured presentations of model simulations and recent analyses combined with group discussion. The meeting agenda is included in Appendix I.

The meeting was attended by 25 experts who contributed insights, experience and analyses, and worked to produce a set of recommendations drafted at the meeting. The list of participants is included in Appendix II.

The recommendations drafted at Reference Group meetings give UNAIDS and WHO guidance on how best to produce estimates of HIV/AIDS, an opportunity to review current approaches and also help to identify information needs (earlier reports are published on the Reference Group website www.epidem.org). This transparent process aims to allow the statistics and reports published by UNAIDS and WHO to be informed by impartial, scientific peer review.

1. Selective non-participation in HIV testing surveys and Heckman-type selection models

Nationally representative surveys are the gold standard for estimates of prevalence within a population; however, the proportion participating in such surveys, such as the Demographic and The conventional approach used to correct for selection bias– imputing missing HIV status adjusting for measured covariates – generally suggests non-participation is not a major cause for concern.[1] However, unobserved factors, such as already knowing your own HIV status, may influence the decision to participate in HIV testing surveys. Imputation-based estimates of HIV prevalence may also overstate precision as they ignore parameter uncertainty. Standard uncertainty estimation incorporates sampling error but ignores parameter uncertainty and thus underestimates true uncertainty. This can be solved with a parametric approach.

Heckman-type selection models have been commonly used in econometrics and social sciences to ensure a coefficient is unbiased when there is non-participation within a sampling frame. Increasingly, these methods have been applied in epidemiology and can be used to identify if there is cause for concern for a potential effect of selection bias, and to define the 95% confidence intervals for uncertainty in selection model parameter estimation.

A recent analysis using these methods[2] suggests there is the potential for selection bias to have an effect on HIV prevalence estimates obtained in population-based surveys in some settings if unobserved factors are associated with both participation and HIV status. This is an important consideration for national estimates of HIV as the data from these surveys are used to fit the level of the trends in prevalence observed.

As a result, the group from Harvard School of Public Health repeated this work for other countries in sub-Saharan Africa to identify:

1) If the findings are consistent across surveys.
2) If the selection model suggests there is cause for concern for potential effect of selection bias.
3) The 95% confidence intervals for uncertainty in selection model parameter estimation.

In addition, a separate research group from the University of Washington replicated this work with the following aims:

1) To conduct a simulation study to characterise:
    a) How well the Heckman selection model estimates prevalence when selection criteria are met.
    b) Evaluate how poorly the Heckman selection model estimates prevalence when the selection criteria requirements are not met.
    c) Explore the performance of the Heckman selection model in more detail
2) To replicate the Barnighausen et al[2] analysis using the 2007 Zambian DHS and then expand to analyse other DHS data.

The following is a brief summary of the main findings from both groups applying Heckman-type selection models in HIV testing surveys in southern Africa:

- **HIV prevalence is likely underestimated among men in a few countries**
    - HIV prevalence was found to be significantly higher among men as compared to conventional imputation in DHS surveys for: **Côte d'Ivoire 2005, Mali 2006, and Zambia 2007**
- **Conventional imputation may substantially underestimate uncertainty around HIV prevalence estimates in many countries.**
    - The uncertainty intervals around estimated prevalence increased by a factor of 4.5 (on average across all) compared to conventional imputation.

- **The use of different methods produced very similar results (including replication of the Zambia findings), thus there is external validity of the approach.**
- **Model testing and evaluation found robustness that the interviewer does not independently affect HIV status.**
- **Heckman-type election models could be used for sensitivity analysis for conventional estimates.**

It is worth nothing that the relationship between HIV status and participation in HIV testing may vary across surveys (the Heckman point estimate was higher in 8 of 12 surveys for men and 11 of 12 surveys for women). There was also an inconsistent effect of the adjustment on the F:M prevalence ratio (decreased in 7 of 12 surveys). The main limitations of this approach are that it cannot be used with all surveys and the model is quite sensitive to violations of its assumptions (will result in non-convergence).

2. Recommendations for further research and the use of Heckman methods

Overall, it was identified that there are a few specific instances that need further investigation to more fully understand what is occurring and that the additional uncertainty should be captured. The following details the specific areas for further investigation and consideration and the recommendations derived at this meeting.

2.1 Sex ratio of prevalence

The Heckman adjustments to the male prevalence in the three surveys where there were significant differences, changes the ratio of the M:F prevalence, shifting the two prevalences closer together. After review and discussion it was decided that more research is needed on the sex ratio of prevalence; it is possible that this more equal ratio of prevalence between males is females is real and something that has been missed. For example, mortality data from other sources, including vital registration data from South Africa and mortality estimates from the Institute for Health Metrics and Evaluation (IHME), both suggest that the prevalence ratio might actually be closer to 1. Across DHS surveys, the variation in F:M prevalence ranges from approximately 1-2.3. More information is needed on sex ratios of prevalence before Heckman methods are used in a routine manner.

Recommendations:

- **Investigate sex ratios in detail for Zambia, Mali and Coite d'Ivoire, looking at mortality and AIDS cases by sex, age patterns of infection and differential access to treatment.**
  UNAIDS to coordinate contacting country representatives in the first instance
- **Look at the sex differential in overall and HIV-specific mortality data of countries with very good vital registration systems.**
  Rob Dorrington
- **Review Futures Institute's analysis of DHS data for variables that might be related to differences in sex ratios for comparison**
  Futures Institute, review results at Reference Group meeting, September
- **Investigate sex ratios in HIV prevalence and in HIV-related mortality and how the two sex ratios relate to each other, in community-based longitudinal studies**
  ALPHA Network, Futures Institute; review results at Reference Group meeting, September

2.2. Uncertainty and confidence intervals derived from the use of Heckman methods

The additional uncertainty and confidence intervals should be incorporated into Spectrum in the future; however, more information and analyses are needed before it isrecommended that all countries use Heckman methods routinely. Specifically, more information is needed on how to implement the additional uncertainty in EPP and Spectrum, how to use this approach in countries that do not have DHS surveys, or have more than one DHS survey, and how to extrapolate for countries for which the methods do not work (do not converge). The following are the key factors to address in order identify the optimum strategy for implementation of the additional uncertainty derived from Heckman methods:

- **Urban vs rural and geographical differences:** Many countries are doing urban/rural or provincial fits and the nature of the bias from selective non-participation may vary by urban/rural and by geography.
  Recommendation to use Heckman methods by urban/rural and by province and generate confidence intervals for each.
  HSPH team, Review at Reference Group meeting, September

- **Estimating rho:** In countries where Heckman methods could not be used, the problem was due to not being able to estimate rho. Jeff Eaton's proposed method is to specify a prior on rho and use a Bayesian approach which will help convergence and give uncertainty bounds.
  Recommendation to try this approach and review the results
  Jeff Eaton and HSPH team, review results at Reference Group meeting, September

- **Countries with >1 DHS:** The naive analysis is to separate the surveys and use Heckman methods for each survey, however they probably need to be analysed together (essentially correlation in the error).
  Recommendation to incorporate this work as part of the research agenda
  HSPH team, review progress at Reference Group meeting, September

- **Countries with no DHS**
  Further development of the methods will increase their applicability, particularly for countries that have not conducted a nationally representative survey.
  Recommendation to develop procedures for extrapolation for the countries that do not have a Demographic and Health Survey.
  HSPH team, review progress at Reference Group meeting, September

2.3 Research agenda for moving forward with Heckman methods

Before any adjustments are made to current prevalence estimates, full confidence is needed in the results obtained using Heckman methods as the adjustments will also have implications, particularly in the settings where these adjustments result in a significant change in the F:M prevalence ratios. Additionally, if the findings from Heckman methods suggest a large change, there should be a reconsideration of the confidence in the previous estimates obtained and further investigation.

- **Selection variables:** The underlying assumptions of Heckman methods are that the bivariate error structure is approximately normal and the selection variables are valid. More research is needed on the selection variables.
  Recommendation for fieldwork to further develop and validate selection variables.
  Sam Clark group, longer term recommendation

- **Misclassifying the interviewer:** More research is needed on what happens when the interviewer is misclassified, for example, if the person who conducts the DHS interview is not the same person who obtains consent for HIV testing and performs the HIV test. It is hypothesized that misclassification would degrade the information in the selection variable (which may bias the interviewer effect towards the null, i.e. no effect of interviewer identity on participation). It would be useful to investigate this in more detail, which would require collecting data on the interviewer.
  Recommendation for DHS to collect interviewer information.
  Sam Clark team to derive recommendations for collecting data on interviewers

- **In-depth investigation of countries that resulted in significant changes to the estimates: Mali, Zambia, Coite d' Ivoire, Ghana**
  It is important to fully understand what happened in these countries, the data collected, and the under-estimation of prevalence in males.
  UNAIDS to coordinate, Review at Reference Group meeting, September

2.4 Use of Heckman methods as sensitivity analyses

The Heckman selection model is a useful tool for assessing the possibility, direction and extent of selection bias. This can be very useful information for countries and may be a meaningful approach as sensitivity analyses in HIV prevalence estimation. The results can suggest caution or confirmation of the data obtained, which could then help prioritisation of investment in data collection. This

approach would be a fairly simple and cost effective method to indicate that further research is needed or to justify the results obtained.

Recommendation: Consider the use of Heckman methods as sensitivity analyses.

2.5 Maximum likelihood vs. posterior distribution

In the EPP component of Spectrum, the maximum likelihood curve is currently driven through the point estimate obtained from nationally representative household surveys. After discussions surrounding how to handle the point estimate when incorporating Heckman methods and a review of mortality estimates, it was agreed and recommended to move away from the current approach and to instead use the mean of the posterior distribution instead of the maximum likelihood curve.

Recommendations:

- **Use the mean of the posterior distribution instead of the maximum likelihood curve; review and compare results**
- **Generate recommendations for how to handle the point estimate**
  Follow-up: EPP team, review at Reference Group meeting, September

2.6 Support and Documentation

When Heckman methods are ready to be routinely incorporated into EPP/Spectrum, there will need to be documentation in place in order to explain the methods and rationale to countries, to communicate that the results are based on the best statistical methods available, and to provide tools to support countries in the adjustment of their survey data.

Recommendations:

- **Develop an explanatory document for countries**
- **Create a simple toolbox made available in order to adjust the data**
- **Include the methods in an analytic report made available by DHS**
  Begin compiling information now; develop for 2013 round of estimates

Appendix I: Meeting Agenda

Tuesday, April 3, 2012			
Start	**Duration**	**Subject**	**Speaker**
930	*30*	*Continental breakfast available*	-
1000	15	Opening remarks and introductions	Peter Ghys/Geoff Garnett
Session 1 - Heckman methods (Chair: Geoff Garnett)			
1015	20	Heckman-type selection models: Review of work conducted, results from sensitivy analyses, findings and conclusions	Dan Hogan
1035	20	Discussion	-
1055	20	Heckman-type selection models: Ongoing and potential future work using Heckman methods	Till Barnighausen
1115	15	Discussion	-
1130	*20*	*Coffee break*	-
1150	25	Heckman-type selection models: Insights revealed from application to South Africa	Sam Clark/Brian Houle
1215	30	Discussion	-
1245	25	Heckman-type selection models: Results from sub-Saharan Africa (draft paper)	Sam Clark/Brian Houle
1310	20	Discussion	-
1330	*60*	*Lunch*	-
1430	45	Discussion continued, recommendations for follow-up work and wider research agenda	-
1515	30	Recommendations regarding the use of survey-derived prevalence data for national estimates, and regarding technical support by survey implementing organisations	-
1545	15	Close	Peter Ghys/Geoff Garnett
1600			

Appendix II: List of Participants

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References

1. Mishra V, Barrere B, Hong R, Khan S. Evaluation of bias in HIV seroprevalence estimates from national household surveys. Sex Transm Infect. 2008 Aug;84 Suppl 1:i63-i70.

2. Barnighausen T, Bor J, Wandira-Kazibwe S, Canning D. Correcting HIV prevalence estimates for survey nonparticipation using Heckman-type selection models. Epidemiology. 2011 Jan;22(1):27-35.