

# What range could your causal effect lie between if the instrumental variable assumptions held?

## Find out with our bpbounds R package and Shiny app!

### bpbounds: R package and web app

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### Introduction

- We present our bpbounds R package and Shiny web app for the nonparametric bounds for the average causal effect (ACE) due to Balke and Pearl (**Palmer et al. 2018**).
- This is an R implementation of our Stata programs (**Palmer et al. 2011**).
- The package can be installed from CRAN as follows:

```
install.packages("bpbounds")
```

- Code development is on the GitHub repository: <https://github.com/remlapmot/bpbounds>

### Methods

- Under the instrumental variable assumptions alone, without additional parametric model assumptions, the ACE is not identified.
- Balke and Pearl (1997)** showed it is possible to derive bounds for the ACE.
- The bounds have the following interpretation:

There is some joint distribution of the unobserved confounders and the observed variables that yields a true ACE as small as the lower bound, while another choice produces an ACE as large as the upper bounds (the bounds are tight).

- There are at least two ways to implement the Balke-Pearl bounds:
  - using conditional probabilities calculated from contingency tables;
  - the polytope method due to **Dawid (2003)**.

- We implemented the polytope method since it is generalisable for identified IV models with

- exposures, outcomes, and instruments with more than 2 categories.
- Currently, we allow for a binary or 3 category instrument, and binary exposure and outcome.

### Example Mendelian randomization analysis

- We extract an example from **Meleady et al. (2003)**.
- We have a 3 category instrument and binary exposure and outcome.
- We use the 677CT polymorphism (rs1801133) in the MTHFR gene, involved in folate metabolism, as an instrumental variable to investigate the causal effect of homocysteine on the risk of cardiovascular disease.
- The code is shown on the right.
- The ACE lies between a risk difference of -9% to 74% increase in absolute risk.
- Additionally, we see that the monotonicity inequality is not satisfied.

### Conclusion

- Use of bounds in instrumental variable analyses is regaining interest (**Swanson et al. 2018; Labrecque and Swanson 2018**).
- The empirical experience that the bounds are often wide is not a bad property of the method, it is a property of the typical data: Mendelian randomization data simply often are uninformative in that sense due to weak instrumental variables.
- We recommend using the bounds when the variables are genuinely discrete, but not when the exposure is genuinely continuous (**Sheehan and Didelez 2019**).
- Our R package and app provide a convenient interface to the bounds.

### References

Balke, A., and J. Pearl. 1997. "Bounds on treatment effects from studies with imperfect compliance." *Journal of the American Statistical Association* 92 (439): 1172–6. <https://doi.org/10.1080/01621459.1997.10474074>.

Dawid, A. P. 2003. "Causal Inference Using Influence Diagrams: The Problem of Partial Compliance (with Discussion)." In *Highly Structured Stochastic Systems*, edited by P. J. Green, N. L. Hjort, and S. Richardson, 45–65. New York: Oxford University Press.

Labrecque, Jeremy, and Sonja A Swanson. 2018. "Understanding the Assumptions Underlying Instrumental Variable Analyses: A Brief Review of Falsification Strategies and Related Tools." *Current Epidemiology Reports* 5 (3): 214–20. <https://doi.org/10.1007/s4047>.

Meleady, Raymond, Per M Ueland, Henk Blom, Alexander S Whitehead, Helga Refsum, Leslie E Daly, Stein Emil Vollset, et al. 2003. "Thermolabile Methylene tetrahydrofolate Reductase, Homocysteine, and Cardiovascular Disease Risk: The European Concerted Action Project." *The American Journal of Clinical Nutrition* 77 (1): 63–70. <https://doi.org/10.1093/ajcn/77.1.63>.

Palmer, T. M., R. Ramsahai, V. Didelez, and N. A. Sheehan. 2018. *bpbounds: R package implementing Balke-Pearl bounds for the average causal effect*. <https://CRAN.R-project.org/package=bpbounds>.

Palmer, T. M., R. R. Ramsahai, V. Didelez, and N. A. Sheehan. 2011. "Nonparametric Bounds for the Causal Effect in a Binary Instrumental-Variable Model." *Stata Journal* 11 (3): 345–67. <http://www.stata-journal.com/article.html?article=st0232>.

Sheehan, Nuala A, and Vanessa Didelez. 2019. "Epidemiology, genetic epidemiology and Mendelian randomisation: more need than ever to attend to detail." *Human Genetics*, 1–16. <https://doi.org/10.1007/s00439-019-02027-3>.

Swanson, Sonja A., Miguel A. Hernán, Matthew Miller, James M. Robins, and Thomas S. Richardson. 2018. "Partial Identification of the Average Treatment Effect Using Instrumental Variables: Review of Methods for Binary Instruments, Treatments, and Outcomes." *Journal of the American Statistical Association* 113 (522): 933–47. <https://doi.org/10.1080/01621459.2018.1434530>.

### Extra Figures & Tables

```
library(bpbounds)

mt3 <- c(.83, .05, .11, .01,
        .88, .06, .05, .01,
        .72, .05, .20, .03)

p3 <- array(mt3, dim = c(2, 2, 3),
            dimnames = list(x = c(0, 1),
                             y = c(0, 1),
                             z = c(0, 1, 2)))

bpres3 <- bpbounds(as.table(p3))

summary(bpres3)

##
## Data:                               trivariate
## Instrument categories:              3
##
## Instrumental inequality: TRUE
## Causal parameter Lower bound Upper bound
##          ACE          -0.09      0.74000
##          P(Y|do(X=0))      0.06      0.12000
##          P(Y|do(X=1))      0.03      0.80000
##          CRR           0.25     13.33333
##
## Monotonicity inequality: FALSE
```



Figure 1: Shiny app <https://remlapmot.shinyapps.io/bpbounds>

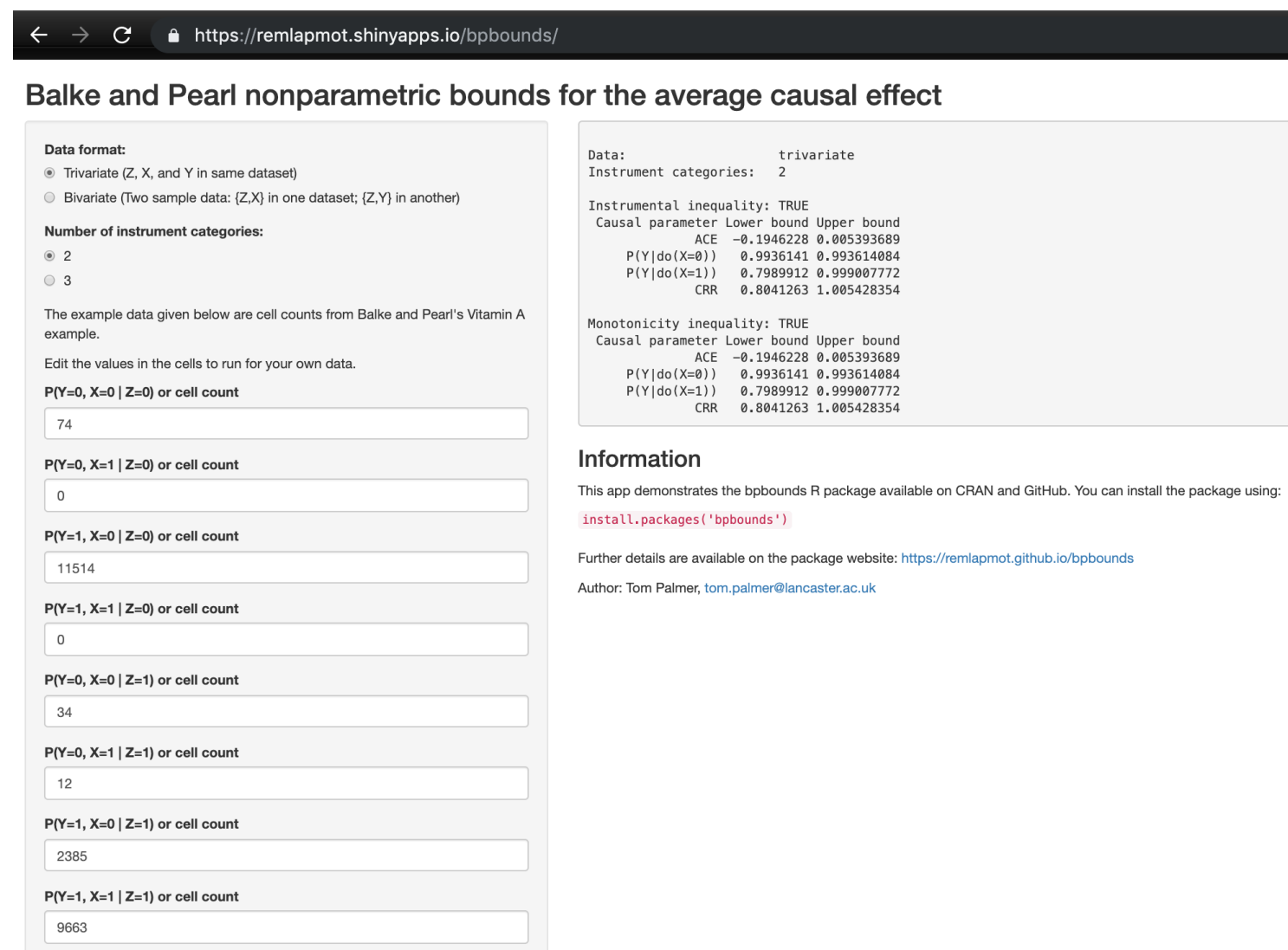


Figure 2: Screenshot of our Shiny app.



Figure 3: Package website <https://remlapmot.github.io/bpbounds/>

