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# Estimation Strategies

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# Setup

## The Generalized Roy Model

Potential Outcomes

$$Y_1 = \mu_1(X) + U_1$$

$$Y_0 = \mu_0(X) + U_0$$

Observed Outcome

$$Y = DY_1 + (1 - D)Y_0$$

Choice

$$D = I[\mu_D(X, Z) - V > 0]$$

## Key Concept

**Definition:** Individuals select their treatment status based on gains unobservable by the econometrician. More formally,

$$Y_1 - Y_0 \not\perp D \mid X = x.$$

⇒ consequences for the choice of the estimation strategy

## Useful Notation

$$P(X, Z) = \Pr(D = 1 \mid X, Z) = F_V(\mu_D(X, Z))$$

$$U_D = F_V(V)$$

## Key Assumptions

- ▶  $(U_1, U_0, V)$  are independent of  $Z$  conditional on  $X$
- ▶  $\mu_D(X, Z)$  is a nondegenerate random variable conditional on  $X$
- ▶  $0 < \Pr(D = 1 | X) < 1$
- ▶ ...

## Evaluation Problem

$$Y = DY_1 + (1 - D)Y_0 = \begin{cases} Y_1 & \text{if } D = 1 \\ Y_0 & \text{if } D = 0 \end{cases}$$



## Selection Problem

$$\begin{aligned} E[Y | D = 1] - E[Y | D = 0] &= \underbrace{E[Y_1 - Y_0]}_{B^{ATE}} \\ &+ \underbrace{E[Y_1 - Y_0 | D = 1] - E[Y_1 - Y_0]}_{\text{Sorting Gain}} \\ &+ \underbrace{E[Y_0 | D = 1] - E[Y_0 | D = 0]}_{\text{Selection Bias}} \end{aligned}$$

## Estimation Strategies

- ▶ Randomization
- ▶ Matching
- ▶ Instrumental Variables
  - ▶ conventional and local
- ▶ Regression Discontinuity
  - ▶ fuzzy and sharp design

# Randomization

## Treatment Status

$D$	self-selected
$\xi$	assigned
$A$	actual

## Key Identifying Assumptions

$$(Y_1, Y_0) \perp\!\!\!\perp D$$

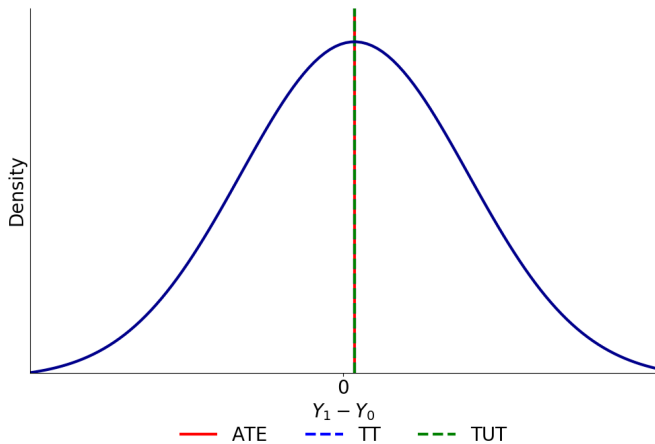
$$(Y_1, Y_0) \perp\!\!\!\perp \xi$$

$$(Y_1, Y_0) \perp\!\!\!\perp A$$

When do we have to worry about compliance?

$$\begin{aligned}
& E(Y \mid A = 1) - E(Y \mid A = 0) \\
&= E(Y_1 \mid A = 1) - E(Y_0 \mid A = 0) && \text{(by full compliance)} \\
&= E(Y_1) - E(Y_0) && \text{(by randomization)} \\
&= ATE = TT = TUT
\end{aligned}$$

Figure: Distribution of Effects



What if we can only deny program participation to individuals who are willing to participate?

$$\begin{aligned} &E(Y \mid D = 1, A = 1) - E(Y \mid D = 1, A = 0) \\ &= E(Y_1 \mid D = 1, A = 1) - E(Y_0 \mid D = 1, A = 0) \\ &= E(Y_1 \mid D = 1) - E(Y_0 \mid D = 1) \\ &= TT \neq ATE \neq TUT \end{aligned}$$



## Issues

- ▶ Compliance
- ▶ Imperfect Randomization
- ▶ Ethical Concerns
- ▶ Feasibility
- ▶ Expenses
- ▶ External Validity

## Challenges to Scaling Experiments

- ▶ market equilibrium effects
- ▶ spillovers
- ▶ political reactions
- ▶ context dependence
- ▶ randomization or site-selection bias
- ▶ piloting bias

See Banerjee et al. (2017) for a discussion of these challenges and their attempts to address them in their work.

# Matching

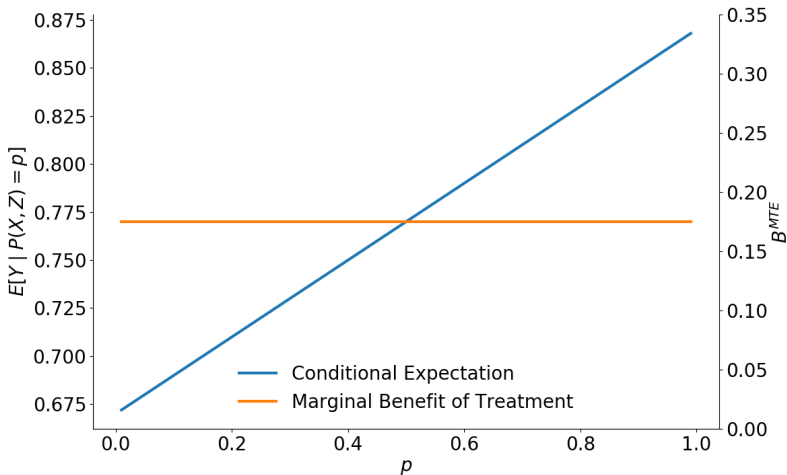
## Key Identifying Assumption

$$(Y_1, Y_0) \perp\!\!\!\perp D \mid X$$

What is in the agent's and econometrician's information set?

- ▶ J. J. Heckman and Navarro-Lozano (2004) highlights the sensitivity of results to different conditioning variables.

Figure: Matching and Essential Heterogeneity



# **Instrumental Variables**

## Key Identifying Assumption

$$(Y_1, Y_0) \perp\!\!\!\perp Z \mid X$$

Even in the best cases, this is sometimes not as obvious as you think. See J. Heckman (1997) for a study of implicit behavioral assumptions used in making program evaluations.

## Conventional Notation

$$Y = \alpha + \beta D + \epsilon,$$

where

$$\alpha = \mu_0(X)$$

$$\beta = (Y_1 - Y_0) = \mu_1(X) - \mu_0(X) + (U_1 - U_0)$$

$$\epsilon = U_0$$



Assume for now that there is no treatment effect heterogeneity, i.e.  $Y_1 - Y_0$  is the same for everybody. If we have access to a variable  $Z$  with the following properties ...

$$\text{cov}(Z, D) \neq 0$$

$$\text{cov}(Z, \epsilon) = 0$$

then the following holds

$$\text{plim } \hat{\beta}_{IV} = \frac{\text{cov}(Z, Y)}{\text{cov}(Z, D)} = \beta$$

What happens if  $\beta$  varies in the population?

- ▶ Do individuals select their treatment status based on gains?  
⇒ essential heterogeneity

Let  $\beta = E[\beta] + \eta$ , where  $U_1 - U_0 = \eta$ , then

$$Y = \alpha + \bar{\beta}D + [\epsilon + \eta D].$$

and

$$\text{plim } \hat{\beta}_{IV} = \bar{\beta} + \frac{\text{cov}(Z, \epsilon + \eta D)}{\text{cov}(D, Z)}$$

So we cannot even learn about the mean effect of treatment unless we rule out essential heterogeneity, i.e. individuals selecting their treatment status based on gains.

## Local Average Treatment Effect

- ▶ Average effect for those induced to change treatment because of a change in the instrument.  
⇒ instrument-dependent parameter

$$\frac{E(Y | Z = z) - E[Y | Z = z']}{P(z) - P(z')} = E(Y_1 - Y_0 | D(z) = 1, D(z') = 0)$$

# *Local Instrumental Variables*

## Local Instrumental Variable

$$\begin{aligned}\frac{\partial E(Y \mid P(Z) = p)}{\partial p} \bigg|_{p=u_D} &= E(Y_1 - Y_0 \mid U_D = u_D) \\ &= B^{MTE}(u_D)\end{aligned}$$

$\Rightarrow$  we can only identify the  $B^{MTE}(u_D)$  over the support of  $p$  in our data

Figure: Observed Outcome and Essential Heterogeneity

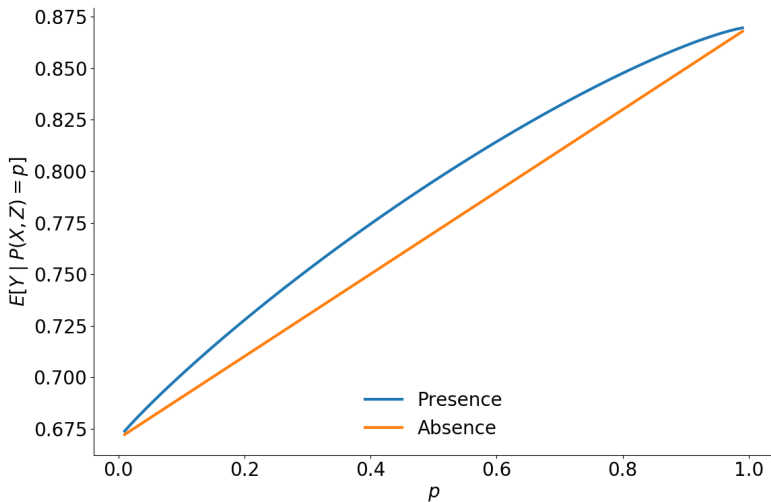
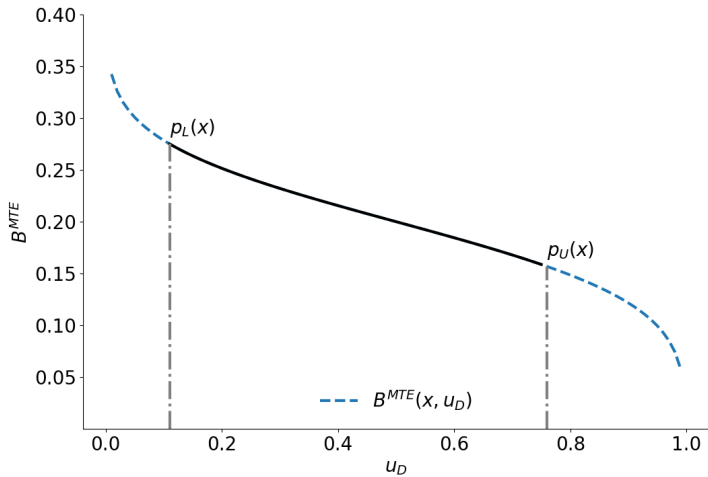


Figure: Identification I





Making  $X = x$  explicit

$$\begin{aligned} E(Y_1 - Y_0 | X = x, U_D = u_D) \\ = (\mu_1(x) - \mu_0(x)) + E(U_1 - U_0 | X = x, U_D = u_D) \end{aligned}$$

but if we are willing to assume  $(U_1 - U_0) \perp\!\!\!\perp X$  then

$$\begin{aligned} E(Y_1 - Y_0 | X = x, U_D = u_D) \\ = (\mu_1(x) - \mu_0(x)) + E(U_1 - U_0 | U_D = u_D) \end{aligned}$$

Figure: Identification II

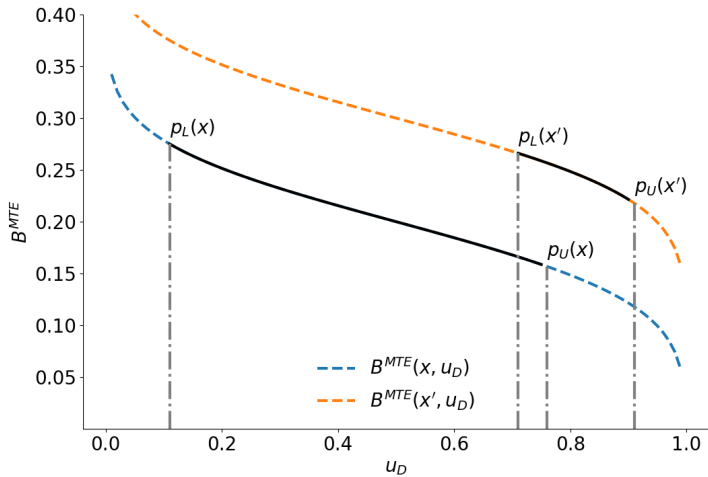
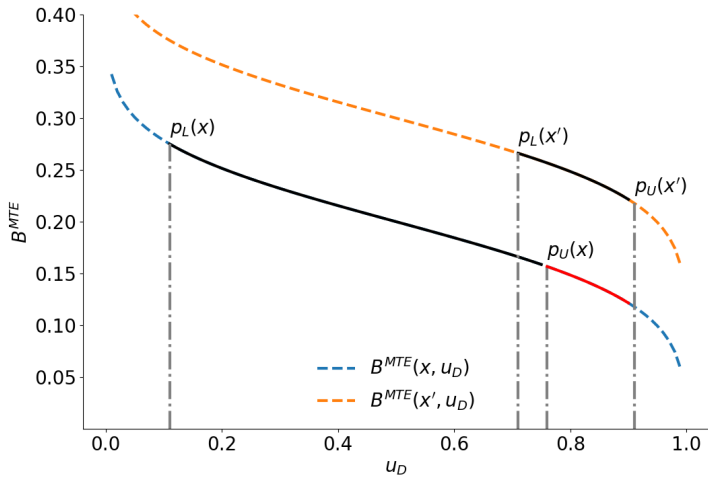


Figure: Identification III



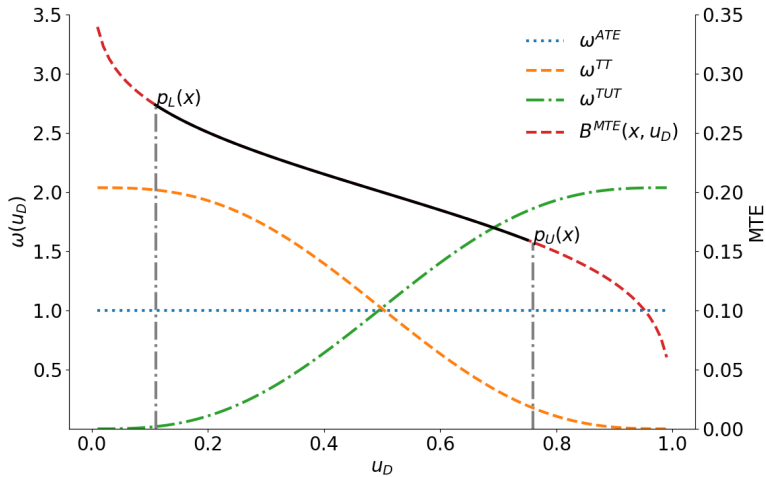
## Effects of Treatment as Weighted Averages

Parameter  $\Delta_j$ , can be written as a weighted average of the  $B^{MTE}(x, u_D)$ .

$$\Delta_j(x) = \int_0^1 B^{MTE}(x, u_D) \omega^j(x, u_D) du_D,$$

where the weights  $\omega^j(x, u_D)$  are specific to parameter  $j$  and integrate to one.

Figure: Identification IV



# **Regression Discontinuity Design**

Suppose  $D = 1$  if  $X \geq x_0$ , and  $D = 0$  otherwise

$$\Rightarrow \begin{cases} E(Y | X = x) = E(Y_0 | X = x) & \text{for } x < x_0 \\ E(Y | X = x) = E(Y_1 | X = x) & \text{for } x \geq x_0 \end{cases}$$

Suppose  $E(Y_1 | X = x), E(Y_0 | X = x)$  are continuous in  $x$ .

$$\Rightarrow \begin{cases} \lim_{\epsilon \searrow 0} E(Y_0 | X = x_0 - \epsilon) = E(Y_0 | X = x_0) \\ \lim_{\epsilon \searrow 0} E(Y_1 | X = x_0 + \epsilon) = E(Y_1 | X = x_0) \end{cases}$$

$$\begin{aligned}
& \lim_{\epsilon \searrow 0} E(Y \mid X = x_0 + \epsilon) - \lim_{\epsilon \searrow 0} E(Y \mid X = x_0 - \epsilon) \\
&= \lim_{\epsilon \searrow 0} E(Y_1 \mid X = x_0 + \epsilon) - \lim_{\epsilon \searrow 0} E(Y_0 \mid X = x_0 - \epsilon) \\
&= E(Y_1 \mid X = x_0) - E(Y_0 \mid X = x_0) \\
&= E(Y_1 - Y_0 \mid X = x_0)
\end{aligned}$$



Figure: Probability

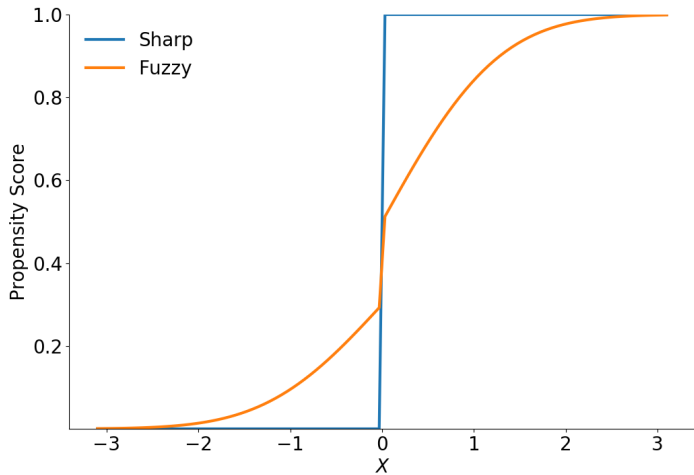


Figure: Observed Outcome in a Sharp Design

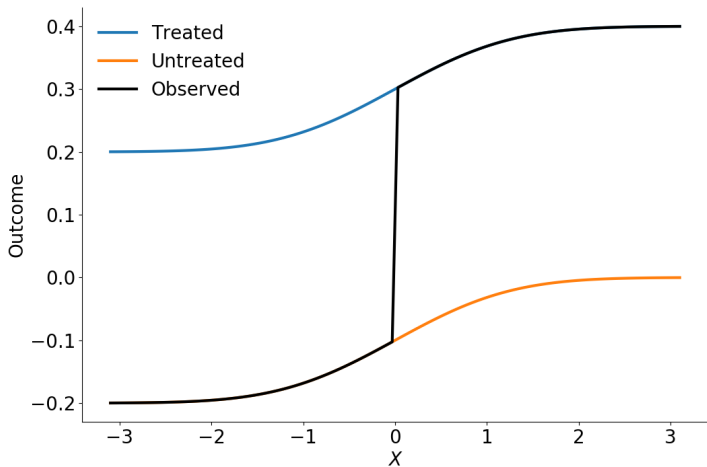
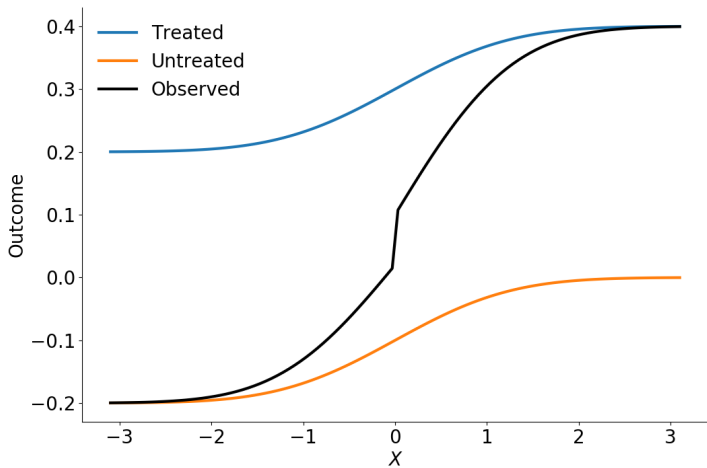


Figure: Observed Outcome in a Fuzzy Design



# Conclusion

*We must not cease from exploration  
and the end of all our exploring will  
be to arrive where we began and to  
know the place for the first time.*

- T. S. Eliot (1943)

# Appendix

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