**Comparative Effectiveness Research Methods Training**

Module 4: Propensity Score Application

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## A little (more) about me.

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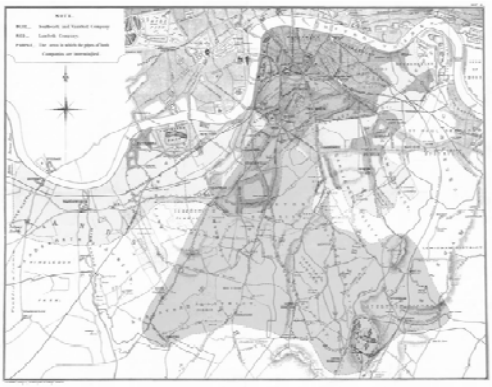

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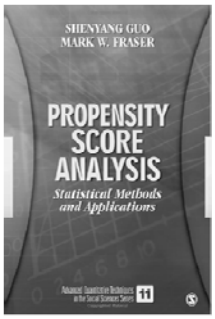


**(2010)**

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## Module #4 Outline

1. Review of Core Ideas
2. ATE, ACE, ATT, TOT
3. A Typical Analysis
4. Propensity Score Methods
5. Issues & Assumptions
6. Review
7. Questions

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## 1. Review Core Ideas

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## Potential Outcomes

| Condition Assigned | Outcome if Treated, $Y^1$ | Outcome if not Treated, $Y^0$ |
|---|---|---|
| Treatment | Observed | Unobservable Counterfactual |
| Control | Unobservable Counterfactual | Observed |

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## Analysis of Experimental Data

$$Y = \alpha + \beta_1 T + \varepsilon$$

$$\hat{\beta}_1 \Rightarrow \bar{\Delta} = \text{ average causal effect}$$

*T* is (0,1) treatment indicator which, for large samples, is independent of background characteristics by study design (ie, randomization)

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## Absent Randomization

$$Y = \alpha + \beta_1 T + \mathbf{\beta Z} + \varepsilon$$

**Covariates, *Z*, serve to adjust groups for confounding…**

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## Absent Randomization

**Unless specification of the model, including X, is perfect, bias results**

$$\beta_1 = \bar{\Delta} + \text{BIAS}$$

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## Propensity Score Methods

**An approach to confounder control that better mimics the experimental approach.**

Introduced by Rosenbaum and Rubin in 1983

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## Propensity Score, *p(z)*

In the analysis of treatment effects, suppose that we have a binary treatment *T*, an outcome *Y*, and background variables *Z*. The propensity score is defined as the conditional probability of treatment given background variables:

$$p(z) \equiv \Pr(T = 1 \mid Z = z)$$

Propensity score

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## Ignorable TAM

$$TAM \perp Y(0), Y(1) \mid p(z)$$

Propensity score

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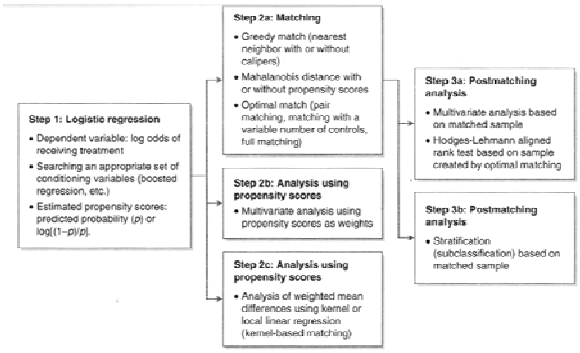


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Gou & Fraser, Fig 5.1

Because they require us to think about the ideal experiment we would have liked to have conducted, propensity score methods are a better tool than multiple regression. Setting aside the outcome variable, Y, until it's time to assess differences between observed outcomes and counterfactual substitutes, is an invaluable addition to the practice of applied research.

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## 2. ATE, ACE, ATT, TOT

**What "effect" do we wish to estimate?**

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Ideally, we'd like the treatment effect for each individual in our study. If we could observe every person and their counterfactual we could just take the average across all persons as an estimate of delta.

$$\tau_i = Y_i(1) - Y_i(0)$$

$$\overline{\tau} \Rightarrow \Delta$$

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But of course we cannot calculate a causal effect for a particular person.

We must move up the population level.

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The **average treatment effect** (**ATE**) is the difference in the average of the outcome variable in the treatment group minus the average of the outcome variable in the control group. ATE is the same as the **average causal effect (ACE).**

$$\text{ATE} = \text{ACE} = E[Y(1) - Y(0)]$$

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The **average treatment effect** (**ATE**) is the difference in the average of the outcome variable in the treatment group minus the average of the outcome in the control group. ATE is the same as the **average causal effect (ACE).**

$$\text{ATE} = \text{ACE} = E[Y(1) - Y(0)]$$

**Often desired and easily estimable in RCTs**

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The **average treatment effect on the treated (ATT)** is the mean difference between those actually treated or exposed and their counterfactuals. ATT is the same as the **treatment effect on the treated (TOT)**.

$$\text{ATT} = \text{TOT} = E[Y(1) - Y(0) \mid \text{T=1}]$$

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The **affect of the treatment on the treated (ATT)** is the mean effect of those actually treated or exposed . ATT is the same as the **treatment effect on the treated (TOT)**.

$$\text{ATT} = \text{TOT} = E[Y(1) - Y(0) \mid \text{T=1}]$$

**Often better for observational designs**

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When we randomize the treatment assignment mechanism (TAM) is independent of the outcomes and all subjects have a positive probability of being treated. Accordingly, the ATT = ATE:

$$\text{ATT} = \text{ATE} = E(Y \mid T = 1) - E(Y \mid T = 0) = E[Y(1) - Y(0)]$$

This is because randomization produces exchangeable groups (ie, balance) and yields excellent counterfactual substitutes. In other words, the control group serves to substitute for the unobservable counterfactuals of the treatment group, at least with large samples.

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But when we do not randomize the treatment assignment mechanism (TAM) is rarely independent of the outcomes and some subjects may have a zero probability of being treated. Accordingly,

$$\text{ATT} \neq \text{ATE}$$

Thus we are often better off comparing treated subjects to the best counterfactuals we can find for them. The best ones are the non-treated subjects that have the same probability of being treated as the treated subjects being studied (or the set of them). This theoretically satisfied the critical assumption about independence of the treatment assignment mechanism: $TAM \perp Y(0), Y(1) \mid p(z)$

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Incredibly, neither of the desired effect estimates (ATT, ATE) is (easily) identifiable through regression modeling in an observational study.

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## 3. Typical Analysis

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## Let's use Stata

**What is Stata?** Stata is a full-featured statistical programming language for Windows, Macintosh, Unix and Linux. It can be considered a "stat package," like SAS, SPSS, or R.

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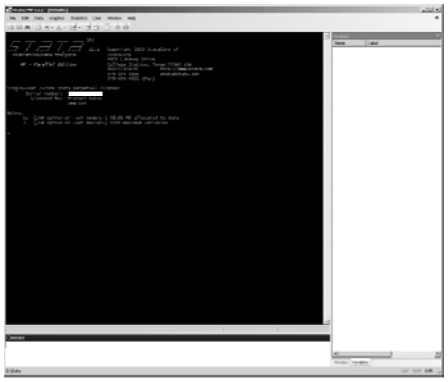

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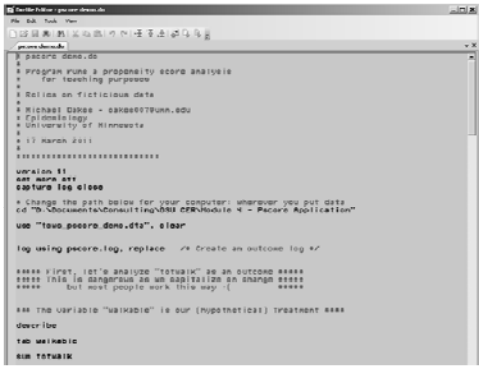

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**Data and program for this entire module are available on "class website".**

**Data……. tcws_pscore_demo.dta**

**Program…. pscore demo.do**

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**Data are based on my Twin Cities Walking Study (TCWS) but have been altered for pedagogical purposes. The data are <u>fictitious</u>!**

**Epidemiologic Perspectives & Innovations**

Methodology

Open Access

**The effects of neighborhood density and street connectivity on walking behavior: the Twin Cities walking study**

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Email: J Michael Oakes* - oakes007@umn.edu; Ann Forsyth - af41@cornell.edu; Kathryn H Schmitz - schmitz@mail.med.upenn.edu

* Corresponding author



```
. d
Contains data from D:\Documents\Consulting\OSU CER\Module 4 - PScore Application\tcws_pscore_demo.dta
  obs:           358                          Teaching Demo
 vars:            15                          20 Mar 2011 00:47
 size:        17,542 (99.9% of memory free)    (_dta has notes)

              storage  display     value
variable name   type   format      label      variable label
-------------------------------------------------------------------------------
id              int    %10.0g                 Subject ID
walkable        float  %9.0g       yesno      Fictitious Walkability Measure
area            byte   %9.0g                  Neighborhood ID
bmi             float  %9.0g                  Subjects Body Mass Index
totwalk         float  %9.0g                  Total walking METS: Diaries
totpa           float  %9.0g                  Physical activity: Mean Accel counts
health          byte   %9.0g       health2    Self reported Health: 5 = Excellent
tenure          double %10.0g                 Years living at address
hhinc           byte   %19.0g      hhinc      Household Income
rent_own        byte   %8.0g       yesno      Owned or rented
male            float  %9.0g       yesno      Subject is male
white           byte   %9.0g       yesno      Subject self-report race white
married         byte   %9.0g       yesno      Subject is married
college         byte   %9.0g       yesno      Subject completed college
age             float  %9.0g                  Subject age, years
-------------------------------------------------------------------------------
Sorted by:
```

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```
. d

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  obs:           358                          Teach
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              storage  display     value
variable name   type   format      label      variab
-------------------------------------------------------------------------------
id              int    %10.0g                 Subjec
```

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```
. sum totwalk, d

                    Total walking METS: Diaries

      Percentiles      Smallest
 1%     541.2266            500
 5%     956.7971            500
10%         2500       527.4055       Obs                 343
25%         4500       541.2266       Sum of Wgt.         343

50%         6225                      Mean           6814.193
                       Largest        Std. Dev.      3834.148
75%         8858          14760
90%        13100          14792       Variance       1.47e+07
95%        14198          14892       Skewness       .4462299
99%        14760          15000       Kurtosis       2.368513
```

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25%         4500       541.2266       Sum of Wgt.         343

50%         6225                      Mean           6814.193
                       Largest        Std. Dev.      3834.148
75%         8858          14760
90%        13100          14792       Variance       1.47e+07
95%        14198          14892       Skewness       .4462299
99%        14760          15000       Kurtosis       2.368513
```

**Was 358!**

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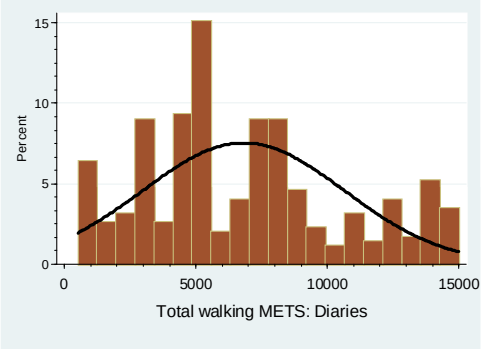


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```
. tab walkable

Ficticious
Walkablity
  Measure |      Freq.     Percent        Cum.
----------+-----------------------------------
       No |        170       47.49       47.49
      Yes |        188       52.51      100.00
----------+-----------------------------------
    Total |        358      100.00

.
. tab walkable, sum(totwalk)

Ficticious
Walkablity
  Measure |  Summary of Total walking METS: Diaries
          |        Mean   Std. Dev.       Freq.
----------+------------------------------------
       No | 4466.9781   2349.2146         164
      Yes | 8964.7132   3669.4137         179
----------+------------------------------------
    Total | 6814.1926   3834.1481         343
```



## t-test of totwalk (Y) by walkable (X)

```
. ttest totwalk, by(walkable) unequal

Two-sample t test with unequal variances

   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
      Tx |     179    8964.713    274.2649    3669.414    8423.484    9505.942
      Cx |     164    4466.978    183.4428    2349.215    4104.747    4829.209
---------+--------------------------------------------------------------------
combined |     343    6814.193    207.0245    3834.148    6406.991    7221.394
---------+--------------------------------------------------------------------
    diff |            4497.735    329.9583                3848.461    5147.009
------------------------------------------------------------------------------
    diff = mean(Tx) - mean(Cx)                                    t =  13.6312
Ho: diff = 0                     Satterthwaite's degrees of freedom =  306.007

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```



```
. ttest totwalk, by(walkable) unequal

Two-sample t test with unequal variances

   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
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Ho: diff = 0                     Satterthwaite's degrees of freedom =  306.007

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

## Bivariate Regression: totwalk (Y) on walkable (X)

```
. reg totwalk walkable   /* Fit a crude model */
      Source |       SS       df       MS              Number of obs =     343
-------------+------------------------------           F(  1,   341) =  179.11
       Model |  1.7314e+09     1  1.7314e+09           Prob > F      =  0.0000
    Residual |  1.2961e+09   341  9666463.74           R-squared     =  0.3444
-------------+------------------------------           Adj R-squared =  0.3424
       Total |  5.0276e+09   342  14700691.9           Root MSE      =  3109.1

------------------------------------------------------------------------------
     totwalk |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    walkable |    4497.735   336.0721    13.38   0.000      3836.7    5158.77
       _cons |    4466.978   242.7794    18.40   0.000     3989.444    4944.512
------------------------------------------------------------------------------
```




```
. reg totwalk walkable   /* Fit a crude model */
      Source |       SS       df       MS
-------------+------------------------------
       Model |  1.7314e+09     1  1.7314e+09
    Residual |  3.2963e+09   341  9666463.74
-------------+------------------------------
       Total |  5.0276e+09   342  14700691.9

------------------------------------------------------------------------------
     totwalk |      Coef.   Std. Err.      t    P>
-------------+----------------------------------------------------------------
    walkable |    4497.735   336.0721    13.38   0.
       _cons |    4466.978   242.7794    18.40   0.
------------------------------------------------------------------------------
```

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## Assess differences in averagesof suspected confounders across treatment (walkable) and control (no walkable) conditions.

### Use a t-test

**(better methods available)**

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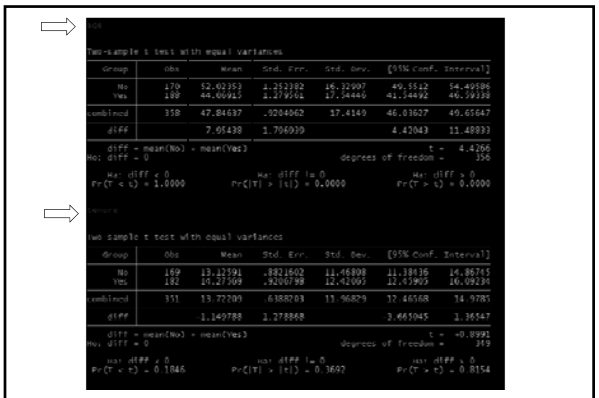


. age

Two-sample t test with equal variances

| Group | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| No | 170 | 52.02353 | 1.252382 | 16.32997 | 49.5512 | 54.49586 |
| Yes | 188 | 44.06915 | 1.279561 | 17.54446 | 41.54492 | 46.59338 |
| combined | 358 | 47.84637 | .9204062 | 17.4149 | 46.03627 | 49.65647 |
| diff | | 7.95438 | 1.796939 | | 4.42043 | 11.48833 |

diff = mean(No) - mean(Yes) t = 4.4266
Ho: diff = 0 degrees of freedom = 356

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 1.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t) = 0.0000

. ttest

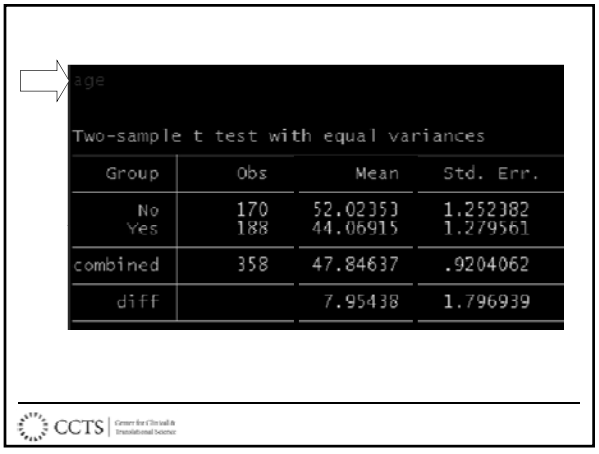
Two-sample t test with equal variances

| Group | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| No | 169 | 13.12591 | .8821602 | 11.46808 | 11.38436 | 14.86745 |
| Yes | 182 | 14.27509 | .9206798 | 12.42065 | 12.45905 | 16.09234 |
| combined | 351 | 13.72209 | .6388283 | 11.96829 | 12.46568 | 14.9785 |
| diff | | -1.149788 | 1.278868 | | -3.665045 | 1.36547 |

diff = mean(No) - mean(Yes) t = -0.8991
Ho: diff = 0 degrees of freedom = 349

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.1846 Pr(|T| > |t|) = 0.3692 Pr(T > t) = 0.8154



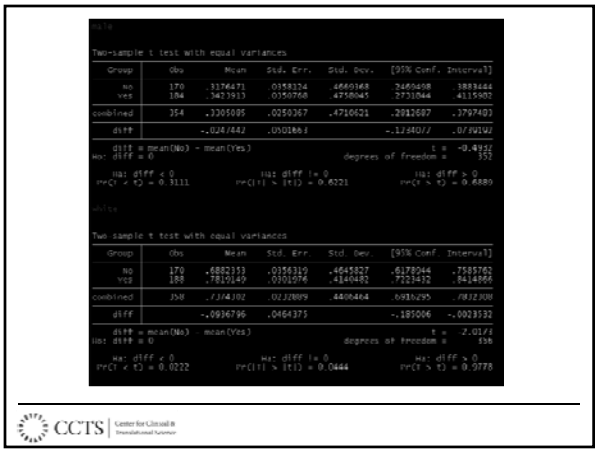


. age

Two-sample t test with equal variances

| Group | Obs | Mean | Std. Err. |
|---|---|---|---|
| No | 170 | 52.02353 | 1.252382 |
| Yes | 188 | 44.06915 | 1.279561 |
| combined | 358 | 47.84637 | .9204062 |
| diff | | 7.95438 | 1.796939 |





. ttest

Two-sample t test with equal variances

| Group | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| No | 170 | .3176471 | .0358334 | .4660368 | .2469698 | .3883244 |
| Yes | 184 | .3423913 | .0350768 | .4758045 | .2731044 | .4115905 |
| combined | 354 | .3305085 | .0250367 | .4710621 | .2812697 | .3797473 |
| diff | | -.0247442 | .0501884 | | -.1234077 | .0739192 |

diff = mean(No) - mean(Yes) t = -0.4932
Ho: diff = 0 degrees of freedom = 352

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.3111 Pr(|T| > |t|) = 0.6221 Pr(T > t) = 0.6889

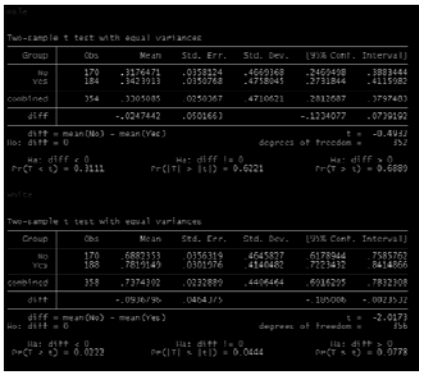
. ttest

Two-sample t test with equal variances

| Group | Obs | Mean | Std. Err. | Std. Dev. | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| No | 170 | .6882353 | .0356310 | .4645837 | .6178044 | .7585762 |
| Yes | 188 | .7819149 | .0301976 | .4140481 | .7223432 | .8414866 |
| combined | 358 | .7374302 | .0232889 | .4406464 | .6916295 | .7832308 |
| diff | | -.0936796 | .0464375 | | -.185006 | -.0023532 |

diff = mean(No) - mean(Yes) t = -2.0174
Ho: diff = 0 degrees of freedom = 356

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.0222 Pr(|T| > |t|) = 0.0444 Pr(T > t) = 0.9778

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## Summary of t-tests

| Potential Confounder | Means: Treatment (Walkable) | Means: Control (Not-Walkable) | Difference | p-value |
|---|---|---|---|---|
| **Age** | 44.07 | 52.02 | 7.95 | 0.000 |
| **Tenure** | 14.28 | 13.13 | -1.15 | 0.369 |
| **% Males** | 34.24 | 31.76 | -2.47 | 0.622 |
| **% White** | 78.19 | 68.82 | -9.37 | 0.044 |
| **% Married** | 31.91 | 48.82 | 16.91 | 0.001 |
| **% College degree** | 81.38 | 48.82 | -32.56 | 0.000 |
| **HH Income Scale** | 6.63 | 5.21 | -1.42 | 0.000 |

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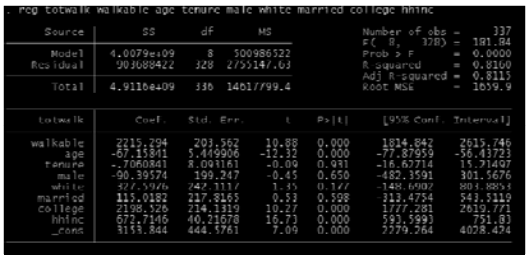
## Multiple Regression

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```
. reg totwalk walkable age tenure male white married college hhinc

      Source |       SS       df       MS              Number of obs =     337
-------------+------------------------------           F(  8,   328) =  181.84
       Model |  4.0079e+09     8  500986522             Prob > F      =  0.0000
    Residual |  903688472    328  2755147.63            R-squared     =  0.8160
-------------+------------------------------           Adj R-squared =  0.8115
       Total |  4.9116e+09   336  14617799.4            Root MSE      =  1659.9

------------------------------------------------------------------------------
     totwalk |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    walkable |   2215.294   203.562    10.88   0.000     1814.842    2615.746
         age |  -67.13841   5.449906   -12.32   0.000    -77.87959   -56.39723
      tenure |  -.7060841   8.093161    -0.09   0.931    -16.62714    15.21497
        male |  -90.39574   199.247    -0.45   0.650    -482.1591    301.5676
       white |   327.5976   242.1117     1.35   0.177    -148.6002    803.8853
     married |   115.0182   217.8165     0.53   0.598    -313.4754    543.5119
     college |   2198.126   214.1319    10.27   0.000     1777.281    2618.971
      hhinc |   672.7146   40.21678    16.73   0.000     593.5993     751.83
       _cons |   3153.844   444.1761     7.09   0.000     2279.264    4028.424
------------------------------------------------------------------------------
```



```
. reg totwalk walkable age tenure male wh

      Source |       SS       df       MS
-------------+------------------------------
       Model |  4.0079e+09     8  500986
    Residual |  903688472    328  2755147
-------------+------------------------------
       Total |  4.9116e+09   336  146177

------------------------------------------------------------------------------
     totwalk |      Coef.   Std. Err.
-------------+----------------------------------------------------------------
    walkable |   2215.294   203.562
         age |  -67.13841   5.449906
      tenure |  -.7060841   8.093161
        male |  -90.39574   199.247
       white |   327.5976   242.1117
     married |   115.0182   217.8165
     college |   2198.126   214.1319
      hhinc |   672.7146   40.21678
       _cons |   3153.844   444.1761
------------------------------------------------------------------------------
```



## Keep variables with small p-values

```
. reg totwalk walkable age college hhinc  /* retain just stat signif */

      Source |       SS       df       MS              Number of obs =     340
-------------+------------------------------           F(  4,   335) =  367.62
       Model |  4.0057e+09     4  1.0014e+09            Prob > F      =  0.0000
    Residual |  912549180    335  2724027.4            R-squared     =  0.8145
-------------+------------------------------           Adj R-squared =  0.8122
       Total |  4.9183e+09   339  14508139.9            Root MSE      =  1650.5

------------------------------------------------------------------------------
     totwalk |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    walkable |   2205.745   198.7595    11.10   0.000     1814.771    2596.719
         age |  -67.34886   5.305079   -12.70   0.000    -77.78433   -56.9134
     college |   2191.201   210.4568    10.42   0.000     1776.217    2607.184
      hhinc |   685.9745   33.20772    20.66   0.000     620.6535    751.2954
       cons |   3338.407   351.1121     9.51   0.000     2647.744    4029.069
------------------------------------------------------------------------------
```

```
. reg totwalk walkable age college hhinc  /* retain just stat signif */
      Source |       SS       df       MS              Number of obs =     340
-------------+------------------------------           F(  4,   335) =  367.63
       Model |  4.0053e+09     4  1.0014e+09            Prob > F      =  0.0000
    Residual |  912549180   335  2724027.4            R-squared     =  0.8145
-------------+------------------------------           Adj R-squared =  0.8122
       Total |  4.9178e+09   339  14508139.9           Root MSE      =  1650.5

------------------------------------------------------------------------------
    totwalk |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------+----------------------------------------------------------------
   walkable |   2205.745   198.7595    11.10   0.000     1814.771    2596.719
        age |  -67.34886   5.305079   -12.70   0.000    -77.78433   -56.91341
    college |   2193.201   210.4168    10.42   0.000     1779.217    2607.184
      hhinc |   685.9745   33.20722    20.66   0.000     620.6535    751.2954
      cons |   3338.407   351.1121     9.51   0.000     2647.744    4029.069
------------------------------------------------------------------------------
```



```
. estimates table crude adjusted pvalue, b(%7.2f) keep(walkable) star

    Variable |    crude      adjusted     pvalue
-------------+-------------------------------------
    walkable |  4497.74***   2215.29***   2205.75***

  legend: * p<0.05; ** p<0.01; *** p<0.001
```



```
. estimates table crude adjusted pvalue, b(%7.2f) keep(

    Variable |    crude      adjusted     pvalue
-------------+-------------------------------------
    walkable |  4497.74***   2215.29***   2205.75***

  legend: * p<0.05; ** p<0.01; *** p<0.001
```

## 4. Propensity Score Analysis

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## Nearest Neighbor Matching
within caliper

```
. * First let's do nearest neighbor matching w/in caliper and check balance
. psmatch2 walkable age tenure male white married college hhinc, ///
>         logit neighbor(1) common caliper(.01) ties

Logistic regression                               Number of obs     =        441
                                                  LR chi2(7)        =      78.96
                                                  Prob > chi2       =     0.0000
Log likelihood = -199.47867                       Pseudo R2         =     0.1652

------------------------------------------------------------------------------
    walkable |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |  -.0129125   .0074342    -4.41   0.000    -.0274833   -.0103418
      tenure |   .0214485   .0111162     1.93   0.054    -.0003387    .0432358
        male |  -.2941632   .270094     -1.09   0.276    -.8235327    .2352112
       white |  -.1120042   .3194737    -0.35   0.726    -.738165     .5141566
     married |   .4441075   .2823876     1.57   0.116    -.907577     .109362
     college |   1.484254   .2756098     5.39   0.000     .9440691    2.02444
      hhinc |   .1099414   .0538205     2.04   0.041     .0044551    .2154277
       _cons |   .0781083   .5615665     0.14   0.889    -1.022743    1.178759
------------------------------------------------------------------------------
```

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## Assess Balance

```
. pstest age tenure male white married college hhinc /* Evaluate balance */

                 |                Mean                     |    %reduct   |     t-test
Variable  Sample |    Treated     Control      %bias      |bias|      t    p>|t|
-----------------+-----------------------------------------+--------------+-----------
     age  Unmatch |     44.309      52.413      -47.8       |            -4.41  0.000
          Matched |     46.574      46.636       -0.4       |  99.2      -0.03  0.972
-----------------+-----------------------------------------+--------------+-----------
  tenure  Unmatch |     14.119      11.068        8.8       |             0.82  0.413
          Matched |     13.733      13.845       -0.9       |  89.4       0.09  0.928
-----------------+-----------------------------------------+--------------+-----------
    male  Unmatch |      .3427      .32335        4.1       |             0.38  0.704
          Matched |      .3456      .22222       26.1       | -538.2      2.40  0.014
-----------------+-----------------------------------------+--------------+-----------
   white  Unmatch |      .8089      .68862       27.9       |             2.60  0.010
          Matched |      .7901      .81481       -5.7       |  79.5      -0.56  0.578
-----------------+-----------------------------------------+--------------+-----------
 married  Unmatch |      .2977      .49102      -40.2       |            -3.74  0.000
          Matched |      .3216      .32099        1.3       |  96.8       0.12  0.906
-----------------+-----------------------------------------+--------------+-----------
 college  Unmatch |      .8202      .40503       75.0       |             6.99  0.000
          Matched |      .8025      .74074       13.8       |  81.6       1.37  0.187
-----------------+-----------------------------------------+--------------+-----------
   hhinc  Unmatch |     6.6798      5.1976       53.3       |             4.94  0.000
          Matched |     6.3765      6.8642      -17.5       |  67.1      -1.59  0.114
-----------------+-----------------------------------------+--------------+-----------
```

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```
. pstest age tenure male white married college hhinc /* Evaluate balance */
```

| Variable | Sample | Mean Treated | Mean Control | %bias | %reduct \|bias\| | t-test t | t-test p>\|t\| |
|---|---|---|---|---|---|---|---|
| age | Unmatched | 44.309 | 52.413 | -47.8 | | -4.43 | 0.000 |
| | Matched | 46.574 | 46.636 | -0.4 | 99.2 | -0.03 | 0.972 |
| tenure | Unmatched | 14.119 | 13.068 | 8.8 | | 0.82 | 0.413 |
| | Matched | 13.733 | 13.845 | -0.9 | 89.4 | -0.09 | 0.928 |
| male | Unmatched | .3427 | .32335 | 4.1 | | 0.38 | 0.704 |
| | Matched | .34568 | .22222 | 26.1 | -538.2 | 2.48 | 0.014 |
| white | Unmatched | .80899 | .68862 | 27.9 | | 2.60 | 0.010 |
| | Matched | .79012 | .81481 | -5.7 | 79.5 | -0.56 | 0.578 |
| married | Unmatched | .29775 | .49102 | -40.2 | | -3.74 | 0.000 |
| | Matched | .32716 | .32099 | 1.3 | 96.8 | 0.12 | 0.906 |
| college | Unmatched | .82022 | .48503 | 75.0 | | 6.99 | 0.000 |
| | Matched | .80247 | .74074 | 13.8 | 81.6 | 1.37 | 0.187 |
| hhinc | Unmatched | 6.6798 | 5.1976 | 53.3 | | 4.94 | 0.000 |
| | Matched | 6.3765 | 6.8642 | -17.5 | 67.1 | -1.59 | 0.114 |



```
. pstest age tenure male white married college hhinc /* Evalu
```

| Variable | Sample | Mean Treated | Mean Control | %bias | %reduct \|bias\| |
|---|---|---|---|---|---|
| age | Unmatched | 44.309 | 52.413 | -47.8 | |
| | Matched | 46.574 | 46.636 | -0.4 | 99.2 |
| tenure | Unmatched | 14.119 | 13.068 | 8.8 | |
| | Matched | 13.733 | 13.845 | -0.9 | 89.4 |
| male | Unmatched | .3427 | .32335 | 4.1 | |
| | Matched | .34568 | .22222 | 26.1 | -538.2 |
| white | Unmatched | .80899 | .68862 | 27.9 | |
| | Matched | .79012 | .81481 | -5.7 | 79.5 |



```
. * Slightly different - smaller caliper
.
. psmatch2 walkable age tenure male white married college hhinc, ///
>           logit neighbor(1) common caliper(.001) ties
```

```
. pstest age tenure male white married college hhinc /* evaluate balance */
```

| Variable | Sample | Mean Treated | Mean Control | %bias | %reduct \|bias\| | t-test t | t-test p>\|t\| |
|---|---|---|---|---|---|---|---|
| age | Unmatched | 44.309 | 52.413 | -47.8 | | -4.43 | 0.000 |
| | Matched | 50.765 | 49.647 | 6.6 | 86.2 | 0.36 | 0.723 |
| tenure | Unmatched | 14.119 | 13.068 | 8.8 | | 0.82 | 0.413 |
| | Matched | 14.192 | 14.46 | -2.3 | 74.5 | -0.11 | 0.915 |
| male | Unmatched | .3427 | .32335 | 4.1 | | 0.38 | 0.704 |
| | Matched | .51373 | .21569 | 20.7 | -406.8 | 1.12 | 0.266 |
| white | Unmatched | .80899 | .68862 | 27.9 | | 2.60 | 0.010 |
| | Matched | .76471 | .84314 | 18.2 | 34.8 | 0.99 | 0.323 |
| married | Unmatched | .29775 | .49102 | -40.2 | | -3.74 | 0.000 |
| | Matched | .35294 | .39216 | -8.2 | 79.7 | -0.41 | 0.680 |
| college | Unmatched | .82022 | .48503 | 75.0 | | 6.99 | 0.000 |
| | Matched | .7451 | .70588 | 8.8 | 88.3 | 0.44 | 0.661 |
| hhinc | Unmatched | 6.6798 | 5.1976 | 53.3 | | 4.94 | 0.000 |
| | Matched | 6.0588 | 6.1765 | -4.2 | 92.1 | -0.24 | 0.810 |

```
. * Slightly different - smaller caliper
.
. psmatch2 walkable age tenure male white married college hhinc, ///
>          logit neighbor(1) common caliper(.001) ties
```

```
. pstest age tenure male white married  college hhinc  /* evaluate balance */
```

| Variable | Sample | Mean Treated | Mean Control | %bias | %reduct \|bias\| | t-test t | t-test p>\|t\| |
|---|---|---|---|---|---|---|---|
| age | Unmatched | 44.309 | 52.413 | -47.8 | | -4.43 | 0.000 |
| | Matched | 50.765 | 49.647 | 6.6 | 86.2 | 0.36 | 0.723 |
| tenure | Unmatched | 14.119 | 13.068 | 8.8 | | 0.82 | 0.413 |
| | Matched | 14.192 | 14.46 | -2.3 | 74.5 | -0.11 | 0.915 |
| male | Unmatched | .3427 | .32335 | 4.1 | | 0.38 | 0.704 |
| | Matched | .51373 | .21569 | 20.7 | -406.8 | 1.12 | 0.266 |
| white | Unmatched | .80899 | .68862 | 27.0 | | 2.60 | 0.010 |
| | Matched | .76471 | .84314 | -18.2 | 34.8 | -0.99 | 0.323 |
| married | Unmatched | .29775 | .49102 | -40.2 | | -3.74 | 0.000 |
| | Matched | .35294 | .39216 | -8.2 | 79.7 | -0.41 | 0.686 |
| college | Unmatched | .82022 | .48503 | 75.0 | | 6.99 | 0.000 |
| | Matched | .7451 | .70588 | 8.8 | 88.5 | 0.44 | 0.661 |
| hhinc | Unmatched | 6.6798 | 5.1976 | 53.3 | | 4.84 | 0.000 |
| | Matched | 6.0588 | 6.1765 | -4.2 | 92.1 | 0.24 | 0.810 |

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```
. * Slightly different - drop male, increase caliper
.
. psmatch2 walkable age tenure white married college hhinc, ///
>          logit neighbor(1) common caliper(.03) ties
```

```
. pstest age tenure male white married  college hhinc  /* evaluate balance */
```

| Variable | Sample | Mean Treated | Mean Control | %bias | %reduct \|bias\| | t-test t | t-test p>\|t\| |
|---|---|---|---|---|---|---|---|
| age | Unmatched | 44.374 | 52.413 | -47.5 | | -4.41 | 0.000 |
| | Matched | 46.12 | 46.078 | 0.2 | 99.5 | 0.02 | 0.981 |
| tenure | Unmatched | 14.057 | 13.068 | 8.3 | | 0.77 | 0.440 |
| | Matched | 13.636 | 13.973 | -2.8 | 65.9 | -0.26 | 0.793 |
| male | Unmatched | .3427 | .32335 | 4.1 | | 0.38 | 0.704 |
| | Matched | .33333 | .33333 | -0.0 | 99.1 | -0.00 | 0.998 |
| white | Unmatched | .80447 | .68862 | 26.8 | | 2.50 | 0.013 |
| | Matched | .79042 | .83832 | -11.1 | 58.6 | -1.12 | 0.262 |
| married | Unmatched | .30168 | .49102 | -39.3 | | -3.66 | 0.000 |
| | Matched | .32335 | .34731 | -5.0 | 87.3 | -0.46 | 0.644 |
| college | Unmatched | .82123 | .48503 | 75.3 | | 7.03 | 0.000 |
| | Matched | .80838 | .83234 | -5.4 | 92.9 | -0.57 | 0.570 |
| hhinc | Unmatched | 6.6648 | 5.1976 | 52.8 | | 4.90 | 0.000 |
| | Matched | 6.4251 | 6.1796 | 8.8 | 83.3 | 0.83 | 0.407 |

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## Pscore ATT Estimate

```
. ************************************************************
. **** Now to hide dependent variable and estimate ATT ******
. ************************************************************
.
. psmatch2 walkable age tenure white married college hhinc, ///
>          outcome(totwalk) logit neighbor(1) common caliper(.03)
Logistic regression                               Number of obs   =       338
                                                  LR chi2(6)      =     75.79
                                                  Prob > chi2     =    0.0000
Log likelihood = -106.00769                       Pseudo R2       =    0.1620

------------------------------------------------------------------------------
    walkable |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |  -.0321631   .0074776    -4.30   0.000    -.0468189   -.0175073
      tenure |   .0189456   .0108879     1.57   0.117    -.0023937    .0402849
       white |  -.1528003   .3224712    -0.47   0.636    -.7848442    .4792435
     married |  -.3761937   .2866603    -1.31   0.189    -.9379253    .1855378
    college |   1.413942   .2731705     5.28   0.000     .9785176    1.949366
      hhinc |   .1154628   .0541484     2.13   0.033     .0093379    .2215877
      _cons |   .0555153   .573321     0.04   0.965    -1.088177    1.148207
------------------------------------------------------------------------------

------------------------------------------------------------------------------
    Variable     Sample |    Treated     Controls   Difference          S.E.   T-stat
-------------+----------+--------------------------------------------------------
    totwalk  Unmatched |  8930.16697   4417.45113   4512.71657   335.780131    13.44
                 ATT |  8579.78748   6174.38059   2405.40689   407.710923     5.90
------------------------------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.
```

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```
. ***********************************************************
. **** Now include dependent variable and estimate ATT ******
. ***********************************************************
.
. psmatch2 walkable age tenure white married college hhinc, ///
>          outcome(totwalk) logit neighbor(1) common caliper(.03)

Logistic regression                               Number of obs   =        338
                                                  LR chi2(6)      =      75.79
                                                  Prob > chi2     =     0.0000
Log likelihood = -196.09769                       Pseudo R2       =     0.1620

------------------------------------------------------------------------------
    walkable |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |  -.0321631   .0074776    -4.30   0.000    -.046819   -.0175073
      tenure |   .0169556    .010829     1.57   0.117    -.0043687     .03818
       white |  -.1328083   .3224732    -0.41   0.680    -.7648442    .4992275
     married |  -.3701027   .2806608    -1.32   0.187    -.9202853    .1800798
     college |   1.433942   .2731705     5.25   0.000     .9185176    1.949366
      hhinc |   .1134628   .0541464     2.10   0.036     .0073379    .2195877
       _cons |   .025157   .5733171     0.04   0.965    -1.098537    1.148851
------------------------------------------------------------------------------

------------------------------------------------------------------------------
    Variable |    Sample |    Treated     Controls   Difference          S.E.   T-stat
-------------+-----------+----------------------------------------------------------
    totwalk  | Unmatched |  8930.1697   4417.45313   4512.71657    335.700131    13.44
             |       ATT |  8579.78748   6174.38059   2405.40689    407.730923     5.90
------------------------------------------------------------------------------
Note: S.E. does not take into account that the propensity score is estimated.
```



```
hed |  8930.1697   4417.45313   4512.71657   335.
ATT |  8579.78748   6174.38059   2405.40689   407.

into account that the propensity score is estima
```



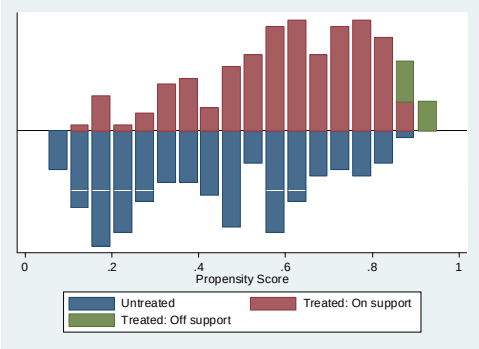
## Assess Support

| psmatch2: Treatment assignment | psmatch2: Common support | | |
|---|---|---|---|
| | Off suppo | On suppor | Total |
| Untreated | 0 | 162 | 162 |
| Treated | 12 | 164 | 176 |
| Total | 12 | 326 | 338 |

| psmatch2: Treatment assignment | psmatch2: Common support | | |
|---|---|---|---|
| | Off suppo | On suppor | Total |
| Untreated | 0 | 162 | 162 |
| Treated | 12 | 164 | 176 |
| Total | 12 | 326 | 338 |

**There are no matches for 12 of the "treated" subjects**








## Bootstrap, k=1000

```
. bootstrap "psmatch2 walkable age male white married college hhinc, outcome(totwalk)" r
> 0)

Command:      psmatch2 walkable age male white married college hhinc , outcome(totwalk)
statistic:    _bs_1       a_r(ATT_totwalk)
note: label truncated to 80 characters

Bootstrap statistics                            Number of obs    =       338
                                                Replications     =     10000

Variable |  Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
---------+-------------------------------------------------------------------
     _bs_1 | 1.0e+04  2513.21  156.1548  284.3708   1955.884   3070.536  (N)
                                                   2130.884   3757.253  (P)
                                                   1875.054   2922.027  (BC)

Note: N   - normal
      P   - percentile
      BC  - bias-corrected
```

```
. bootstrap "psmatch2, walkable age male white married college hhinc, outcome(totwalk)" "r
> (N)

command:      psmatch2 walkable age male white married college hhinc , outcome(totwalk)
statistic:    _bs_1     = r(att_totwalk)
note: label truncated to 80 characters

Bootstrap statistics                            Number of obs    =       359
                                                Replications     =     10000

------------------------------------------------------------------------------
Variable |      Reps  Observed      Bias  Std. Err. [95% Conf. Interval]
---------+--------------------------------------------------------------------
     _bs_1 | 1.0e+04   2513.21  156.1548  284.3208   1955.884   3070.536  (N)
                                                    2130.653   3227.351  (P)
                                                    1875.054   2922.027  (BC)
------------------------------------------------------------------------------
Note:  N  = normal
       P  = percentile
       BC = bias-corrected
```



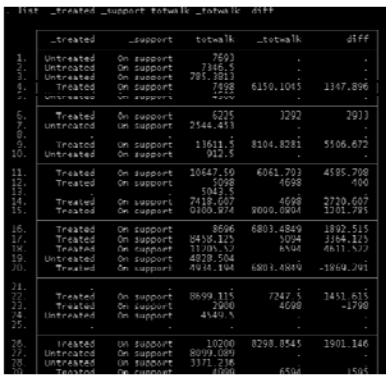
```
Bootstrap statistics                                  Number of
                                                      Replicati

------------------------------------------------------------------------------
Variable |      Reps  Observed      Bias  Std. Err. [95% Co
---------+--------------------------------------------------------------------
     _bs_1 | 1.0e+04   2513.21  156.1548  284.3208   1955
                                                    2130.6
                                                    1875.0
------------------------------------------------------------------------------
Note:  N  = normal
       P  = percentile
       BC = bias-corrected
```



. list _treated _support totwalk _totwalk diff

| | _treated | _support | totwalk | _totwalk | diff |
|---|---|---|---|---|---|
| 1. | Untreated | On support | 7693 | . | . |
| 2. | Untreated | On support | 7340.5 | . | . |
| 3. | Untreated | On support | 785.3813 | . | . |
| 4. | Treated | On support | 4498 | 6750.1045 | -1347.896 |
| 5. | Untreated | On support | 4500 | . | . |
| 6. | Treated | On support | 6225 | 3202 | 3023 |
| 7. | Untreated | On support | 2544.453 | . | . |
| 8. | . | . | . | . | . |
| 9. | Treated | On support | 13611.5 | 8104.8281 | 5506.672 |
| 10. | Untreated | On support | 912.5 | . | . |
| 11. | Treated | On support | 10647.59 | 6061.793 | 4585.798 |
| 12. | Treated | On support | 4098 | 4698 | -600 |
| 13. | . | . | 5043.5 | . | . |
| 14. | Treated | On support | 7418.607 | 4698 | 2720.607 |
| 15. | Treated | On support | 9300.874 | 8099.0894 | 1201.785 |
| 16. | Treated | On support | 8096 | 6803.4849 | 1292.515 |
| 17. | Treated | On support | 8458.125 | 5094 | 3364.125 |
| 18. | Treated | On support | 11705.57 | 6598 | 4811.572 |
| 19. | Untreated | On support | 4828.504 | . | . |
| 20. | Treated | On support | 4934.194 | 6803.4849 | -1869.291 |
| 21. | . | . | . | . | . |
| 22. | Treated | On support | 8699.115 | 7247.5 | 1451.615 |
| 23. | Treated | On support | 7900 | 6098 | 1798 |
| 24. | Untreated | On support | 4549.5 | . | . |
| 25. | . | . | . | . | . |
| 26. | Treated | On support | 10200 | 8298.8545 | 1901.146 |
| 27. | Untreated | On support | 8099.089 | . | . |
| 28. | Untreated | On support | 3171.216 | . | . |
| 29. | Treated | On support | 8098 | 6594 | 1504 |



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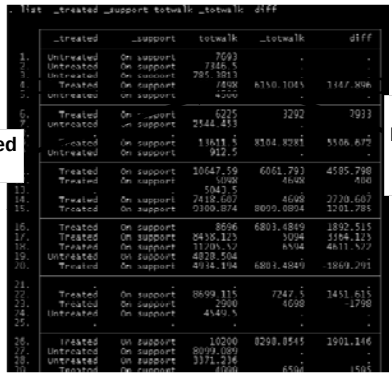


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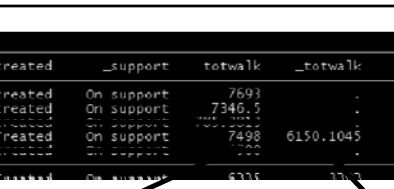


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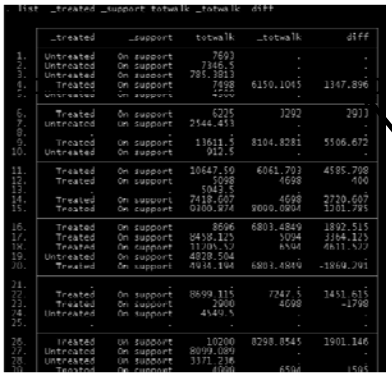

| | _treated | _support | totwalk | _totwalk | diff |
|---|---|---|---|---|---|
| 1. | Untreated | On support | 7693 | . | . |
| 2. | Untreated | On support | 7346.5 | . | . |
| 3. | Untreated | On support | 785.3813 | . | . |
| 4. | Treated | On support | 7498 | 6150.1045 | 1347.896 |
| 5. | Untreated | On support | 4500 | . | . |
| 6. | Treated | On support | 6225 | 3292 | 2933 |
| 7. | Untreated | On support | 2544.453 | . | . |
| 8. | . | . | . | . | . |
| 9. | Treated | On support | 13611.5 | 8104.8281 | 5506.672 |
| 10. | Untreated | On support | 912.5 | . | . |
| 11. | Treated | On support | 10647.59 | 6061.703 | 4585.708 |
| 12. | Treated | On support | 5098 | 4698 | 400 |
| 13. | . | . | 5043.5 | . | . |
| 14. | Treated | On support | 7418.607 | 4698 | 2720.607 |
| 15. | Treated | On support | 9305.974 | 9004.0904 | 1301.795 |
| 16. | Treated | On support | 8696 | 6803.4849 | 1892.515 |
| 17. | Treated | On support | 8458.125 | 5094 | 3364.125 |
| 18. | Treated | On support | 11305.57 | 6694 | 4611.577 |
| 19. | Untreated | On support | 4828.504 | . | . |
| 20. | Treated | On support | 4944.194 | 6803.4849 | -1859.291 |
| 21. | . | . | . | . | . |
| 22. | Treated | On support | 8699.115 | 7247.5 | 1451.615 |
| 23. | Treated | On support | 2900 | 4698 | -1798 |
| 24. | Untreated | On support | 4549.5 | . | . |
| 25. | . | . | . | . | . |
| 26. | Treated | On support | 10200 | 8298.8545 | 1901.146 |
| 27. | Untreated | On support | 8099.089 | . | . |
| 28. | Untreated | On support | 3371.236 | . | . |
| 29. | Treated | On support | 4900 | 6594 | -1695 |

Effect For Subject #4

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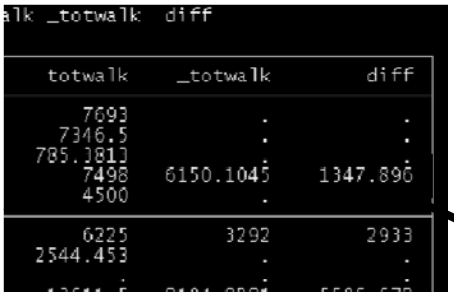

| totwalk | _totwalk | diff |
|---|---|---|
| 7693 | . | . |
| 7346.5 | . | . |
| 785.3813 | . | . |
| 7498 | 6150.1045 | 1347.896 |
| 4500 | . | . |
| 6225 | 3292 | 2933 |
| 2544.453 | . | . |
| . | . | . |

Effect For Subject #4

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## Unmeasured Confounding?

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# Rosenbaum Bounds

A method of sensitivity analysis that uses a parameter "gamma" to measure the degree of departure from random assignment of treatment.

Imagine that 2 subjects with the same observed characteristics differ in the odds of receiving the treatment by at most a factor of "gamma".

In a randomized trial, randomization of the treatment ensures that gamma = 1. In an observational study, if gamma = 2 and two subjects are identical on matched covariates then one might be twice as likely as the other to receive the treatment because they differ in terms of an unobserved covariate.

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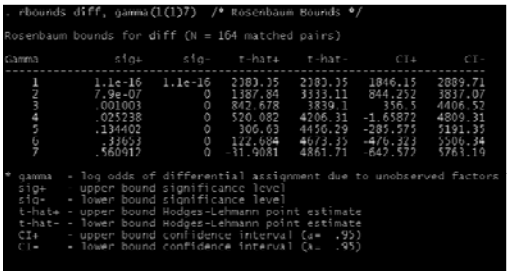

```
. rbounds diff, gamma(1(1)7)  /* Rosenbaum Bounds */

Rosenbaum bounds for diff (N = 164 matched pairs)

Gamma           sig+      sig-     t-hat+    t-hat-       CI+       CI-
----------------------------------------------------------------------
    1        1.1e-16   1.1e-16   2383.35   2383.35   1846.15   2889.71
    2        7.9e-07         0   1387.84   3333.11   844.252   3837.07
    3       .001003         0   842.678    3839.1       356.5   4406.52
    4       .025238         0   520.082   4206.31  -1.65872   4809.31
    5       .134402         0    306.63   4430.29   -285.575   5191.35
    6       .33653          0   122.684   4673.33   -476.323   5506.34
    7       .560917         0  -11.9081   4861.71   -642.577   5761.19

* gamma  - log odds of differential assignment due to unobserved factors
  sig+    - upper bound significance level
  sig-    - lower bound significance level
  t-hat+  - upper bound Hodges-Lehmann point estimate
  t-hat-  - lower bound Hodges-Lehmann point estimate
  CI+     - upper bound confidence interval (a=  .95)
  CI-     - lower bound confidence interval (a=  .95)
```

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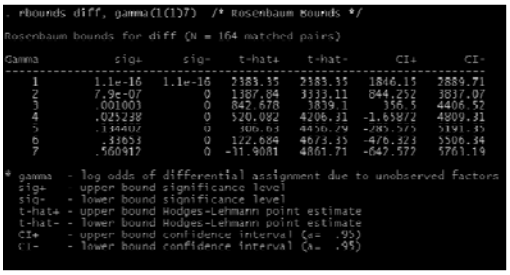

```
. rbounds diff, gamma(1(1)7)  /* Rosenbaum Bounds */

Rosenbaum bounds for diff (N = 164 matched pairs)

Gamma           sig+      sig-     t-hat+    t-hat-       CI+       CI-
----------------------------------------------------------------------
    1        1.1e-16   1.1e-16   2383.35   2383.35   1846.15   2889.71
    2        7.9e-07         0   1387.84   3333.11   844.252   3837.07
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    4       .025238         0   520.082   4206.31  -1.65872   4809.31
    5       .134402         0    306.63   4430.29   -285.575   5191.35
    6       .33653          0   122.684   4673.33   -476.323   5506.34
    7       .560917         0  -11.9081   4861.71   -642.577   5761.19

* gamma  - log odds of differential assignment due to unobserved factors
  sig+    - upper bound significance level
  sig-    - lower bound significance level
  t-hat+  - upper bound Hodges-Lehmann point estimate
  t-hat-  - lower bound Hodges-Lehmann point estimate
  CI+     - upper bound confidence interval (a=  .95)
  CI-     - lower bound confidence interval (a=  .95)
```

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| Gamma | CI+ | CI- |
|---|---|---|
| 1 | 1846.15 | 2889.71 |
| 2 | 844.252 | 3837.07 |
| 3 | 356.5 | 4406.52 |
| 4 | -1.65872 | 4809.31 |
| 5 | -283.373 | 5191.65 |
| 6 | -476.323 | 5506.34 |
| 7 | -643.513 | 5763.19 |

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## Let's Compare!

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| Method | Effect | L95%CI | U95%CI |
|---|---|---|---|
| T-test | 4,498 | 3,849 | 5,147 |
| Bivariate Regression | 4,498 | 3,337 | 5,158 |
| Fully Adjusted Multi Regression | 2,215 | 1,815 | 2,616 |
| P-value Adjusted Multi Regression | 2,206 | 1,815 | 2,597 |
| Pscore: 6 vars, NN match, caliper = 0.03 | 2,405 | 1,605 | 3,205 |
| Pscore: 6 vars, NN match, caliper = 0.03, BS=1k | 2,393 | 1,787 | 2,913 |
| Pscore: 4 vars, NN match, caliper = 0.05 | 2,618 | 1,781 | 3,455 |
| Pscore: 4 vars, NN match, caliper = 0.001 | 3,231 | 2,173 | 4,289 |
| Pscore: 4 vars, NN match, caliper = 0.9 | 2,618 | 1,781 | 3,455 |
| Pscore: 6 vars, Kernel match | 2,730 | 2,068 | 3,392 |

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| Method | Effect | L95%CI | U95%CI |
|---|---|---|---|
| T-test | 4,498 | 3,849 | 5,147 |
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| Pscore: 4 vars, NN match, caliper = 0.001 | 3,231 | 2,173 | 4,289 |
| Pscore: 4 vars, NN match, caliper = 0.9 | 2,618 | 1,781 | 3,455 |
| Pscore: 6 vars, Kernel match | 2,730 | 2,068 | 3,392 |

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## 5. Issues & Assumptions


Image recreated from: Freedman, DA. Oasis or mirage? CHANCE Magazine. 2008; 21: (1):59–61.

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- **Counterfactuals are unobservable**
- **Black box mechanisms**
- **ATE or ATT?**
- **Pscore matching should balance confounders**
- **Must assume no unobservables**
- **Enforce "support"**
- **Missing values are problematic**
- **No predictors that are consequence of outcome**
- **Pscores are mere estimates from one sample**

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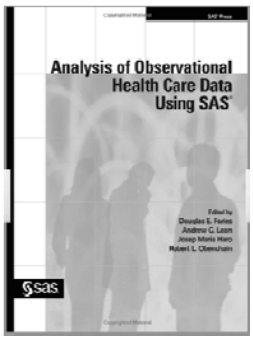
Can also be done in SAS, R, SPSS, and other programs

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**For further study, see also**

**Prof. Liz Stuart's website!**

**Johns Hopkins University**

**http://www.biostat.jhsph.edu/~estuart/propensityscoresoftware.html**

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## Simplified Tasks

(1) Set outcome variable (Y) aside

(2) Model treatment/exposure (0,1) with logistic regression or perhaps better models

(3) Check/Assess balance

(4) Once balance is maximided, use propensity score in analysis to estimate ATT

(5) Estimate potential impact of unobservables

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## Once again… with gusto!

Because they require us to think about the ideal experiment we would have liked to have conducted, propensity score methods are a better tool than multiple regression. Setting aside the outcome variable, Y, until it's time to assess differences between observed outcomes and counterfactual substitutes, is an invaluable addition to the practice of applied research.

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## 6. Review

I. Review of Core Ideas
   a. Causal inference
   b. Countefactuals
   c. Experimental Ideal

II. Effect Measures
   a. ATE = ACE
   b. ATT = TOT
   c. Regression estimates in obs study

III. Typical Analysis
   a. Bivariate Regression
   b. Multivariate Regression
   c. Effect?

IV. Propensity Score Methods
   a. Stata psmatch2
   b. Assess balance
   c. Estimate ATT
   d. Enforce support
   e. Boostrap
   f. Rosenbaum bounds

V. Assumptions & Issues
   a. Black-box mechanisms
   b. Unobservables
   c. Balance & TAM
   d. Missing values
   e. Support

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## 7. Questions

1. What's the difference between ATE and ATT?
2. Why is the assumption that outcomes are independent of the TAM so important?
3. Is Stata the only program that fits propensity score models?
4. What does the "gamma" of Rosenbaum bounds mean?
5. What does "enforcing support" mean?

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# References & Resources


1. Frerichs RR. John Snow Site. http://www.ph.ucla.edu/epi/snow/highressnowmap.html. Updated October 4, 2004. Accessed December 14, 2011.
2. Gou S, Fraser MW. Propensity Score Analysis: Statistical Methods and Applications. Thousand Oaks, CA: SAGE Publications; 2010:Fig 5.1.
3. Oakes JM, Forsyth A, Schmitz KH. The effects of neighborhood density and street connectivity on walking behavior: the Twin Cities walking study. Epidemiology Perspectives and Innovations. 2007; 13: (4):16.
4. Freedman, DA. Oasis or mirage? CHANCE Magazine. 2008; 21: (1): 59–61.