Power and false negatives in Qualitative Comparative Analysis (QCA):

Foundations, Simulation and Estimation for Empirical Studies

Appendix for manuscript forthcoming in *Political Analysis*

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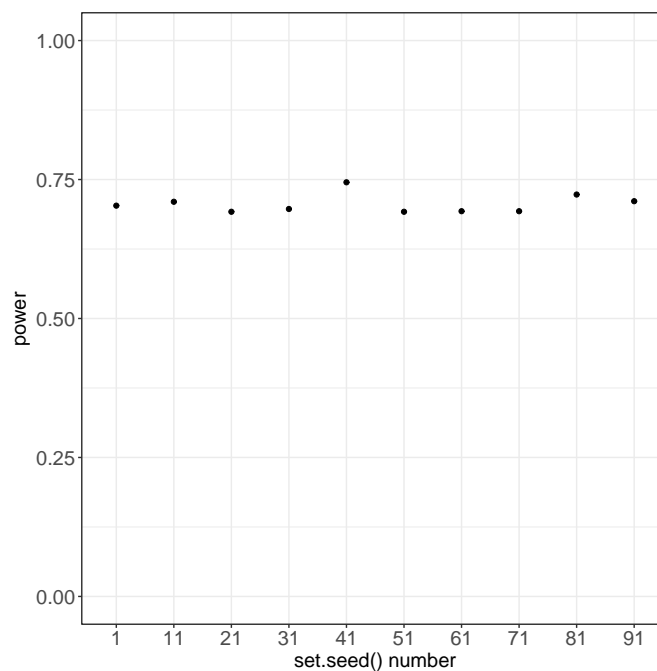Thursday 27th April, 2017

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The appendix deepens the discussion of some issues addressed in the manuscript and presents robustness checks on the simulations summarized in figure 2 in the manuscript.

INDEPENDENCE OF POWER ESTIMATES FROM `SET.SEED()` NUMBER

The simulations are based on randomized permutation tests rather than exact tests. As a check as to whether power estimates are sensitive to different `set.seed()` numbers that ensure reproducibility in `R`, I estimated power for different numbers with otherwise identical parameters. Figure A.1 shows that the power estimates are in a reasonably narrow range and that the chosen `set.seed()` number does not matter for the results.

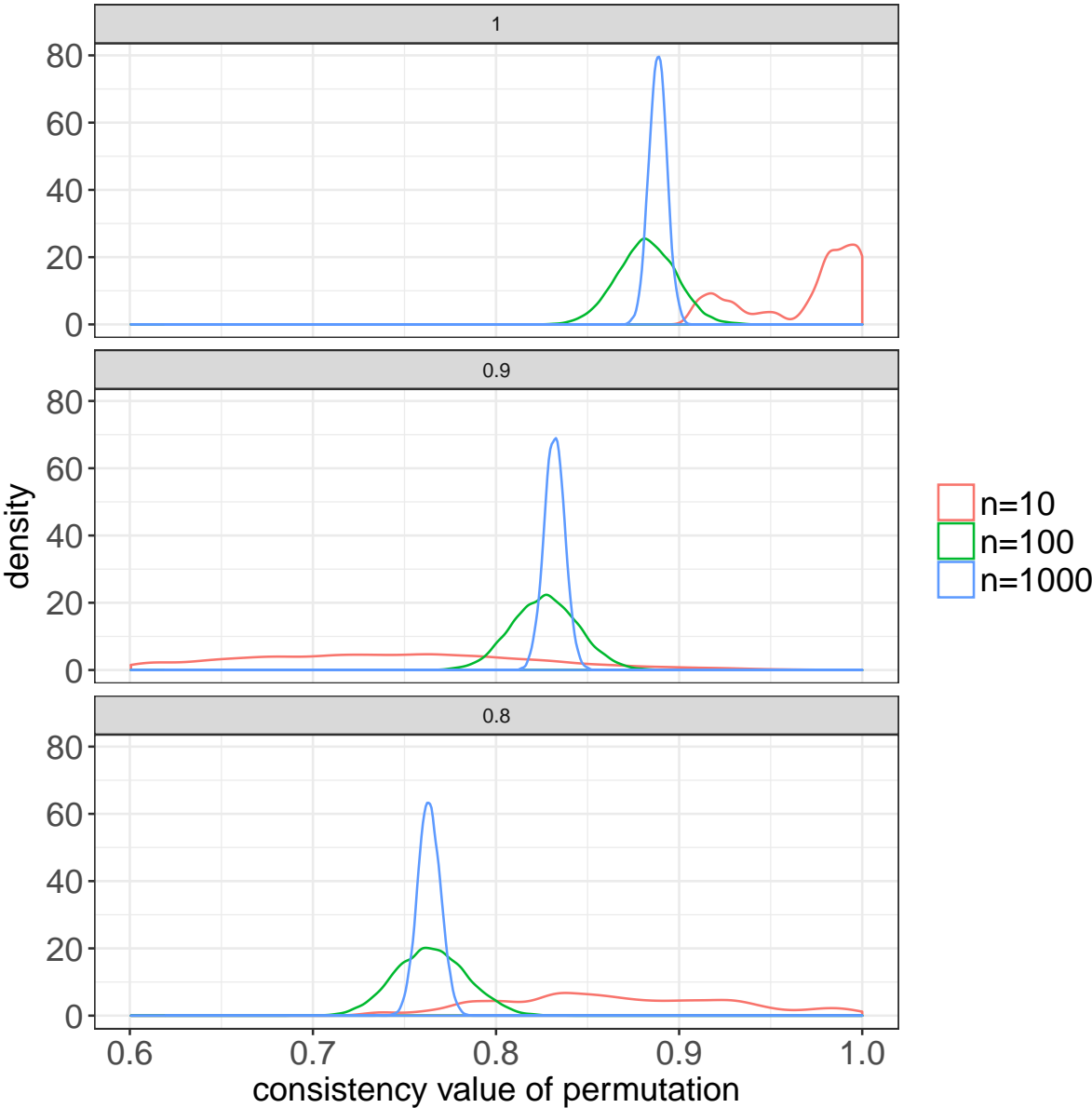Figure A.1: Power estimates for different `set.seed()` numbers

WHY POWER SOMETIMES CANNOT BE LARGE

Figure 2 and table 1 in the manuscript show that power can be high if the number of cases is sufficiently large. However, it is not always possible to achieve high power because it depends on the chosen values of c_{H1} and c_{H0}. If both values are high and, thus, the difference small, power is low regardless of the number of cases and is estimated to be the lower, the smaller the larger the number of cases. The reason for this rests in the calculation of the consistency value and the logic of estimating power by permuting a simulated dataset. If we simulate a dataset with a consistency value of 1, this means that every case membership in the term A is equal to or smaller than its membership value in Y. By permuting the data, it is likely that a case is assigned a membership score for Y that is smaller than membership in A and pushes the consistency value below 1. Because of this relationship between the consistency score and permutations, the permuted consistency values are most often below 1 and yield a distribution that is located somewhere in the upper range of the spectrum of consistency scores. The larger the number of cases, the narrower the distribution and the less likely it is that c_{H0} is located in its lower 5%-quantile. This can already be inferred from figure 5 in the manuscript and might become more obvious in figure A.2.

In figure A.2 that plots three distributions with a different number of cases per value of c_{H1}, we can see why it can be impossible to achieve a sufficiently high level of power. In a sense, the figure is an extension of figure 4 in the manuscript, which illustrates why power decreases as n increases, because it raises n beyond 50. For an n of 100 and 1000, the distribution achieves its median around a value of 0.88 and becomes narrow. For $c_{H1}=1$, a value of 0.95 for c_{H0} then falls into the far right tail of the distribution. It achieves statistic significance, but this is meaningless for power analysis because the test for significance is left-sided. The top panel in figure A.2 shows that more cases don't help in increasing power, but achieve the contrary by narrowing the distribution and making it increasingly

unlikely that a value of 0.95 for c_{H0} is significant. This changes as we lower the value of c_{H1} to 0.9 and 0.8. If we keep the difference to c_{H0} fixed, we see in the middle panel for c_{H0}=0.85 that it is still located in the right tail, but less so than for c_{H0}=0.95 in the top panel. In the lower panel, we achieve statistical significance if we set c_{H0} to 0.75. We are only looking at one permuted distribution here, but figure A.2 and table 1 in the manuscript show that, although the difference between c_{H1} and c_{H0} is only 0.05 points in the lower panel, it is now possible to increase power by raising n further and further.
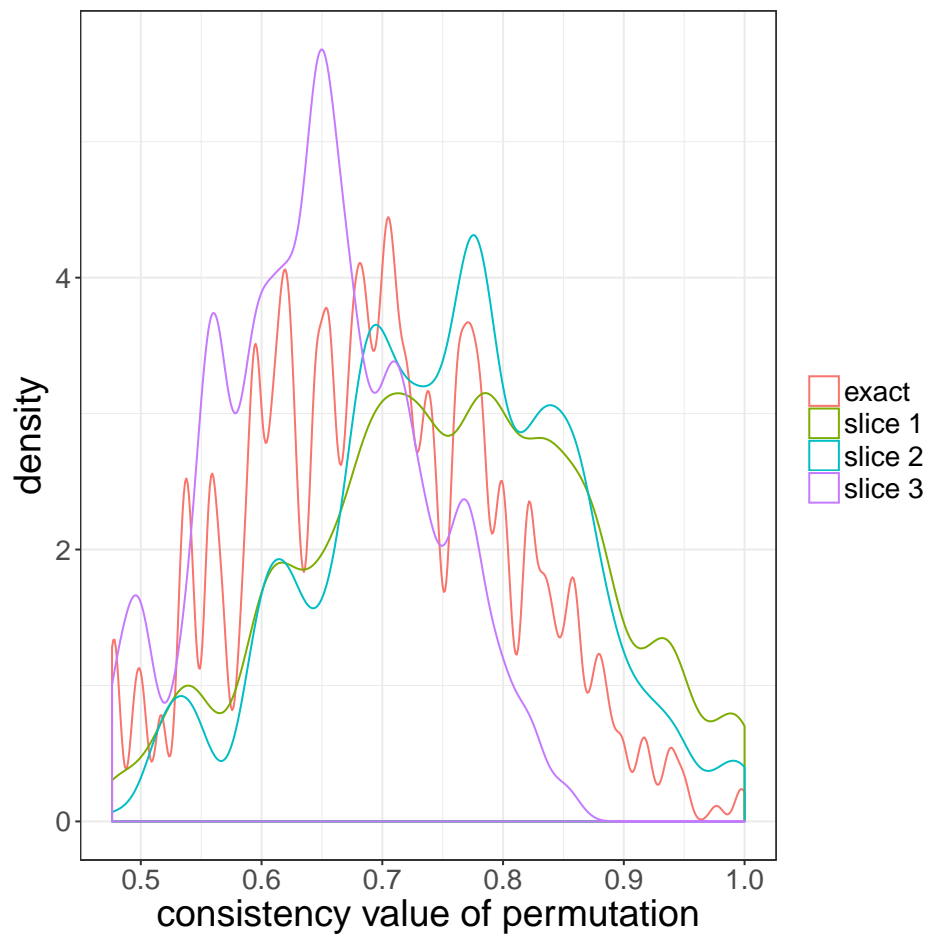
Figure A.2: Illustrative distributions of consistency values for three values of c_{H1}

EXACT PERMUTATION TESTS AND THE CONSISTENCY VALUE DISTRIBUTION

In section 5.2 in the manuscript, I show that the permuted distributions of consistency values differ strongly from each other if the number of cases is ten. The variability of the distributions is not an artifact of generating 10000 permutations, which is a small number compared to the 3628800 permutations needed for an exact permutation test. Figure A.3 presents one exact distribution for a simulated dataset comprising 10 cases. It shows that the distribution is also wide for an exact test and that the problem of variability is not associated with the number of permutations. This is indicated by the three other distributions in figure A.3 each of which is based on an arbitrary slice of 10000 permutations of the full data. The 5%-quantiles of the four distributions are close to each other with 0.53 for the exact distribution and 0.54, 0.56 and 0.5 for the three randomized permutations.

Figure A.3: Exact distribution of consistency values for 10 cases

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