# Different applications of CATE + ASH

David Gerard

March 8, 2016

**Abstract**

I look at the performance of different options of CATE and compare them against the performance of FLASH + MOUTHWASH. FLASH + MOUTHWASH seems to have really good calibration, though it's AUC results are mixed. Sometimes it has very high AUC, sometimes very low.

## 1 Methods

For CATE, I varied three parameters.

1. The factor analysis method: Either quasi-maximimum likelihood ("ml"), PCA ("pc"), or an early stopping method I haven't read about but is an option ("esa").
2. Whether the p-values are calibrated using maximum absolute deviation (TRUE) or not (FALSE). This only matters for the qvalue methods and shouldn't affect the ASH methods.
3. Whether we used the robust-regression version of CATE ("rr") or the negative controls verison of CATE ("nc") using half of the null genes as the negative controls.

For each setting in CATE, I performed two methods. The first method consisted of a two-step procedure:

1. Estimate $\hat{\beta}_{[2,i]}$ and it's corresponding standard error $\hat{s}_i$.
2. Run ASH on $\hat{\beta}_{[2,i]}$ and $\hat{s}_i$.

The second method was to use the p-values output by CATE.

I always ran CATE on $\log(COUNTS + 1)$.

The ASH methods provide an estimate of $\pi_0$. I obtained an estimate of $\pi_0$ from the p-values by the `qvalue` package in `R` [Storey, 2002].

The number of hidden confounders was estimated using the methods of Buja and Eyuboglu [1992] implemented in the `num.sv()` function in the `sva` package in `R`. CATE doesn't work sometimes when there is only one confounder, so I set the minimum number to 2 confounders.

For MOUTHWASH:

- I used homoscedastic FLASH to esitmate the hidden confounders. I ran $k$ iterations of the greedy algorithm of estimating the mean then subtracting off the FLASH rank 1 estimate.
- Since at each iteration, FLASH returns a variance estimate, I just averaged these variance estimates to get an overall variance estimate.
- I used the mixture of normals version with the same regularization and grid-size choices as in the `ashr` package.

## 2 Simulation Study

I ran through 100 repetitions of generating data from GTEX lung data under the following parameter conditions:

- $n \in \{10, 20, 40\}$,
- $p = 1000$,
- $\pi_0 \in \{0.5, 0.9\}$,
- $\sigma_{log2} \in \{1, 5\}$.

I extracted the most expressed $p$ genes (excluding the top 5 expressed genes) from the GTEX lung data and $n$ samples are chosen at random. Half of these samples are randomly given the "treatment" label 1, the other half given the "treatment" label 0. Of the $p$ genes, $\pi_0 p$ were chosen to be non-null. Signal was added by the Poisson-thinning approach in Mengyin's code with a mean log2-fold change of 0 and a standard deviation log2-fold change of $\sigma_{log2}$. That is

$$A_1, \ldots, A_{p/2} \sim N(0, \sigma^2_{log2}) \tag{1}$$

$$B_i = 2^{A_i} \text{ for } i = 1, \ldots, p/2. \tag{2}$$

If $A_i > 0$ then we replace $Y_{[1:(n/2),i]}$ with $Binom(Y_{[j,i]}, 1/B_i)$ for $j = 1, \ldots, n/2$. If $A_i < 0$ then we replace $Y_{[(n/2+1):n,i]}$ with $Binom(Y_{[j,i]}, B_i)$ for $j = n/2 + 1, \ldots, n$.

For each iteration, I calculated two things:

1. The AUC using either the lfdrs or p-values.
2. The estimates of $\pi_0$.

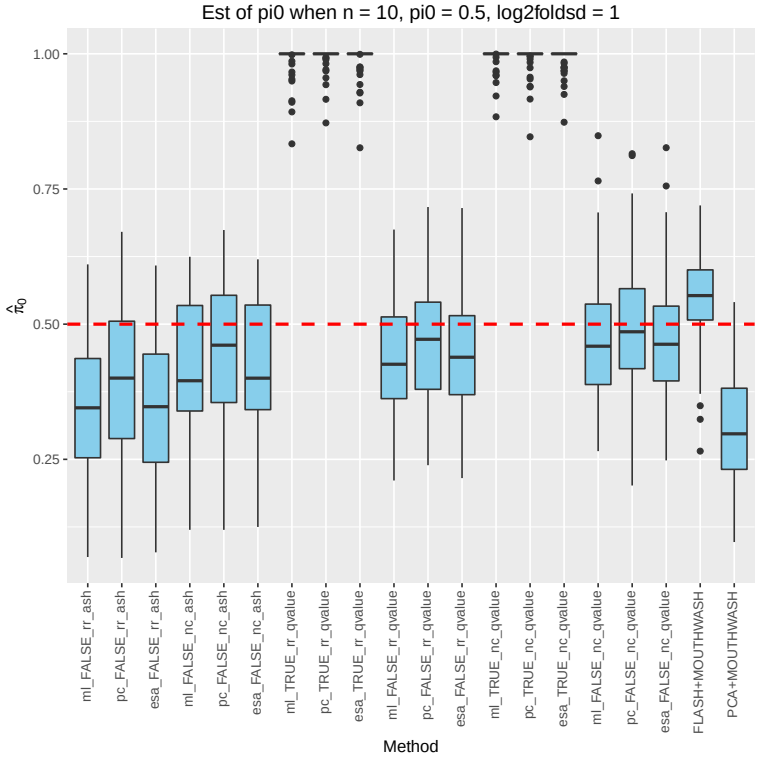
## 3 Results

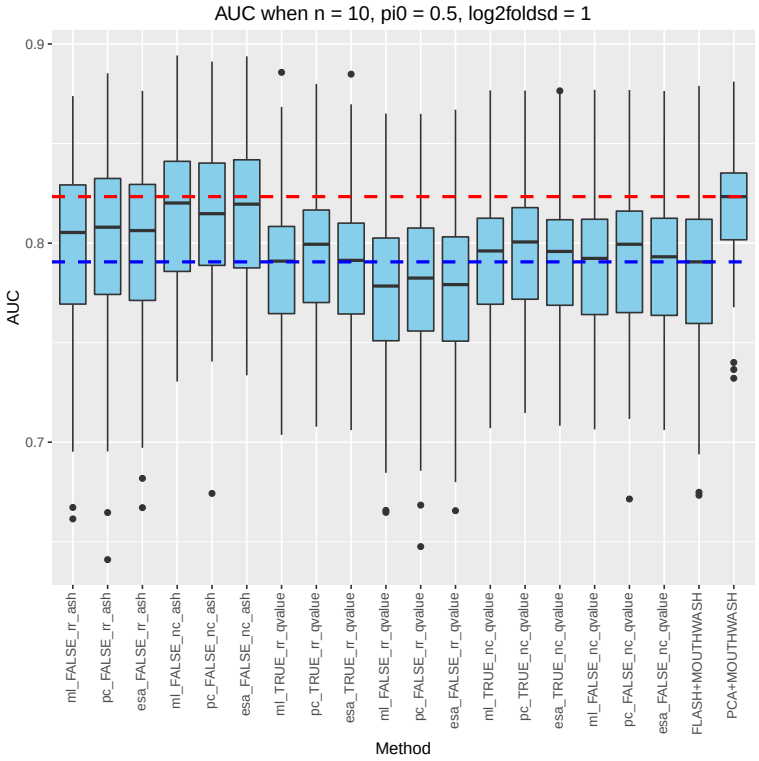
For the frequentist procedures, I used the vector of p-values as the predictions and I used the vector of lfdr's from the ASH-like procedures for prediction. These were used to create ROC curves and calculate AUCs. In general, ASH procedures performed better than just using the p-values and using negative controls worked better than the robust regression version. MOUTHWASH's performance is mixed in terms of AUC — sometimes the best (even compared to the methods that use negative controls), sometimes the worst. It's AUC performance is generally worse than when using PCA + MOUTHWASH.

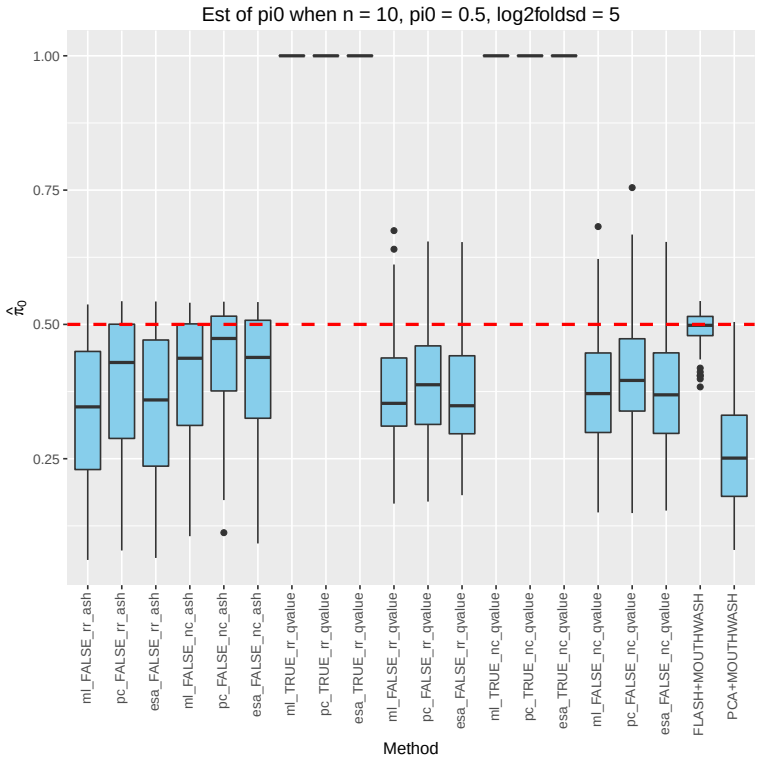
From the p-values, I used the `qvalue` package [Storey, 2002] to estimate $\pi_0$. Estimates of $\pi_0$ are given from `ashr` for the ASH-like methods.

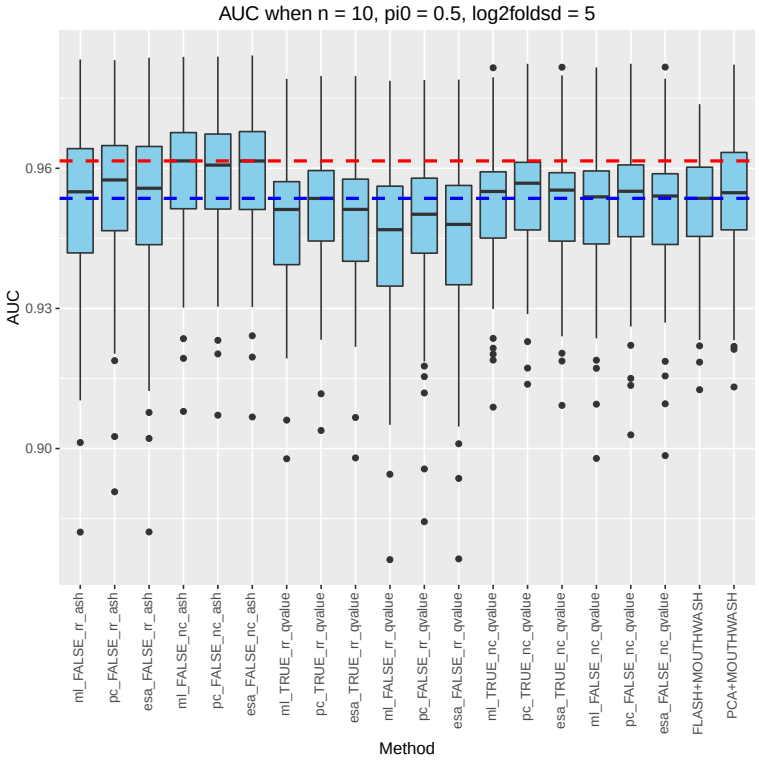
FLASH + MOUTHWASH is by far the best calibrated method, and is a major improvement over PCA+MOUTHWASH. It accurately estimates $\pi_0$ under almost every scenario. It has a small upward bias when $n = 10$, $\pi_0 = 0.5$, and $\sigma_{log} = 1$, but it by far performs better than every other method under this scenario. When $\sigma_{log}$ is high and $\pi_0 = 0.9$, FLASH + MOUTHWASH has a small negative bias.

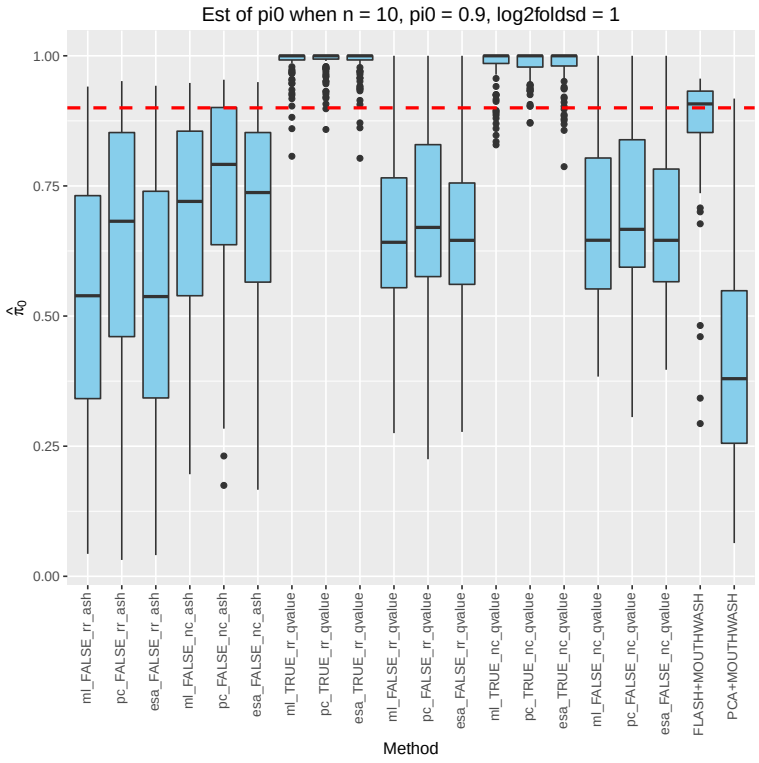
There are two possible explanations for why FLASH performs so well here. First, FLASH just does a much better job at estimating the confounders. Second, I've only ever looked at heteroscedastic models, and maybe homoscedastic models are better. But this second expanation seems counter-intuitive to me.

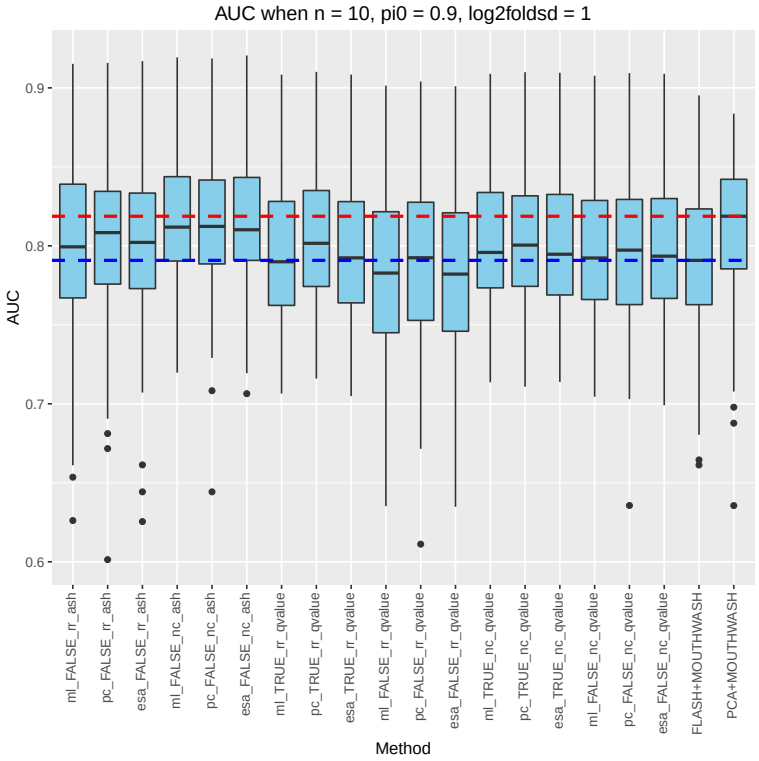

Est of pi0 when n = 10, pi0 = 0.5, log2foldsd = 1
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

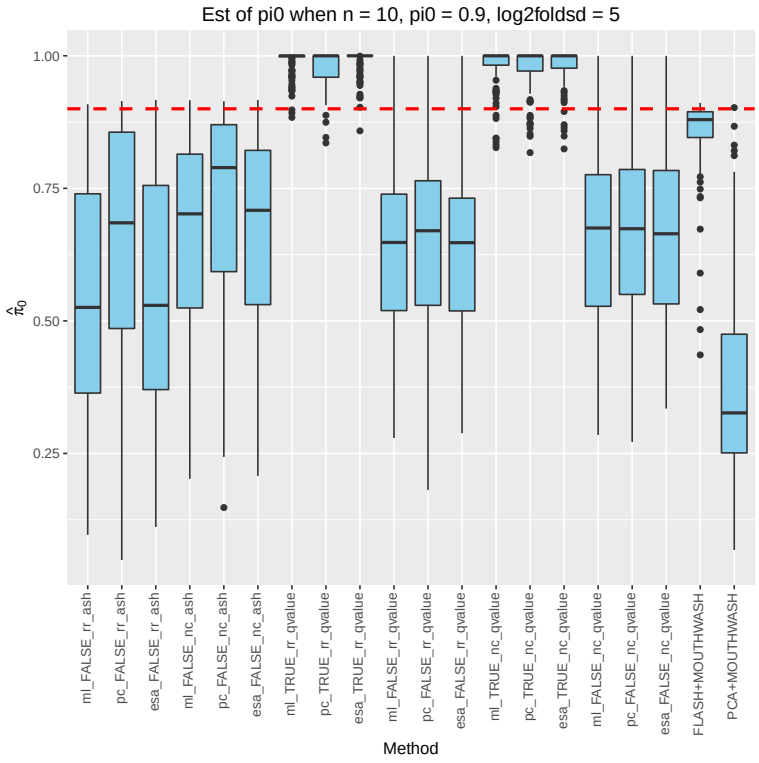

AUC when n = 10, pi0 = 0.5, log2foldsd = 1
0.9
0.8
0.7
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

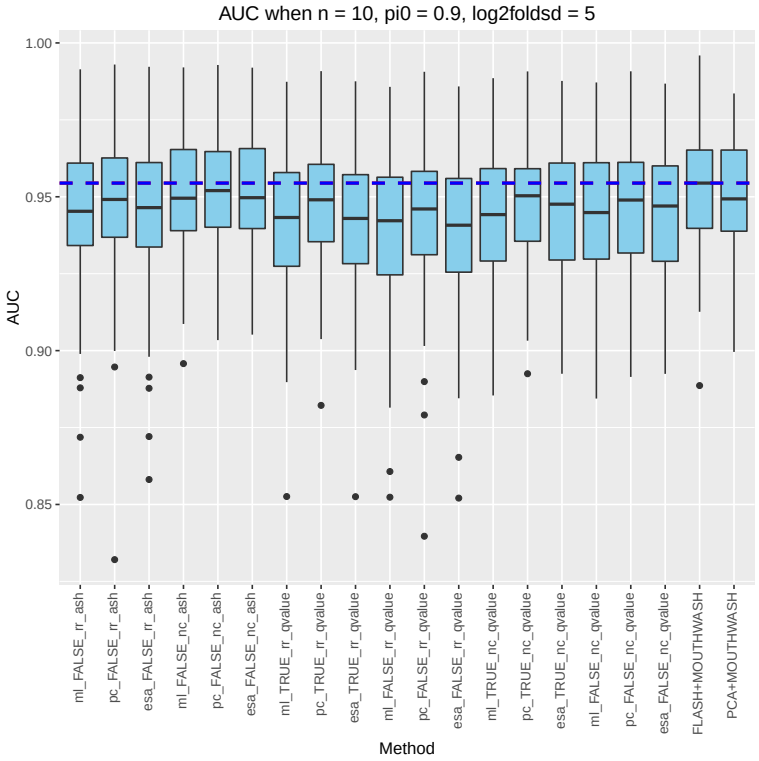

Est of pi0 when n = 10, pi0 = 0.5, log2foldsd = 5
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

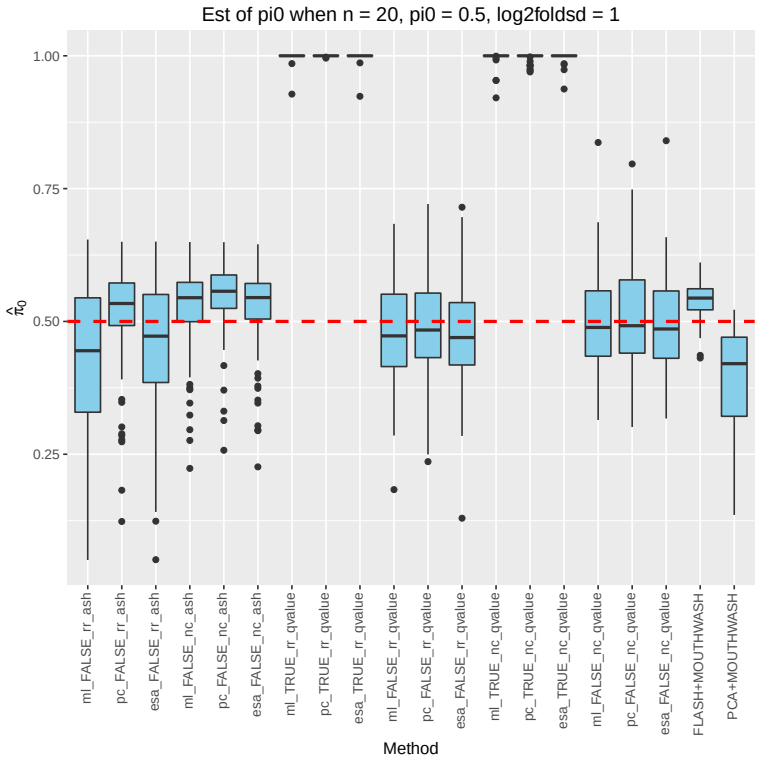

AUC when n = 10, pi0 = 0.5, log2foldsd = 5
0.96
0.93
0.90
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

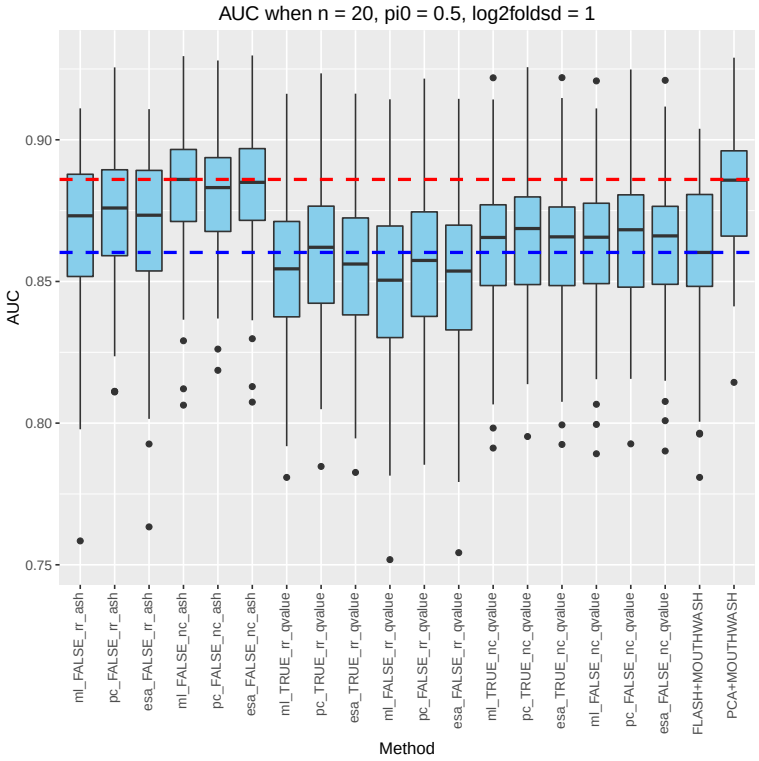

Est of pi0 when n = 10, pi0 = 0.9, log2foldsd = 1
1.00
0.75
0.50
0.25
0.00
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

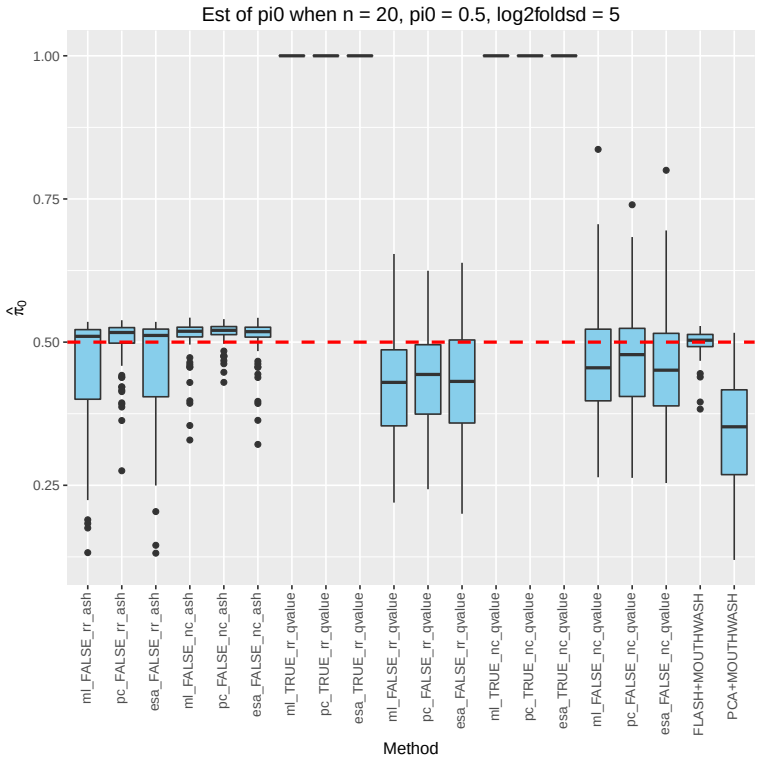

AUC when n = 10, pi0 = 0.9, log2foldsd = 1
0.9
0.8
0.7
0.6
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

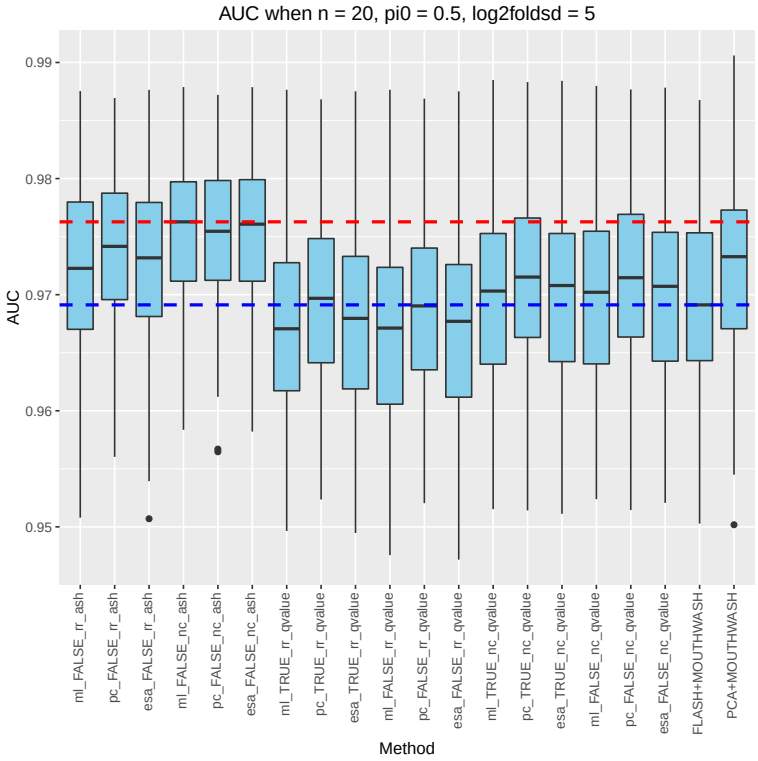

Est of pi0 when n = 10, pi0 = 0.9, log2foldsd = 5
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

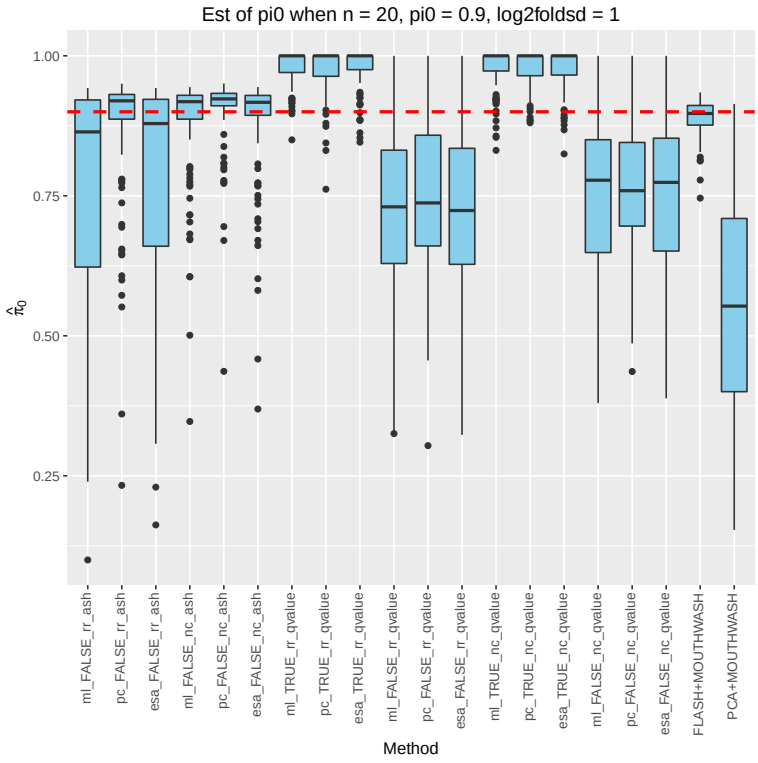

AUC when n = 10, pi0 = 0.9, log2foldsd = 5
1.00
0.95
0.90
0.85
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

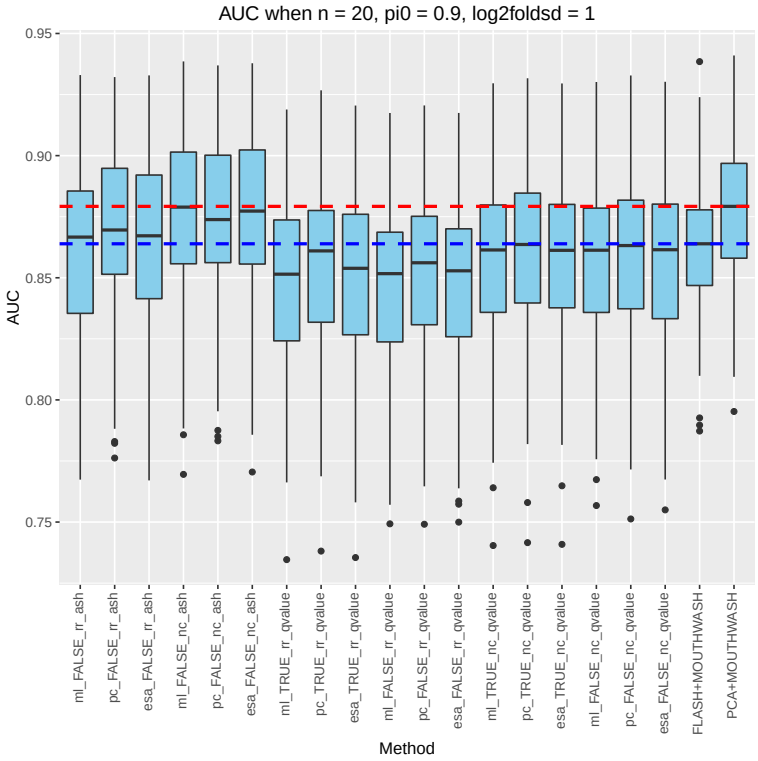

Est of pi0 when n = 20, pi0 = 0.5, log2foldsd = 1
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

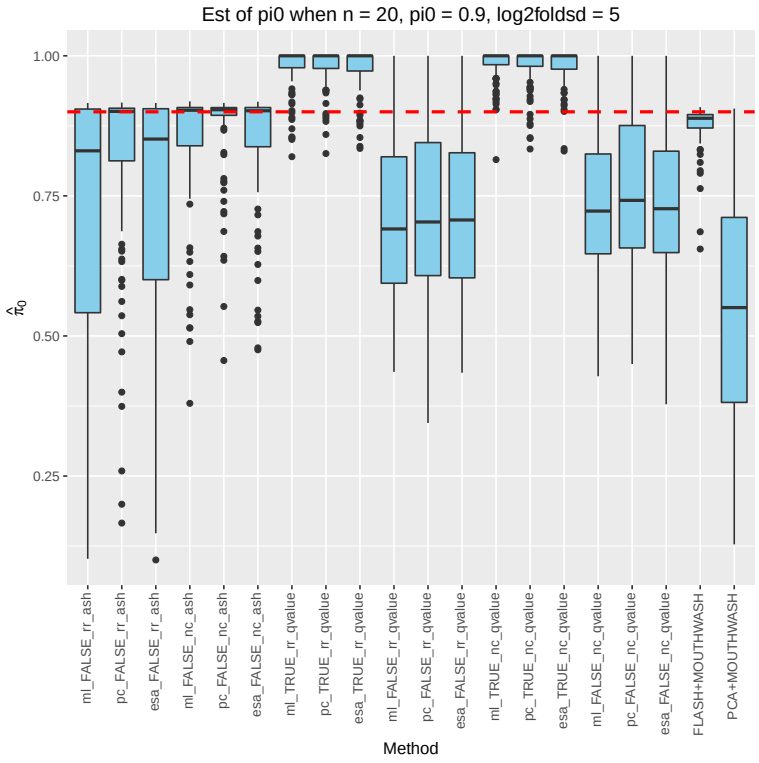

AUC when n = 20, pi0 = 0.5, log2foldsd = 1
0.90
0.85
0.80
0.75
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

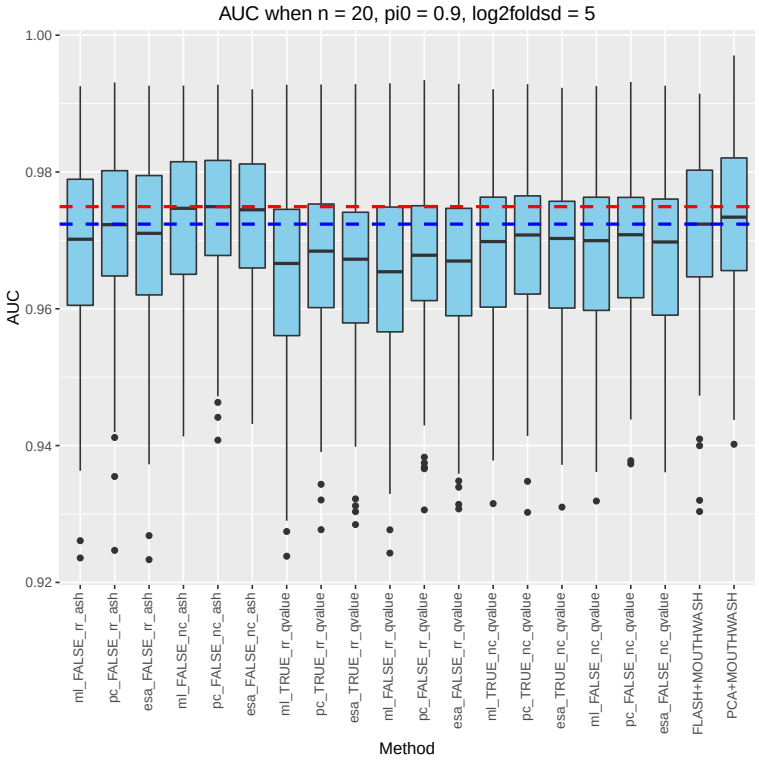

Est of pi0 when n = 20, pi0 = 0.5, log2foldsd = 5
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

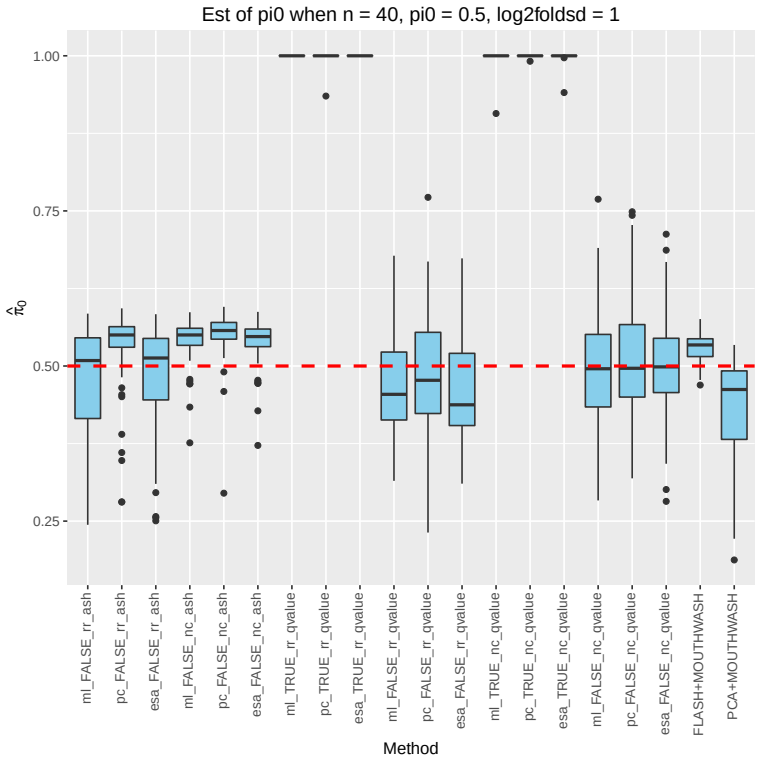

AUC when n = 20, pi0 = 0.5, log2foldsd = 5
0.99
0.98
0.97
0.96
0.95
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

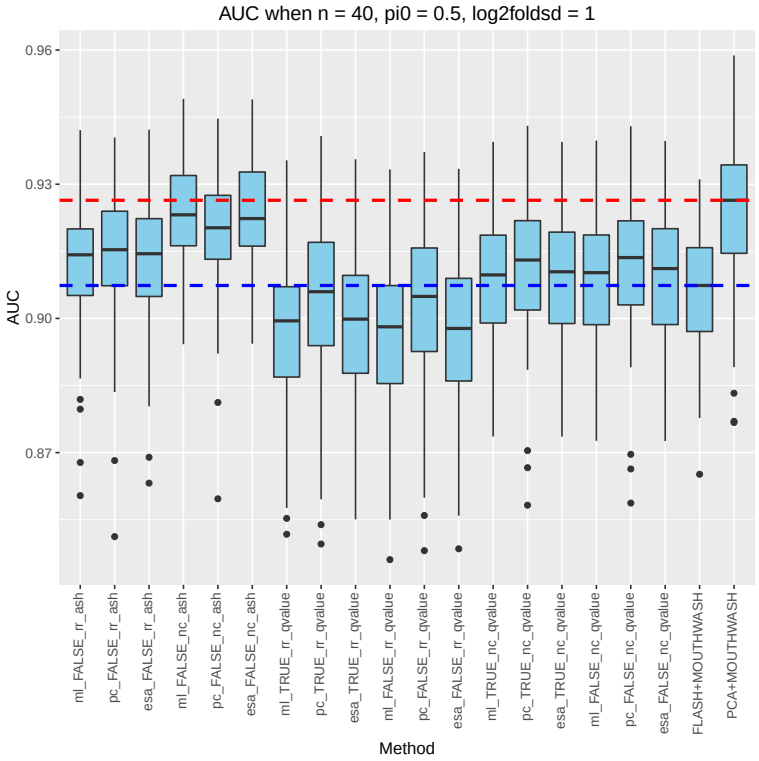

Est of pi0 when n = 20, pi0 = 0.9, log2foldsd = 1
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

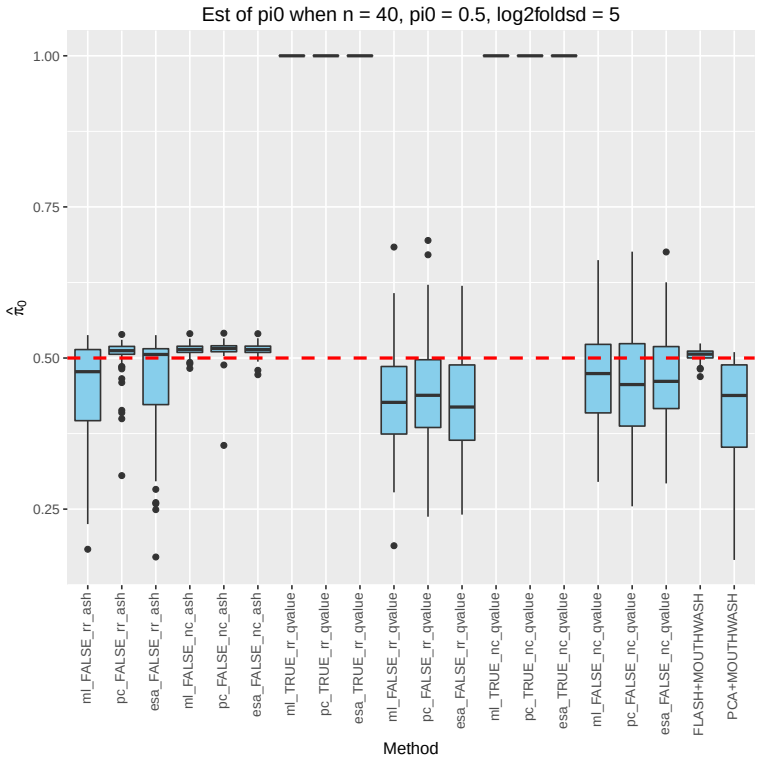

AUC when n = 20, pi0 = 0.9, log2foldsd = 1
0.95
0.90
0.85
0.80
0.75
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

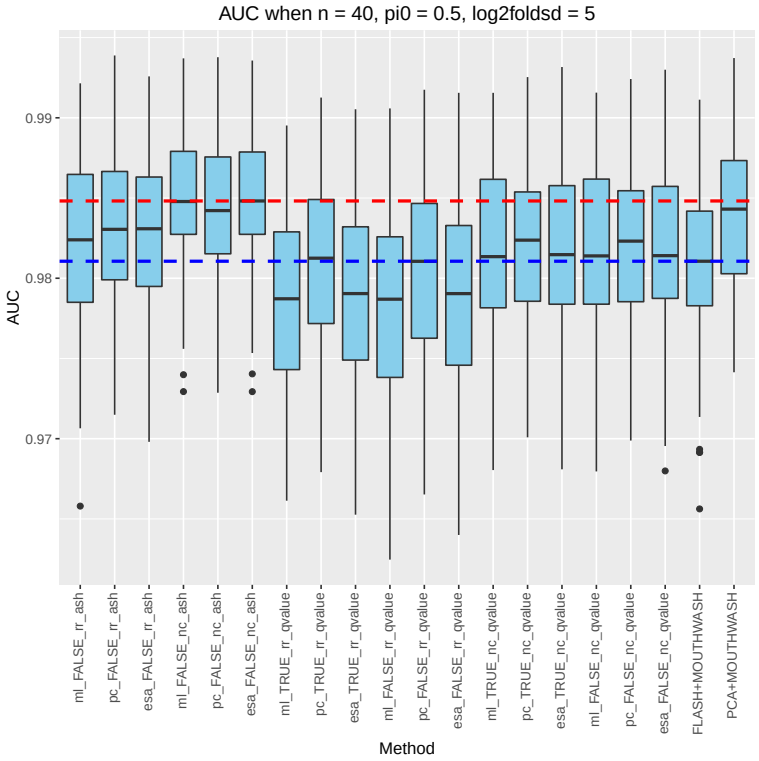

Est of pi0 when n = 20, pi0 = 0.9, log2foldsd = 5
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

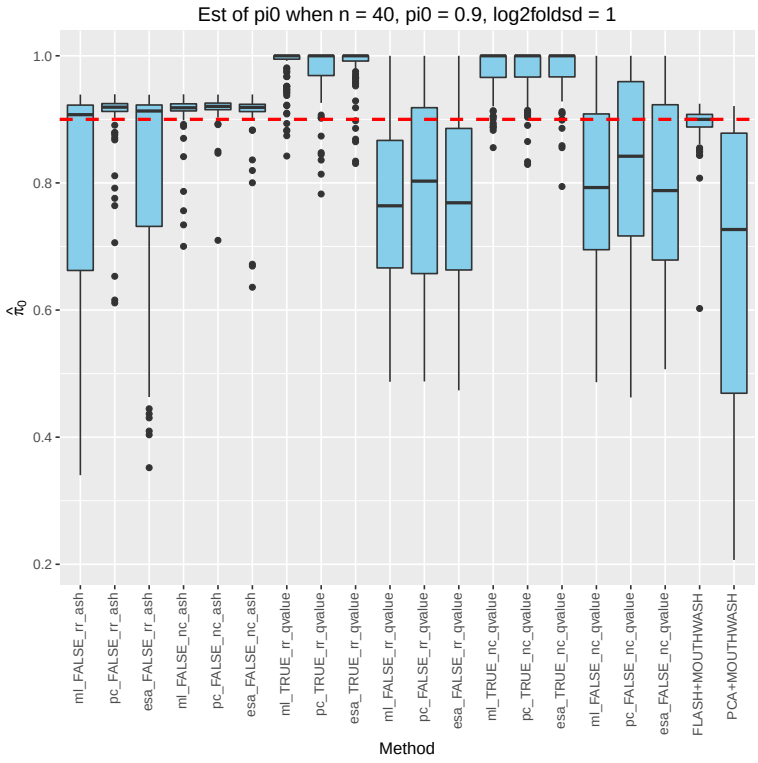

AUC when n = 20, pi0 = 0.9, log2foldsd = 5
1.00
0.98
0.96
0.94
0.92
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

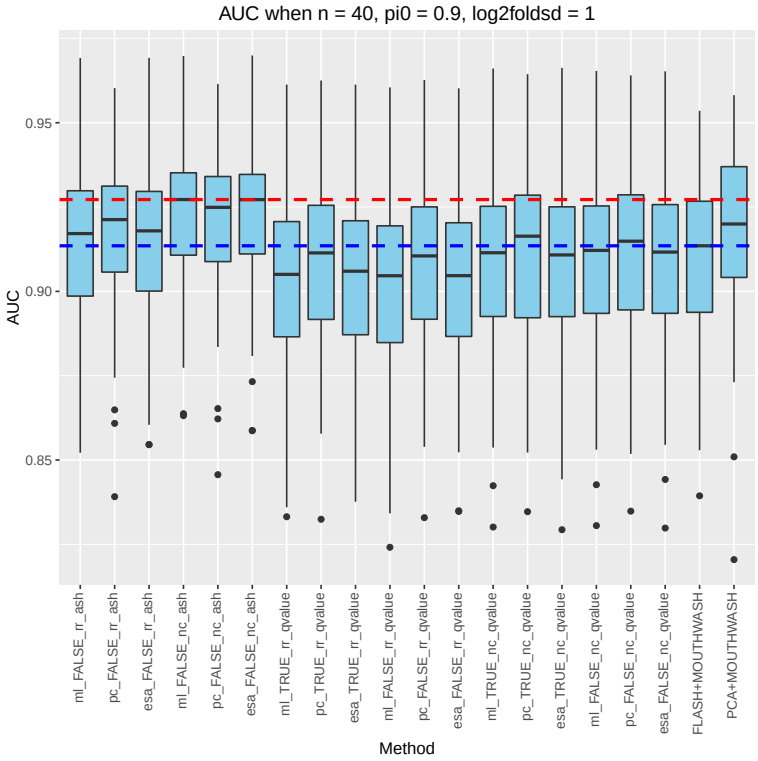

Est of pi0 when n = 40, pi0 = 0.5, log2foldsd = 1
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

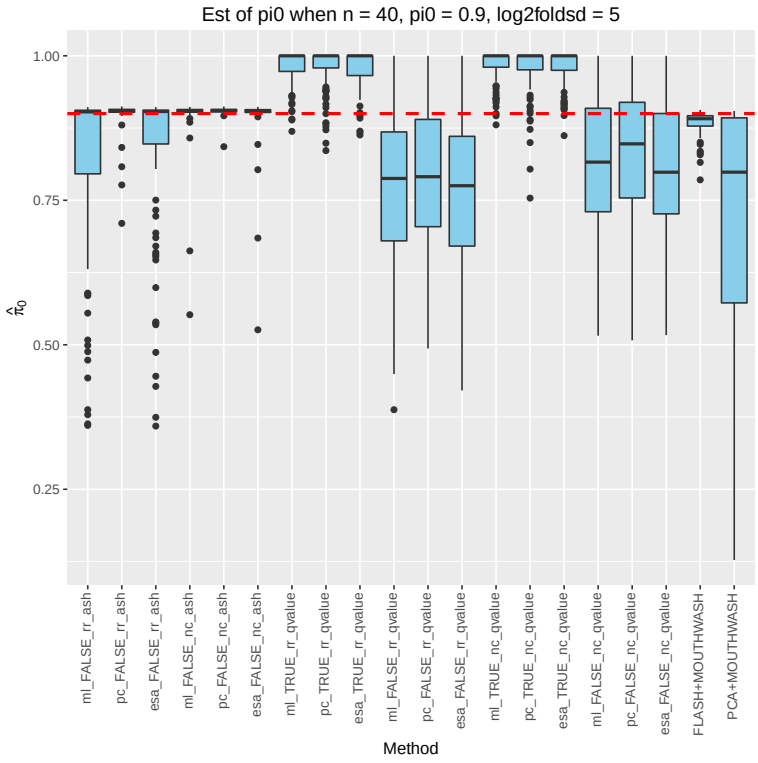

AUC when n = 40, pi0 = 0.5, log2foldsd = 1
0.96
0.93
0.90
0.87
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

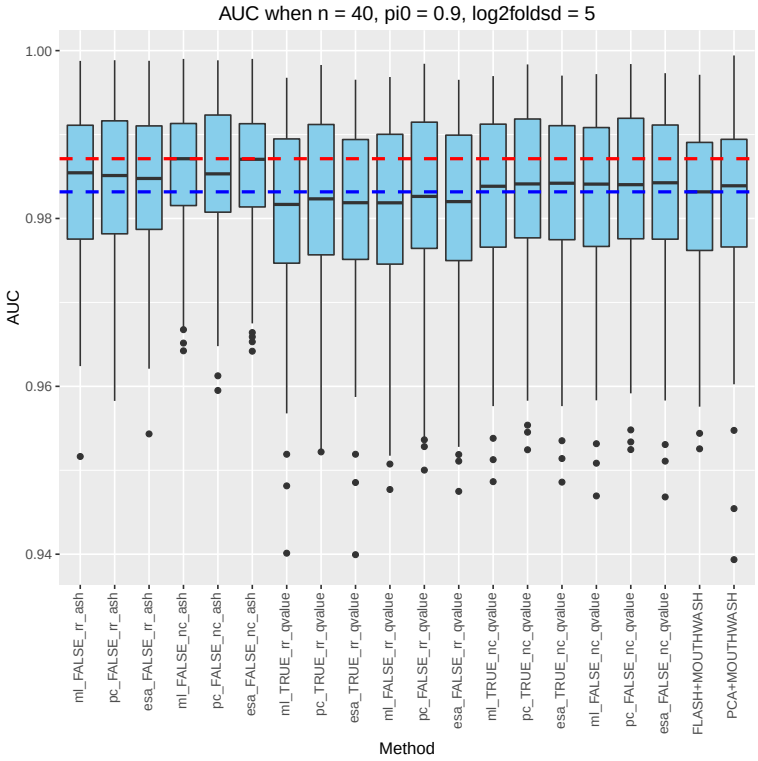

Est of pi0 when n = 40, pi0 = 0.5, log2foldsd = 5
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method


AUC when n = 40, pi0 = 0.5, log2foldsd = 5
0.99
0.98
0.97
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method


Est of pi0 when n = 40, pi0 = 0.9, log2foldsd = 1
1.0
0.8
0.6
0.4
0.2
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method


AUC when n = 40, pi0 = 0.9, log2foldsd = 1
0.95
0.90
0.85
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method


Est of pi0 when n = 40, pi0 = 0.9, log2foldsd = 5
1.00
0.75
0.50
0.25
$\hat{\pi}_0$
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method


AUC when n = 40, pi0 = 0.9, log2foldsd = 5
1.00
0.98
0.96
0.94
AUC
ml_FALSE_rr_ash
pc_FALSE_rr_ash
esa_FALSE_rr_ash
ml_FALSE_nc_ash
pc_FALSE_nc_ash
esa_FALSE_nc_ash
ml_TRUE_rr_qvalue
pc_TRUE_rr_qvalue
esa_TRUE_rr_qvalue
ml_FALSE_rr_qvalue
pc_FALSE_rr_qvalue
esa_FALSE_rr_qvalue
ml_TRUE_nc_qvalue
pc_TRUE_nc_qvalue
esa_TRUE_nc_qvalue
ml_FALSE_nc_qvalue
pc_FALSE_nc_qvalue
esa_FALSE_nc_qvalue
FLASH+MOUTHWASH
PCA+MOUTHWASH
Method

## References

Andreas Buja and Nermin Eyuboglu. Remarks on parallel analysis. *Multivariate behavioral research*, 27(4):509–540, 1992.

John D Storey. A direct approach to false discovery rates. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 64(3):479–498, 2002.