Step-by-Step Guidelines for Propensity Score Weighting with Two Groups

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Four key steps

1) Choose the primary treatment effect of interest (ATE or ATT)
2) Estimate propensity score (ps) weights
3) Evaluate the quality of the ps weights
4) Estimate the treatment effect

Case study

- Aim: To estimate the causal effect of MET/CBT5 versus "usual care"
  - Data from 2 SAMSHA CSAT discretionary grants

MET/CBT5	"Usual Care"
• Longitudinal, observational	• Longitudinal, observational
• 37 sites from EAT study	• 4 sites from ATM study
• N = 2459	• N = 444
• 2003/04 - 2007	• 1998-1999

Case study

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  - Data from 2 SAMSHA CSAT discretionary grants

MET/CBT5

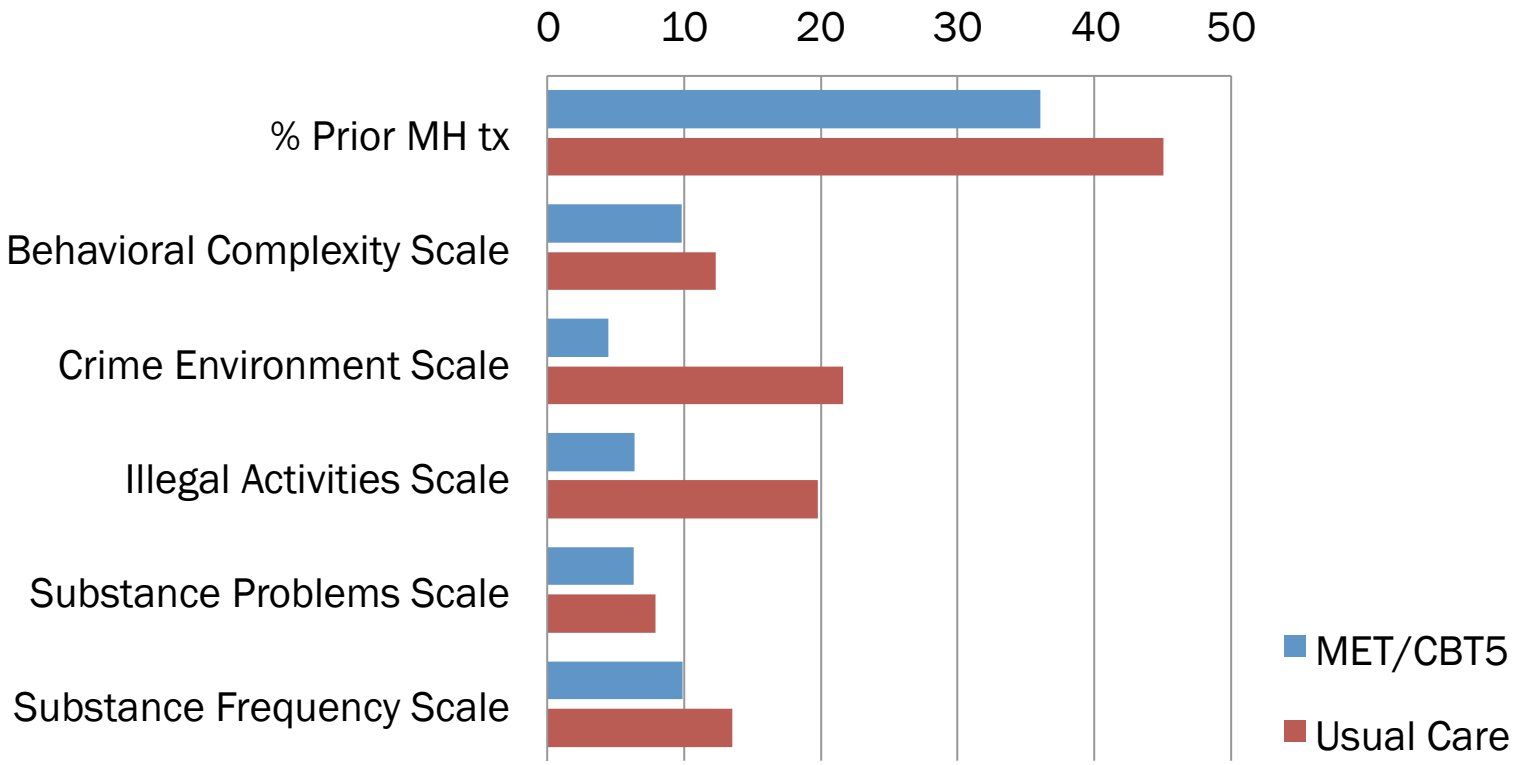
- Longitudinal, observational
- 37 sites from EAT study
- N = 2459
- 2003/04 - 2007

"Usual Care"

- Longitudinal, observational
- 4 sites from ATM study
- N = 444
- 1998-1999

All youth assessed with the GAIN at baseline, 6 months, and 12 months

Selection exists: Various meaningful ways in which the groups differ



Step 1: Choose the primary treatment effect (ATE or ATT)

- Today, we chose to focus on estimating ATT
- Why?
  - Youth in the community are different from those targeted to receive MET/CBT5 in the EAT study
  - Thus, the policy question we want to address is

How would youth like those receiving "usual care" in the community have fared had they received MET/CBT5?

Step 2: Estimate the ps weights

- Only 1 command needed for this step
- Binary treatment command in TWANG currently available in R, SAS and STATA

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
        vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
        class = race4g,
        dataset=sasin.subdata_twogrp,
        ntrees=5000,
        stopmethod=es.max,
        estimand = ATT,
        output_dataset=subdata_twogrp_att_wgts,
        Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
        plotname=binary_twang_att.pdf,
    objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds i
                imds bcs prmhtx,
      class = race4g,
      dataset=sasin.subdata_twogrp,
      ntrees=5000,
      stopmethod=es.max,
      estimand = ATT,
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      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
   objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies name of treatment variable (for ATT, it should = targeted group)

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds ias ces eps
            imds bcs prmhtx,
      class = race4g,
      dataset=sasin.subdata_twogrp,
      ntrees=5000,
      stopmethod=es.max,
      estimand = ATT,
      output_dataset=subdata_twogrp_att_wgts,
      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
 objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies list of pretreatment covariates to balance on

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
        vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
        class = race4g,
        dataset=sasin.subdata_twogrp,
        ntrees=5000,
        stopmethod=es.max,
        estimand = ATT,
        output_dataset=subdata_twogrp_att_wgts,
        Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
        plotname=binary_twang_att.pdf,
objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies which pretreatment variables are categorical

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
      class = race4g,
      dataset=sasin.subdata_twogrp,
      ntrees=5000,
      stopmethod=es.max,
      estimand = ATT,
      output_dataset=subdata_twogrp_att_wgts,
      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
   objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies name of dataset

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
      class = race4g,
      dataset=sasin.subdata_twogrp,
      ntrees=5000,
      stopmethod=es.max,
      estimand = ATT,
      output_dataset=subdata_twogrp_att_wgts,
      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
   objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies the maximum number of iterations used by GBM. Should be large (5000 to 10000)

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
        vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
        class = race4g,
        dataset=sasin.subdata_twogrp,
        ntrees=5000,
        stopmethod=es.max,
        estimand = ATT,
        output_dataset=subdata_twogrp_att
        Rcmd=C:\Program Files\R\R-3.0.1\b
        plotname=binary_twang_att.pdf,
    objpath=C:\Users\bethg\Documents\TWANG\SAS work);
;
```

Specifies the criteria for choosing the optimal number of iterations. Available choices include mean or max ES and mean or max KS statistics

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
      class = race4g,
      dataset=sasin.subdata_twogrp,
      ntrees=5000,
      stopmethod=es.max,
      estimand = ATT,
      output_dataset=subdata_twogrp_att_wgts,
      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
   objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies primary estimand of interest (ATT or ATE)

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
      class = race4g,
      dataset=sasin.subdata_twogrp,
      ntrees=5000,
      stopmethod=es.max,
      estimand = ATT,
      output_dataset=subdata_twogrp_att_wgts,
      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
   objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies name of outputted dataset with ps weights

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds ias ces eps
                imds bcs prmhtx,
      class = race4g,
      dataset=sasin.subdata_twogrp,
      ntrees=5000,
      stopmethod=es.max,
      estimand = ATT,
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      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
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```

Specifies the R executable by name and path

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
      vars=age female race4g sfs sps sds ias ces eps
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      class = race4g,
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      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
   objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

Specifies name of file where diagnostic plots will go

Command to estimate ps weights in SAS

```
%ps(treatvar=atm,
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                imds bcs prmhtx,
      class = race4g,
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      stopmethod=es.max,
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      Rcmd=C:\Program Files\R\R-3.0.1\bin\R.exe,
      plotname=binary_twang_att.pdf,
   objpath=C:\Users\bethg\Documents\TWANG\SAS work);
```

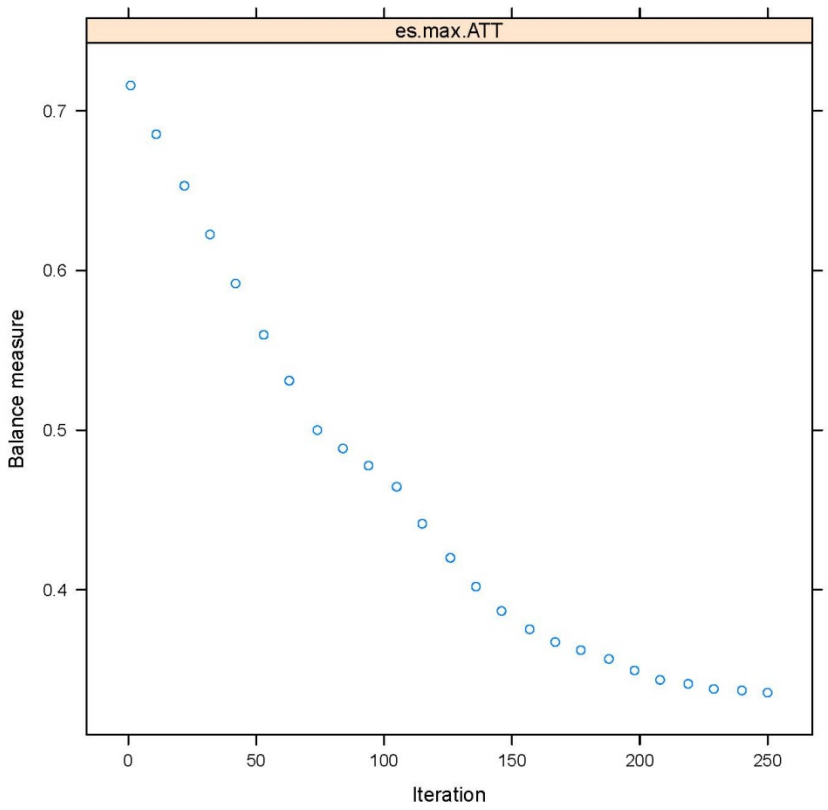
Specifies folder where outputted data and plots will go

Step 3: Evaluate the quality of the ps weights

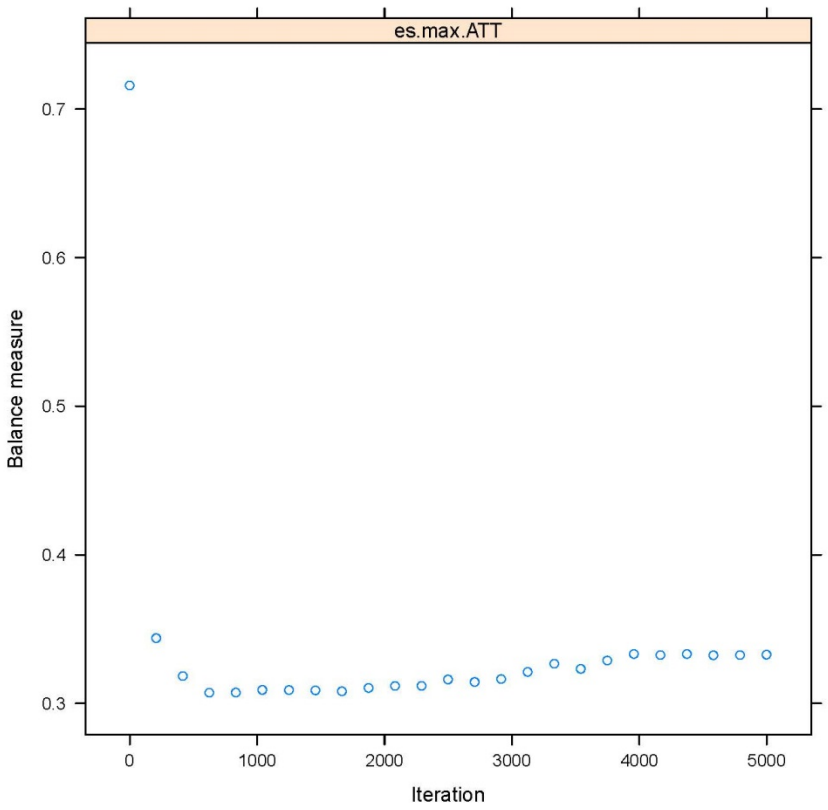
- Key issues that should be checked:
  - Convergence = did the algorithm run long enough
  - Balance = how well matched the two groups look after weighting
  - Overlap = whether there is evidence that the distributions of the pretreatment covariates in the two groups line up well

Step 3: Checking convergence

Bad Convergence



Good Convergence



Step 3: Checking balance

- TWANG has numerous diagnostics for assessing balance

Step 3: Checking balance with tables

Step 3: Checking balance with tables
Unweighted balance table

Balance table: unw

Obs	row_name	tx_mn	tx_sd	ct_mn	ct_sd	std_eff_sz	stat	p	ks	ks_pval	table_name
1	unw.age	15.82	1.09	15.54	1.57	0.26	4.59	0.00	0.12	0.00	unw
2	unw.female	0.21	0.41	0.32	0.47	-0.25	-4.67	0.00	0.10	0.00	unw
3	unw.race4g:1	0.67	0.47	0.51	0.50	0.35	21.45	0.00	0.16	0.00	unw
4	unw.race4g:2	0.14	0.34	0.08	0.27	0.16	.	.	0.05	0.00	unw
5	unw.race4g:3	0.10	0.30	0.24	0.43	-0.49	.	.	0.14	0.00	unw
6	unw.race4g:4	0.09	0.29	0.17	0.37	-0.26	.	.	0.08	0.00	unw
7	unw.race4g: <NA>	0.00	0.05	0.00	0.00	0.05	.	.	0.00	0.00	unw
8	unw.sfs	0.15	0.15	0.11	0.12	0.25	4.89	0.00	0.12	0.00	unw
9	unw.sps	7.93	4.45	6.31	4.27	0.36	7.10	0.00	0.14	0.00	unw
10	unw.sps: <NA>	0.00	0.00	0.00	0.04	-0.04	-27.37	0.00	0.00	0.46	unw
11	unw.sds	3.10	2.33	2.34	2.22	0.33	6.38	0.00	0.15	0.00	unw
12	unw.sds: <NA>	0.00	0.00	0.00	0.06	-0.07	-47.38	0.00	0.00	0.20	unw
13	unw.ias	0.22	0.19	0.09	0.11	0.72	14.73	0.00	0.49	0.00	unw
14	unw.ias: <NA>	0.00	0.00	0.01	0.09	-0.10	-72.54	0.00	0.01	0.05	unw
15	unw.ces	0.24	0.36	0.05	0.18	0.52	10.81	0.00	0.26	0.00	unw
16	unw.eps	0.28	0.19	0.21	0.19	0.37	7.27	0.00	0.19	0.00	unw
17	unw.eps: <NA>	0.00	0.00	0.00	0.04	-0.04	-32.14	0.00	0.00	0.40	unw
18	unw.imds	7.72	8.23	7.83	8.52	-0.01	-0.25	0.80	0.03	0.87	unw
19	unw.imds: <NA>	0.00	0.00	0.00	0.04	-0.04	-32.14	0.00	0.00	0.40	unw
20	unw.bcs	12.26	7.41	9.83	7.78	0.33	6.31	0.00	0.18	0.00	unw
21	unw.bcs: <NA>	0.00	0.00	0.00	0.05	-0.05	-37.83	0.00	0.00	0.30	unw
22	unw.prmhtx	0.45	0.50	0.37	0.48	0.16	3.20	0.00	0.08	0.01	unw
23	unw.prmhtx: <NA>	0.00	0.05	0.01	0.08	-0.06	-1.09	0.28	0.01	0.25	unw

Step 3: Checking balance with tables
Unweighted balance table

Balance table: unw

Obs	row_name	tx_mn	tx_sd	ct_mn	ct_sd	std_eff_sz	stat	p	ks	ks_pval	table_name
1	unw.age	15.82	1.09	15.54	1.57	0.26	4.59	0.00	0.12	0.00	unw
2	unw.female	0.21	0.41	0.32	0.47	-0.25	-4.67	0.00	0.10	0.00	unw
3	unw.race4g:1	0.67	0.47	0.51	0.50	0.35	21.45	0.00	0.16	0.00	unw
4	unw.race4g:2	0.14	0.34	0.08	0.27	0.16	.	.	0.05	0.00	unw
5	unw.race4g:3	0.10	0.30	0.24	0.43	-0.49	.	.	0.14	0.00	unw
6	unw.race4g:4	0.09	0.29	0.17	0.37	-0.26	.	.	0.08	0.00	unw
7	unw.race4g: <NA>	0.00	0.05	0.00	0.00	0.05	.	.	0.00	0.00	unw
8	unw.sfs	0.15	0.15	0.11	0.12	0.25	4.89	0.00	0.12	0.00	unw
9	unw.sps	7.93	4.45	6.31	4.27	0.36	7.10	0.00	0.14	0.00	unw
10	unw.sps: <NA>	0.00	0.00	0.00	0.04	-0.04	-27.37	0.00	0.00	0.46	unw
11	unw.sds	3.10	2.33	2.34	2.22	0.33	6.38	0.00	0.15	0.00	unw
12	unw.sds: <NA>	0.00	0.00	0.00	0.06	-0.07	-47.38	0.00	0.00	0.20	unw
13	unw.ias	0.22	0.19	0.09	0.11	0.72	14.73	0.00	0.49	0.00	unw
14	unw.ias: <NA>	0.00	0.00	0.01	0.09	-0.10	-72.54	0.00	0.01	0.05	unw
15	unw.ces	0.24	0.36	0.05	0.18	0.52	10.81	0.00	0.26	0.00	unw
16	unw.eps	0.28	0.19	0.21	0.19	0.37	7.27	0.00	0.19	0.00	unw
17	unw.eps: <NA>	0.00	0.00	0.00	0.04	-0.04	-32.14	0.00	0.00	0.40	unw
18	unw.imds	7.72	8.23	7.83	8.52	-0.01	-0.25	0.80	0.03	0.87	unw
19	unw.imds: <NA>	0.00	0.00	0.00	0.04	-0.04	-32.14	0.00	0.00	0.40	unw
20	unw.bcs	12.26	7.41	9.83	7.78	0.33	6.31	0.00	0.18	0.00	unw
21	unw.bcs: <NA>	0.00	0.00	0.00	0.05	-0.05	-37.83	0.00	0.00	0.30	unw
22	unw.prmhtx	0.45	0.50	0.37	0.48	0.16	3.20	0.00	0.08	0.01	unw
23	unw.prmhtx: <NA>	0.00	0.05	0.01	0.08	-0.06	-1.09	0.28	0.01	0.25	unw

Red highlights denote rows with absolute ES < 0.20

Step 3: Checking balance with tables
Weighted balance table

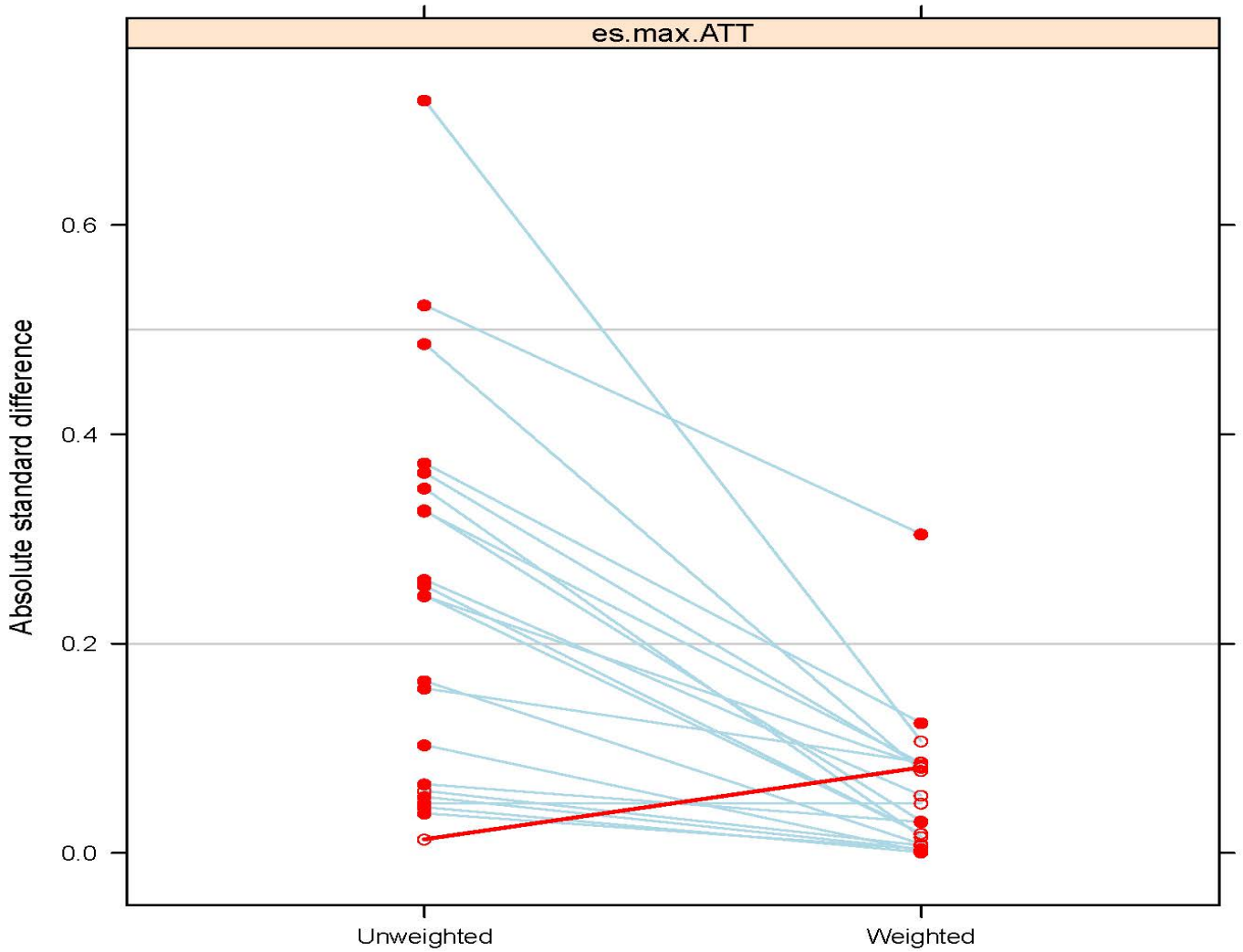
Balance table: es.ma

Obs	row_name	tx_mn	tx_sd	ct_mn	ct_sd	std_eff_sz	stat	p	ks	ks_pval	table_name
24	es.max.ATT.age	15.82	1.09	15.80	1.46	0.02	0.24	0.81	0.05	0.52	es.ma
25	es.max.ATT.female	0.21	0.41	0.25	0.43	-0.08	-1.31	0.19	0.04	0.93	es.ma
26	es.max.ATT.race4g	0.67	0.47	0.67	0.47	0.02	1.08	0.36	0.01	0.36	es.ma
27	es.max.ATT.race4g	0.14	0.34	0.11	0.31	0.09	.	.	0.03	0.36	es.ma
28	es.max.ATT.race4g	0.10	0.30	0.12	0.33	-0.08	.	.	0.02	0.36	es.ma
29	es.max.ATT.race4g	0.09	0.29	0.11	0.31	-0.06	.	.	0.02	0.36	es.ma
30	es.max.ATT.race4g	0.00	0.05	0.00	0.00	0.05	.	.	0.00	0.36	es.ma
31	es.max.ATT.sfs	0.15	0.15	0.15	0.14	-0.02	-0.28	0.78	0.05	0.61	es.ma
32	es.max.ATT.sps	7.93	4.45	7.56	4.25	0.08	1.27	0.20	0.05	0.52	es.ma
33	es.max.ATT.sps:<NA>	0.00	0.00	0.00	0.01	0.00	-20.27	0.00	0.00	0.15	es.ma
34	es.max.ATT.sds	3.10	2.33	2.90	2.25	0.09	1.31	0.19	0.05	0.60	es.ma
35	es.max.ATT.sds:<NA>	0.00	0.00	0.00	0.04	-0.03	-42.25	0.00	0.00	0.00	es.ma
36	es.max.ATT.ias	0.22	0.19	0.20	0.17	0.11	1.67	0.10	0.08	0.07	es.ma
37	es.max.ATT.ias:<NA>	0.00	0.00	0.00	0.01	0.00	-72.30	0.00	0.00	0.00	es.ma
38	es.max.ATT.ces	0.24	0.36	0.13	0.28	0.31	4.32	0.00	0.15	0.00	es.ma
39	es.max.ATT.eps	0.28	0.19	0.26	0.18	0.12	2.06	0.04	0.06	0.28	es.ma
40	es.max.ATT.eps:<NA>	0.00	0.00	0.00	0.01	0.00	-30.06	0.00	0.00	0.03	es.ma
41	es.max.ATT.imds	7.72	8.23	8.40	8.51	-0.08	-1.26	0.21	0.06	0.31	es.ma
42	es.max.ATT.imds:<NA>	0.00	0.00	0.00	0.01	0.00	-30.06	0.00	0.00	0.03	es.ma
43	es.max.ATT.bcs	12.26	7.41	12.48	7.76	-0.03	-0.47	0.64	0.06	0.35	es.ma
44	es.max.ATT.bcs:<NA>	0.00	0.00	0.00	0.01	0.00	-21.96	0.00	0.00	0.13	es.ma
45	es.max.ATT.prmhtx	0.45	0.50	0.45	0.50	-0.01	-0.13	0.90	0.00	1.00	es.ma
46	es.max.ATT.prmhtx	0.00	0.05	0.00	0.05	-0.01	-0.21	0.83	0.00	0.83	es.ma

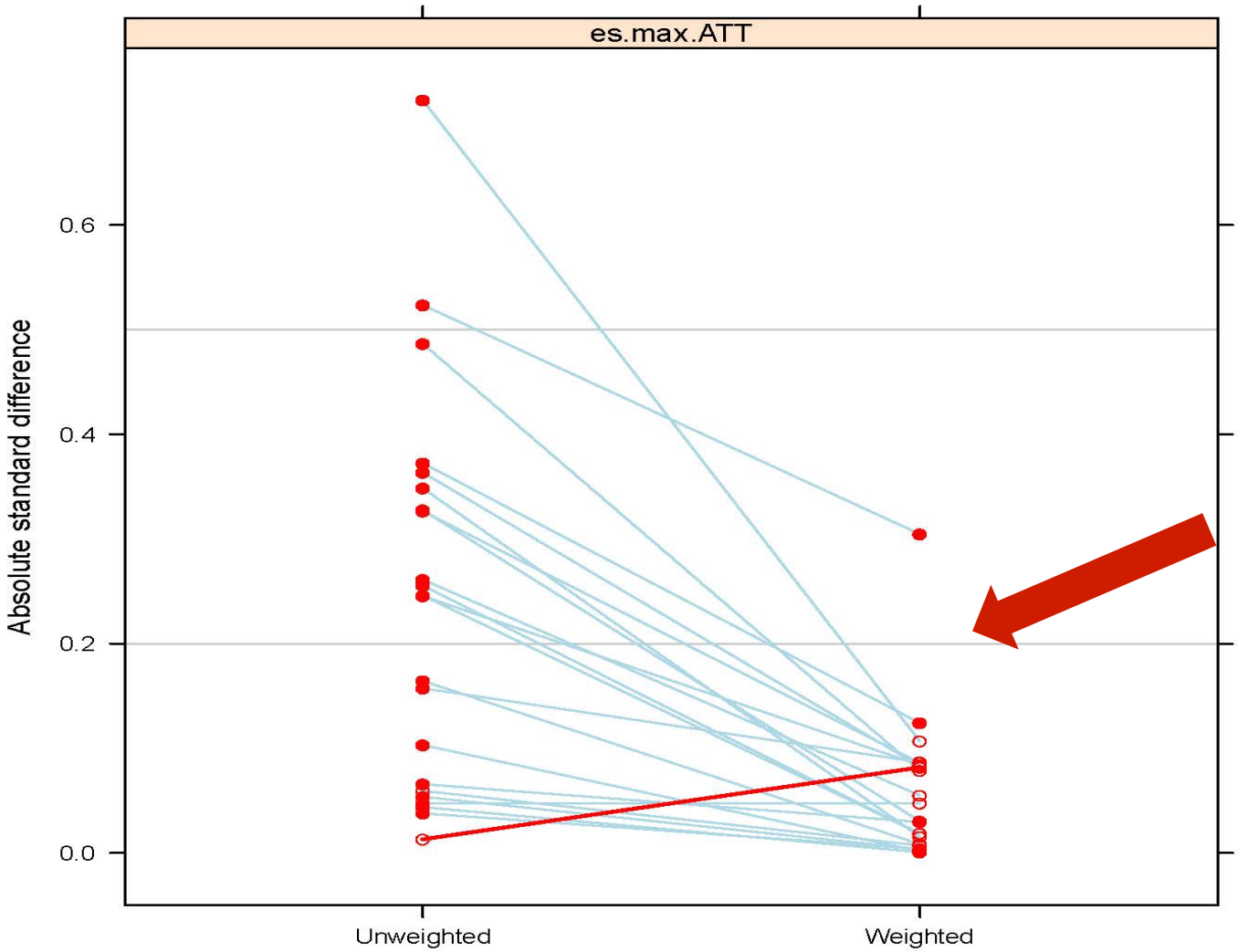
Red highlights denote rows with absolute ES < 0.20

Step 3: Checking balance graphically

Step 3: Checking balance graphically ES plot

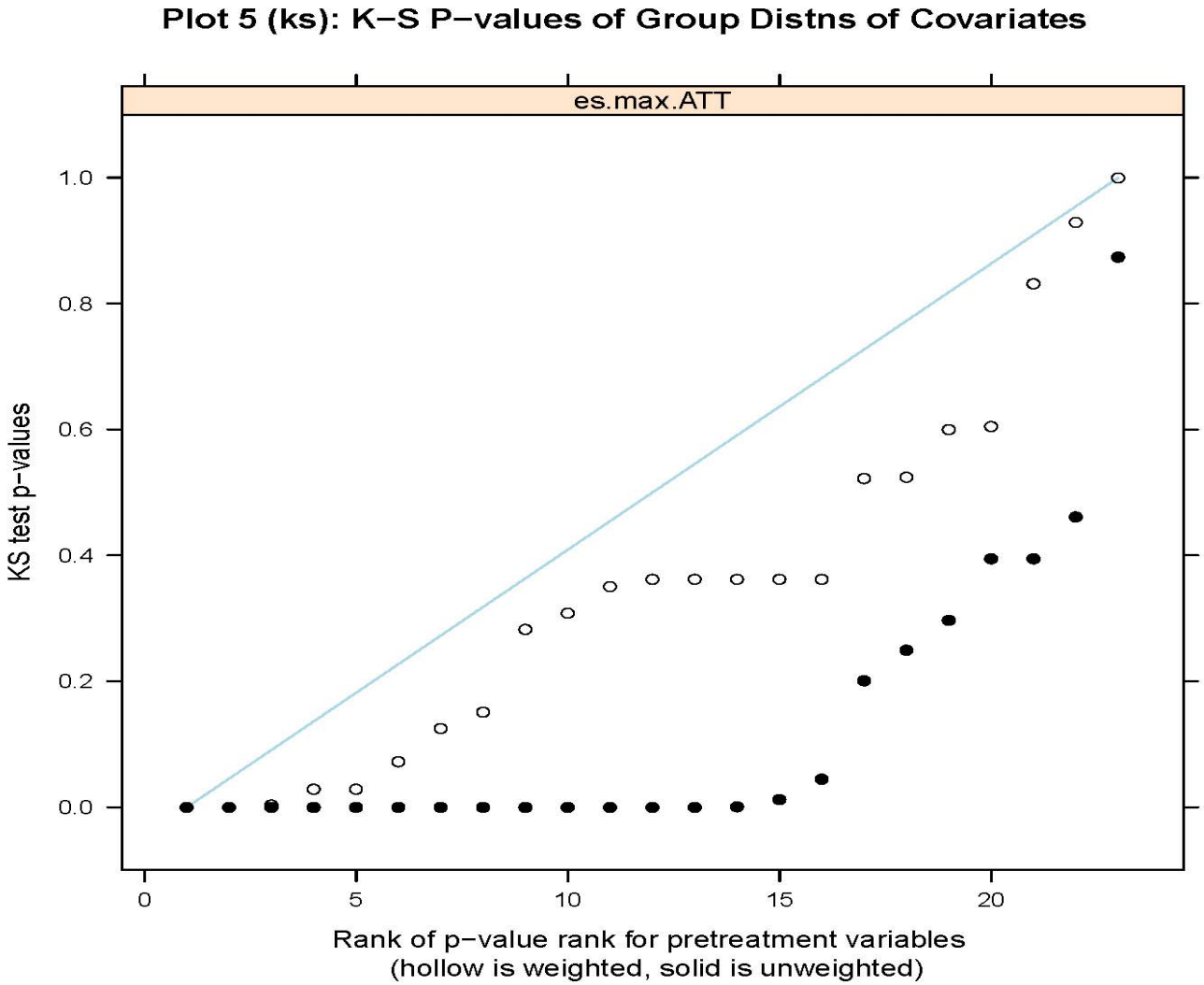


Step 3: Checking balance graphically ES plot

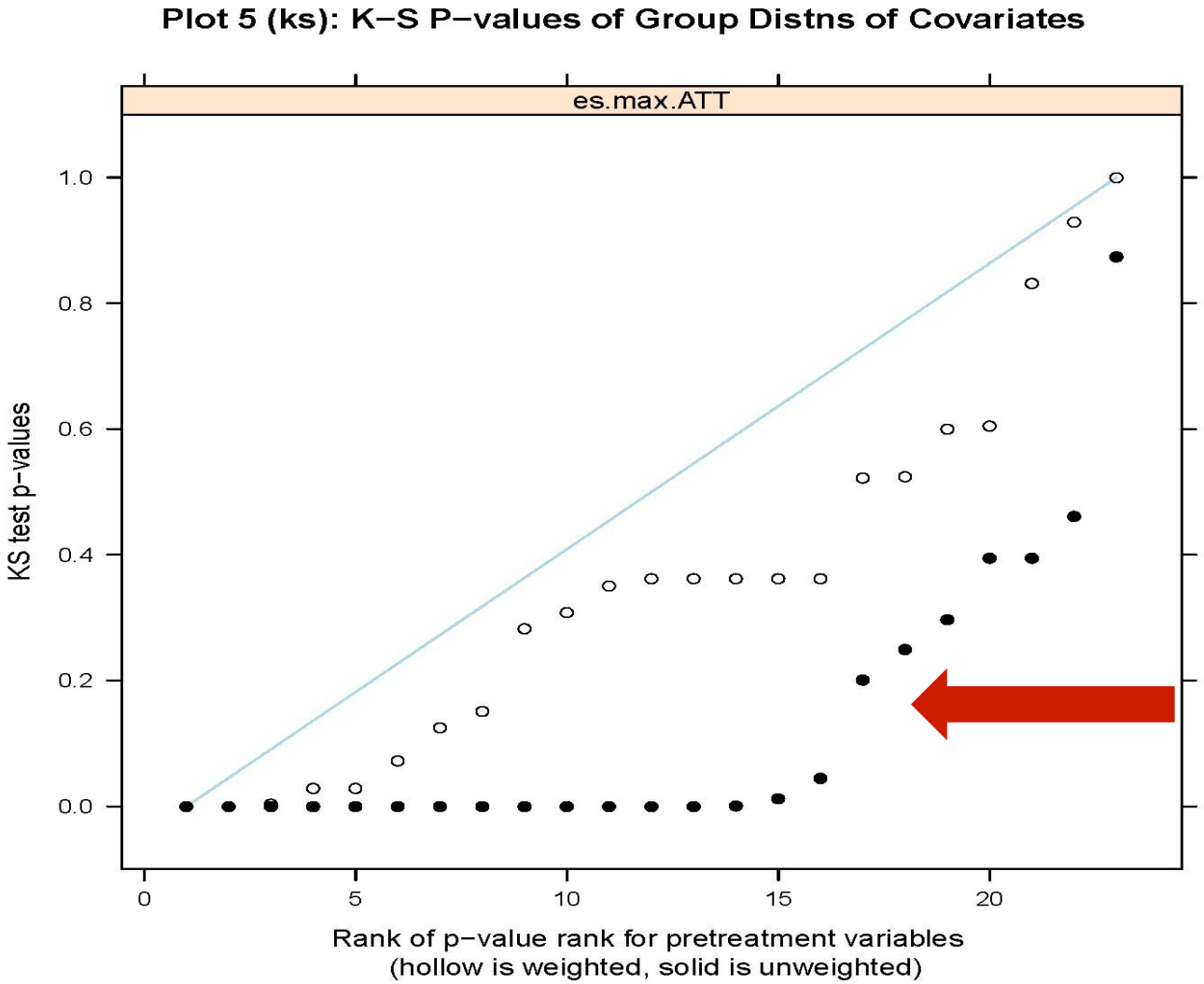


Want as many dots as possible to go below 0.20 after weighting

Step 3: Checking balance graphically KS plot



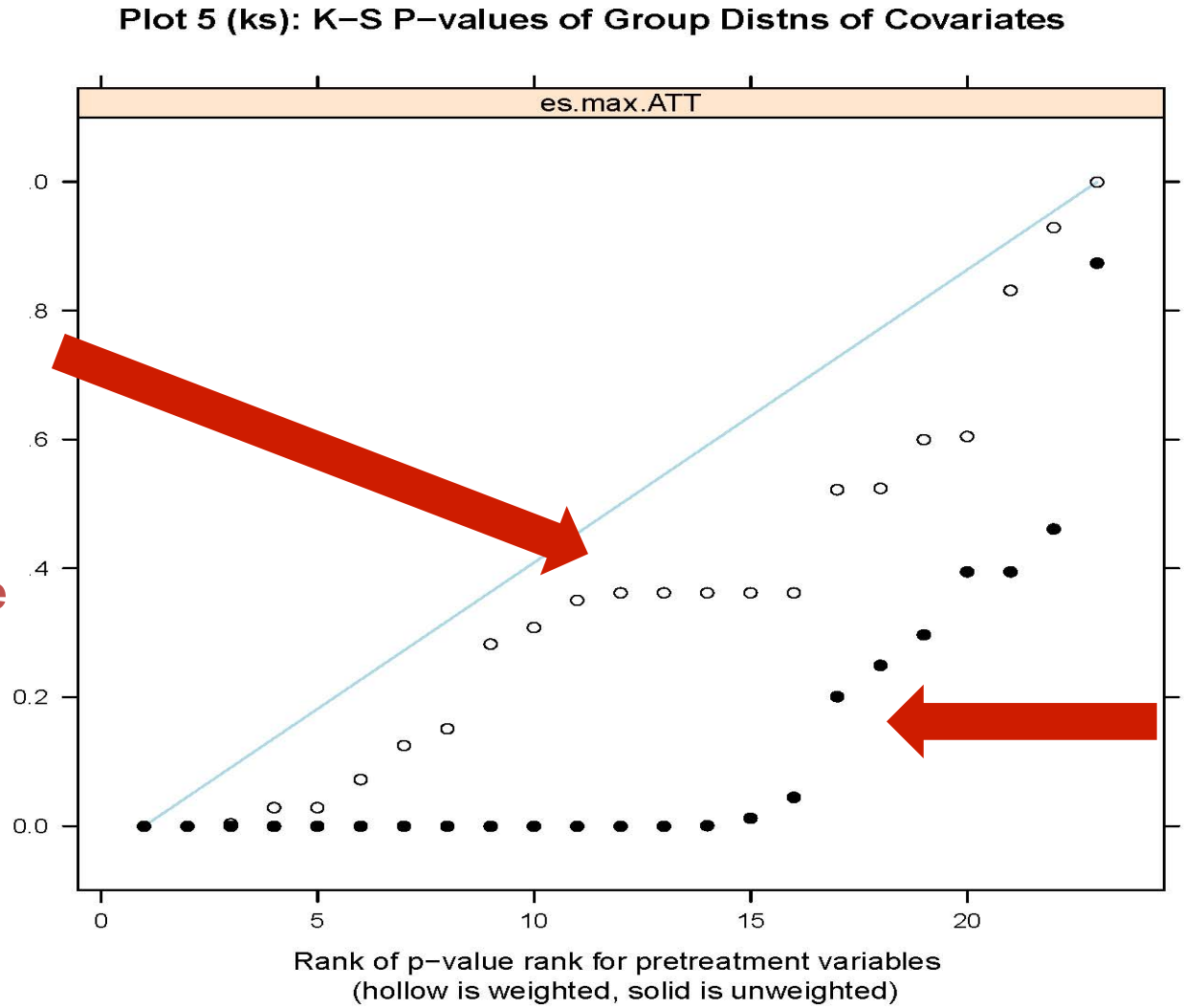
Step 3: Checking balance graphically KS plot



Solid dots = unweighted p-values. Note many less than 0.05

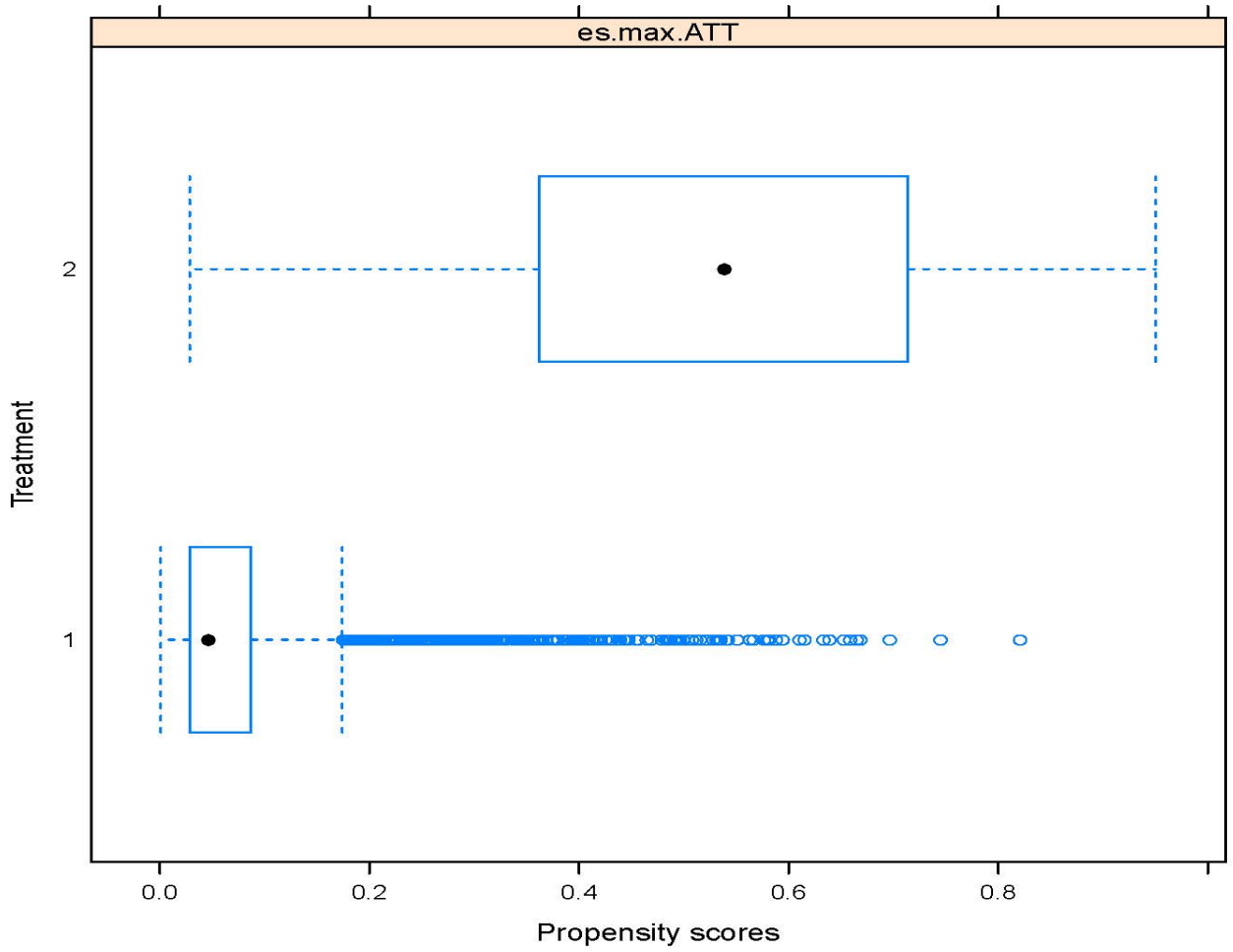
Step 3: Checking balance graphically KS plot

Open dots = weighted p-values. Note getting larger and moving towards the diagonal line



Solid dots = unweighted p-values. Note many less than 0.05

Step 3: Checking overlap



Note: We haven't even begun to talk about the outcome yet

- Steps 1 to 3 do not involve any outcomes
- We first focus on dealing with selection/pre-treatment group differences
- Then, if we do a good job, we will move to outcome analyses

Step 4: Estimate the treatment effect

- Estimate as difference in propensity score weighted means between the two groups of interest
  - Since we are using weights, we need to adjust our standard errors for the weighting
  - Analogous to fitting regression models with survey data with survey weights

Step 4: Estimate the treatment effect

- Estimate as difference in propensity score weighted means between the two groups of interest
  - Since we are using weights, we need to adjust our standard errors for the weighting
  - Analogous to fitting regression models with survey data with survey weights

We can use survey analysis commands in any software to estimate treatment effects

Step 4: Estimate the treatment effect (cont.)

SAS Code:

```
proc surveyreg data=subdata_twogrp_att_wgts;
model sfs8p12 = metcbt5;
weight es_max_att;
run;
```

PS Weighted Regression Coefficients

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.114	0.007	17.13	<.0001
metcbt5	-0.020	0.009	-2.17	0.0304

Step 4: Estimate the treatment effect (cont.)

SAS Code:

```
proc surveyreg data=subdata_twogrp_att_wgts;
model sfs8p12 = metcbt5;
weight es_max_att;
run;
```

PS Weighted Regression Coefficients

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.114	0.007	17.13	<.0001
metcbt5	-0.020	0.009	-2.17	0.0304

Results show that youth like those in "usual care" would have fared better had they received MET/CBT5

Comparison with unweighted treatment effect

SAS Code:

```
proc reg data=subdata_twogrp_att_wgts;
model sfs8p12 = metcbt5;
run;
```

Unweighted Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.114	0.006	20.07	<.0001
metcbt5	1	-0.047	0.006	-7.61	<.0001

Comparison with unweighted treatment effect

SAS Code:

```
proc reg data=subdata_twogrp_att_wgts_atm;
model sfs8p12 = metcbt5;
run;
```

Unweighted Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.114	0.006	20.07	<.0001
metcbt5	1	-0.047	0.006	-7.61	<.0001

- **Also shows significant evidence that youth in "usual care" have higher substance use frequency at 12-months than those in MET/CBT5**
- **Magnitude of the effect unweighted is double (-0.02 vs -0.047)**

Step 4: Doubly robust estimation

- "Doubly robust" estimation is the preferred route for estimating causal treatment effects
  - Combines fitting a propensity score weighted regression model with the inclusion of additional pretreatment control covariates
  - As long as one piece is right (either the multivariate outcome model or the propensity score model), obtain consistent treatment effect estimates

Step 4: Doubly robust estimation: Adding in covariates with lingering imbalances

SAS Code:

```
proc surveyreg data=subdata_twogrp_att_wgts;
model sfs8p12 = metcbt5 ces;
weight es_max_att;
run;
```

PS Weighted Regression Coefficients

Parameter	Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.119	0.008	15.2	<.0001
metcbt5	-0.022	0.010	-2.28	0.0227
ces	-0.019	0.016	-1.18	0.2363

Conclusions

- Use of propensity score weighting reduced bias in our treatment effect estimate
  - Greatly improved balance on observed pretreatment covariates
  - Magnitude of change went from 0.40 effect size difference to 0.20 effect size difference
- Use of propensity score weighting helped us produce more robust estimates of how youth like those in usual care would have fared had they received MET/CBT5

JUSTICE, INFRASTRUCTURE, AND ENVIRONMENT

Please note this video is part of a three-part series. We encourage viewers to watch all three segments.

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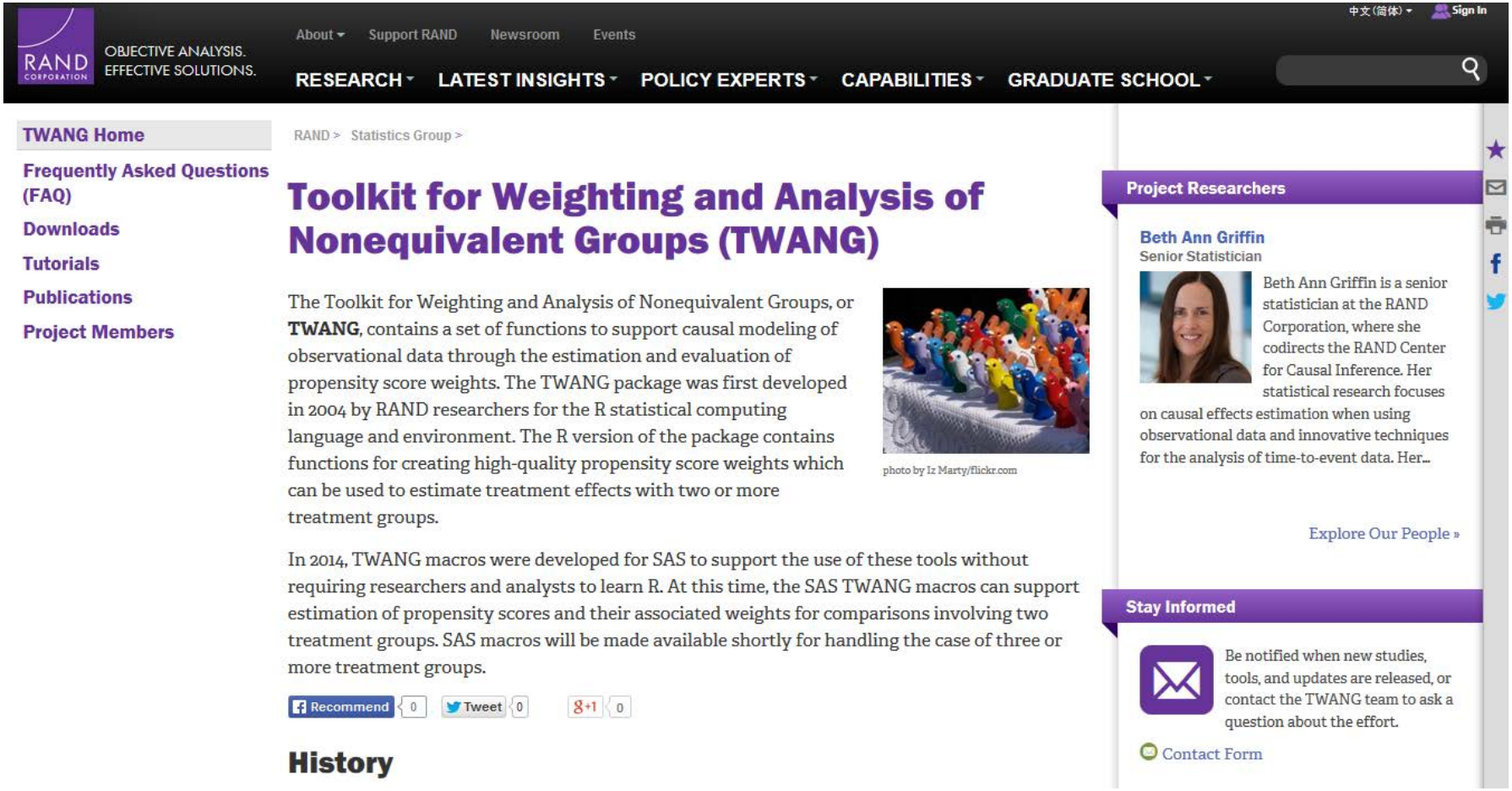
http://www.rand.org/statistics/twang.html



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Toolkit for Weighting and Analysis of Nonequivalent Groups (TWANG)

The Toolkit for Weighting and Analysis of Nonequivalent Groups, or **TWANG**, contains a set of functions to support causal modeling of observational data through the estimation and evaluation of propensity score weights. The TWANG package was first developed in 2004 by RAND researchers for the R statistical computing language and environment. The R version of the package contains functions for creating high-quality propensity score weights which can be used to estimate treatment effects with two or more treatment groups.

photo by Iz Marty/flickr.com

In 2014, TWANG macros were developed for SAS to support the use of these tools without requiring researchers and analysts to learn R. At this time, the SAS TWANG macros can support estimation of propensity scores and their associated weights for comparisons involving two treatment groups. SAS macros will be made available shortly for handling the case of three or more treatment groups.

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Project Researchers

Beth Ann Griffin
Senior Statistician

Beth Ann Griffin is a senior statistician at the RAND Corporation, where she codirects the RAND Center for Causal Inference. Her statistical research focuses on causal effects estimation when using observational data and innovative techniques for the analysis of time-to-event data. Her...

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