DATASCIENCESALON
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Causal Design Patterns

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DSS Salon NYC

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Randomized experiments allow for credible measurement

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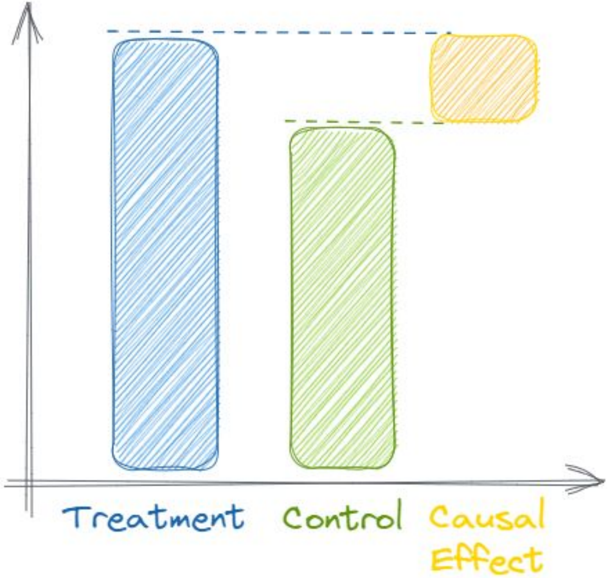
Using the spark of randomization,

assign treatment and control groups

to measure a credible causal effect

by comparing their outcomes



Randomized experiments are not always practical

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Not feasible

- Customer experience
- Ethics

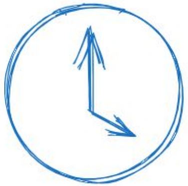
Not easy

- Randomization bugs
- Treatment isolation

$

Not cheap

- Direct costs
- Opportunity costs



Not fast

- Long-term endpoints
- Historical variants

Causal inference helps recreate the 'spark' with historical data

semi-random variation

Using the ~~spark of randomization~~,

+ data & context

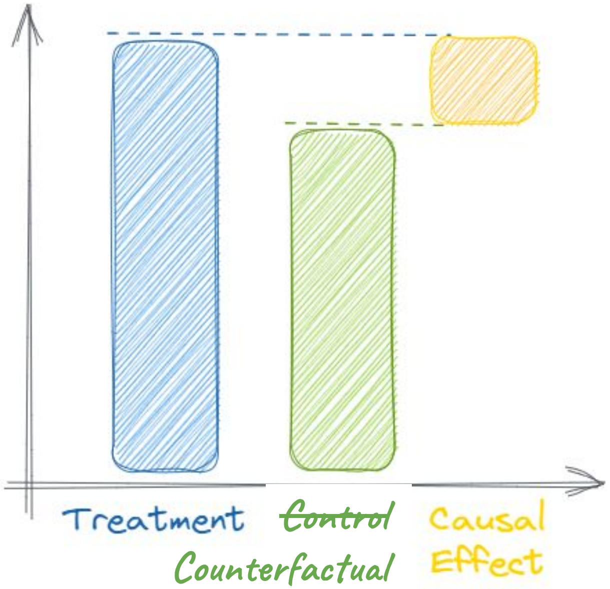
identify those who received the

~~assign~~ treatment and ~~control groups~~

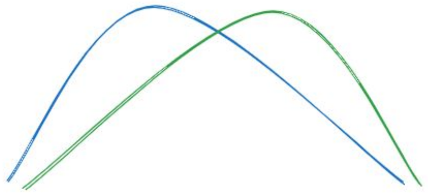
construct a counterfactual 'control'

to measure a credible causal effect

by comparing their outcomes

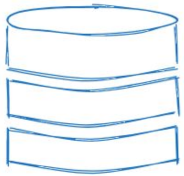


Industry has distinct advantages when applying causal methods



Semi-random Variation

- Segmentation
- Timing
- Execution
- Natural experiments!



Rich Historical Data

- Individual-level
- Integrated, multimodal
- Longitudinal
- Out-of-time

?

Domain-Driven Assumptions

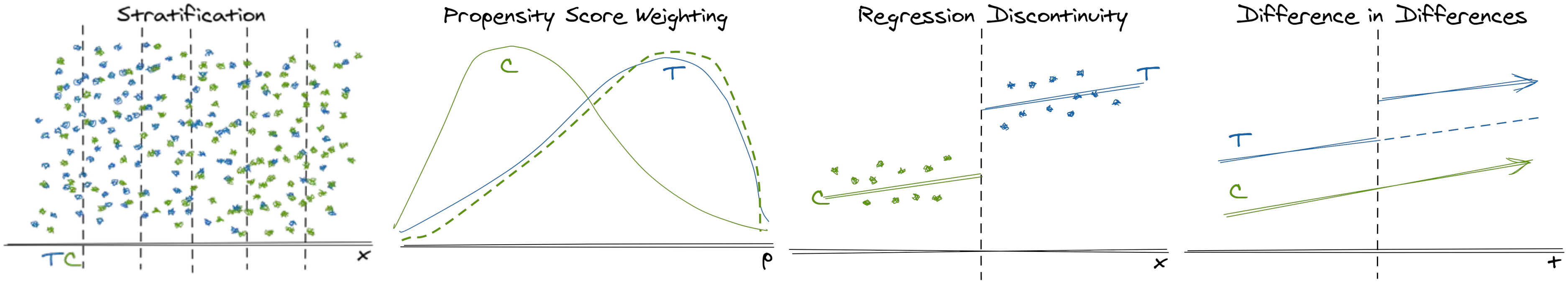
- Context / rationale for decisions, treatment assignments
- Proxies for validation

Agenda

- Common design patterns
- Patterns as building blocks
- Prerequisites for success
- Resources to learn more

Key Design Patterns

Four basic strategies for causal inference

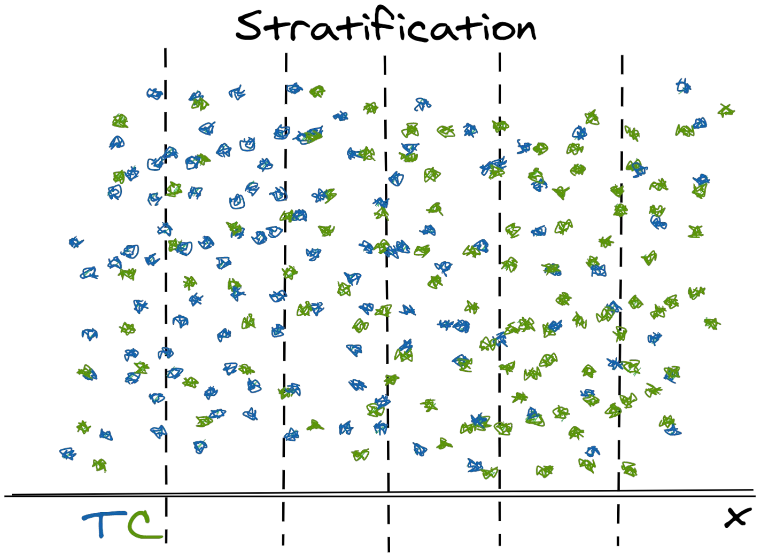


Variation in treatment distribution within a population

Variation across distinct groups

Variation across groups & time

When we have imbalance...



When you have:

- "similar" treated and untreated individuals
- different distributions
- on few relevant dimensions

Tries to:

Bin comparisons into comparable subgroups

⭐ Spark from untreated data and rich featureset ⭐

Stratification pattern

Recipe:

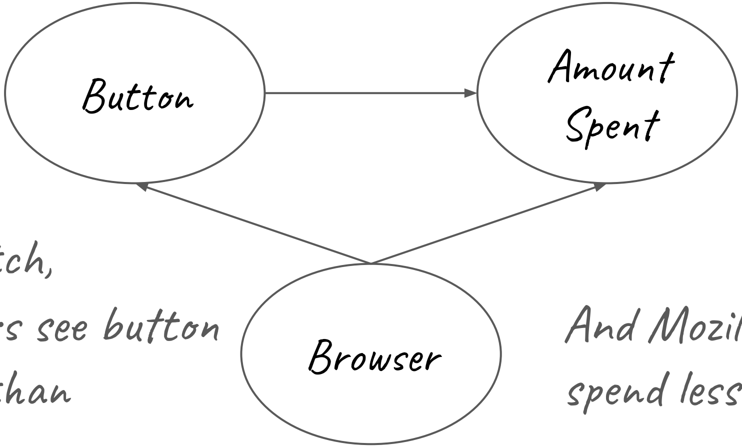
- Bin population by subgroups
- Calculate average effect by group
- Weight average across groups

Assumption:

- All common causes of treatment and outcome are observed
- All observations have positive probability of treatment
- Few variables need adjustment

Stratification application

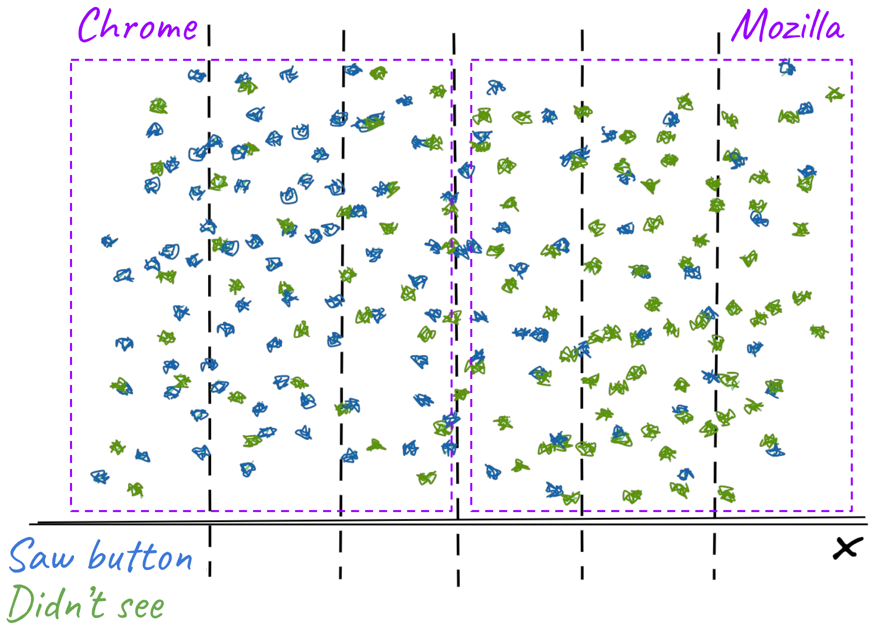
Attempt to A/B test "one-click instant checkout" on Black Friday



Due to a glitch,
Chrome users see button
more often than
Mozilla users

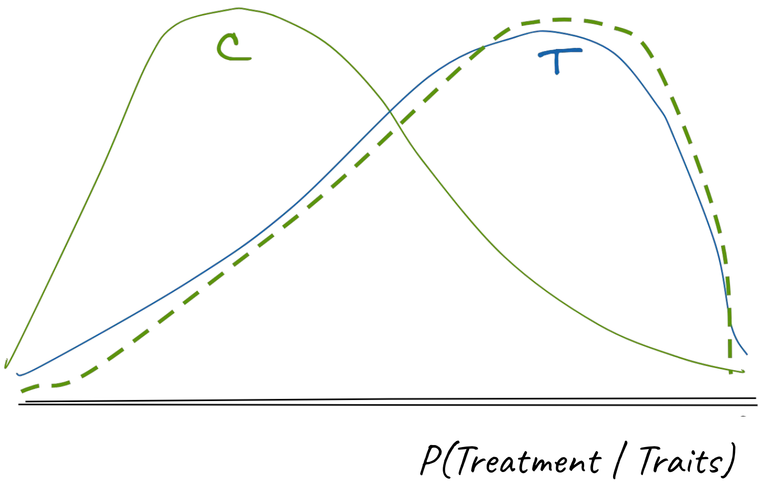
And Mozilla users tend to
spend less on averager

Stratification application



When we have imbalance across many dimensions...

Propensity Score Weighting



When you have:

- "similar" treated and untreated individuals
- different distributions
- on many dimensions

Tries to:

Rebalance to make groups more comparable

⭐ Spark from untreated data and rich featureset ⭐

Propensity Score Weighting pattern

Recipe:

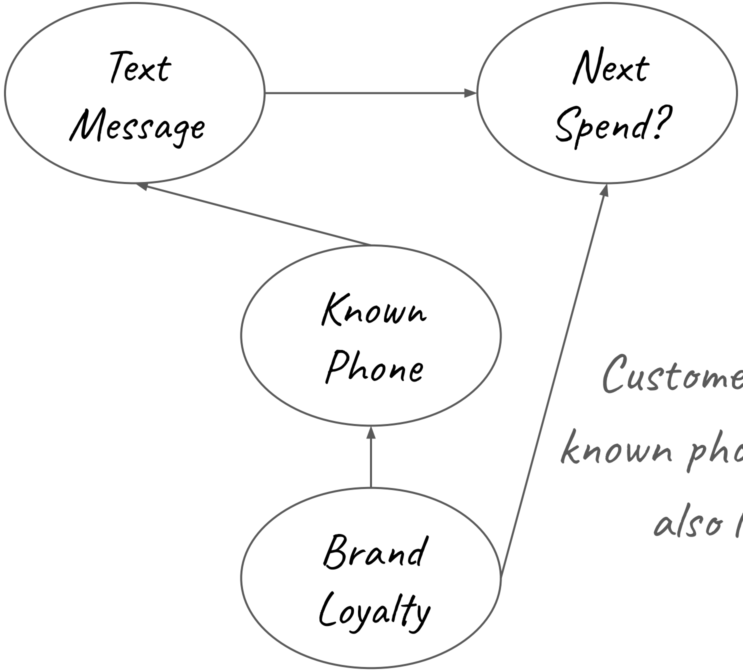
- Model the P(Treatment | Traits)
- Derive weights from predictions
- Calculate average outcome by treatment using weights

Assumption:

- All common causes of treatment and outcome are accounted for
- All observations have positive probability of treatment

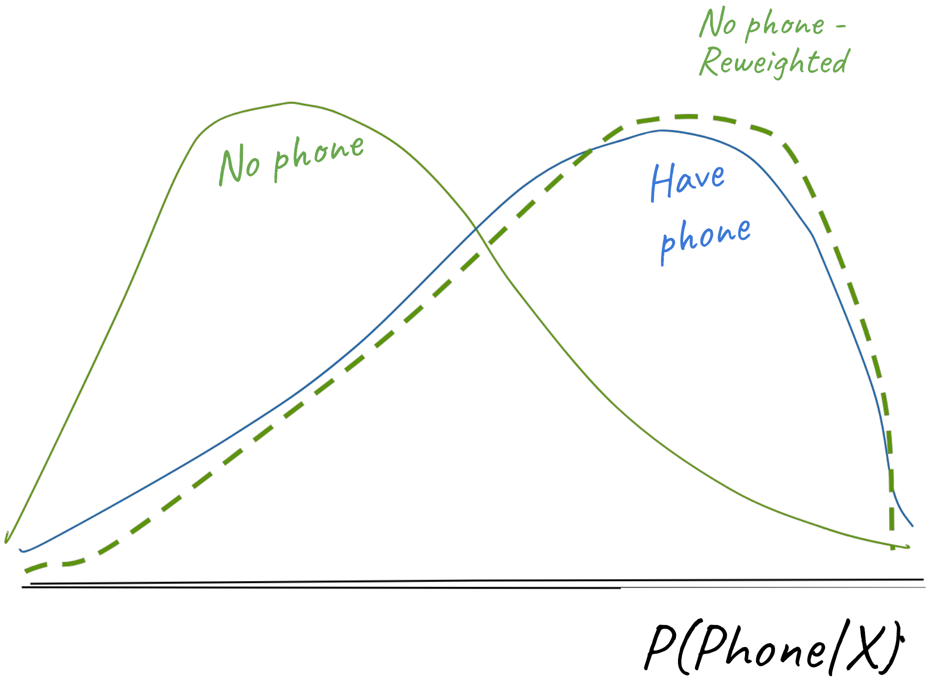
Propensity Score Weighting application

Send text message to all customers with a valid phone number on record

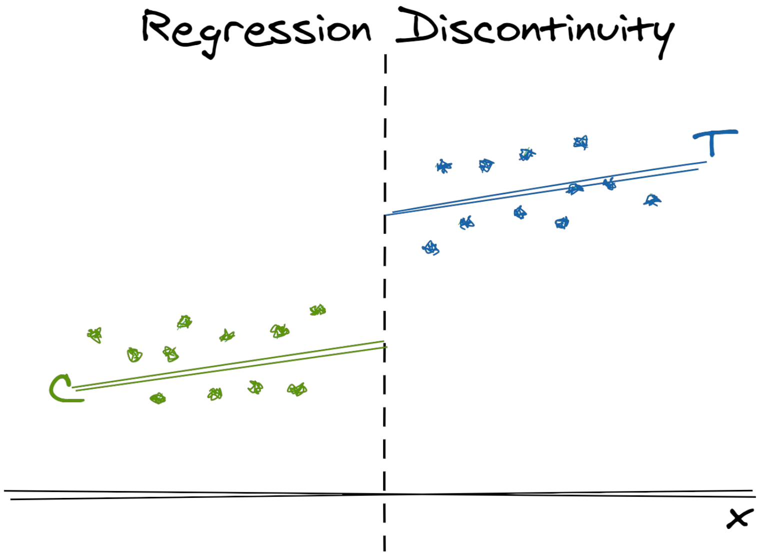


Customers without a known phone number are also less active

Propensity Score Weighting application



When we have no overlap...



When you have:

- disjoint treated and untreated individuals
- separated by sharp cut-off

Tries to:

Exploit arbitrary variation in treatment assignment at cut-off to evaluate local effect

⭐ Spark from sharp policy cut-off ⭐

Regression Discontinuity pattern

Recipe:

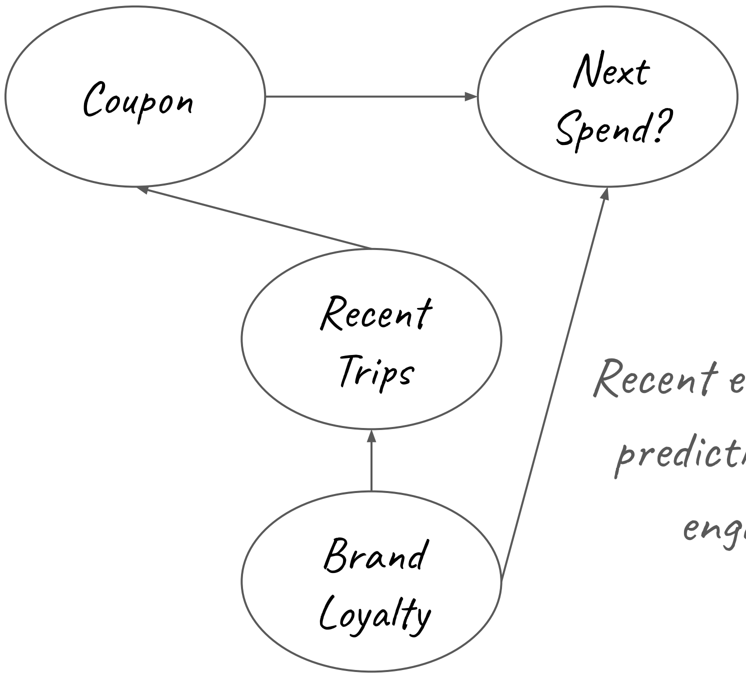
- Model Outcome = f(running var) on each side of cut-off
- Evaluate models at cut-off value
- The local treatment effect is the difference in estimates

Assumption:

- Assignment rule is unknown to individuals (not gameable)
- Outcome is continuous function of running variable
- Can fit a reasonably well-specified and simple model

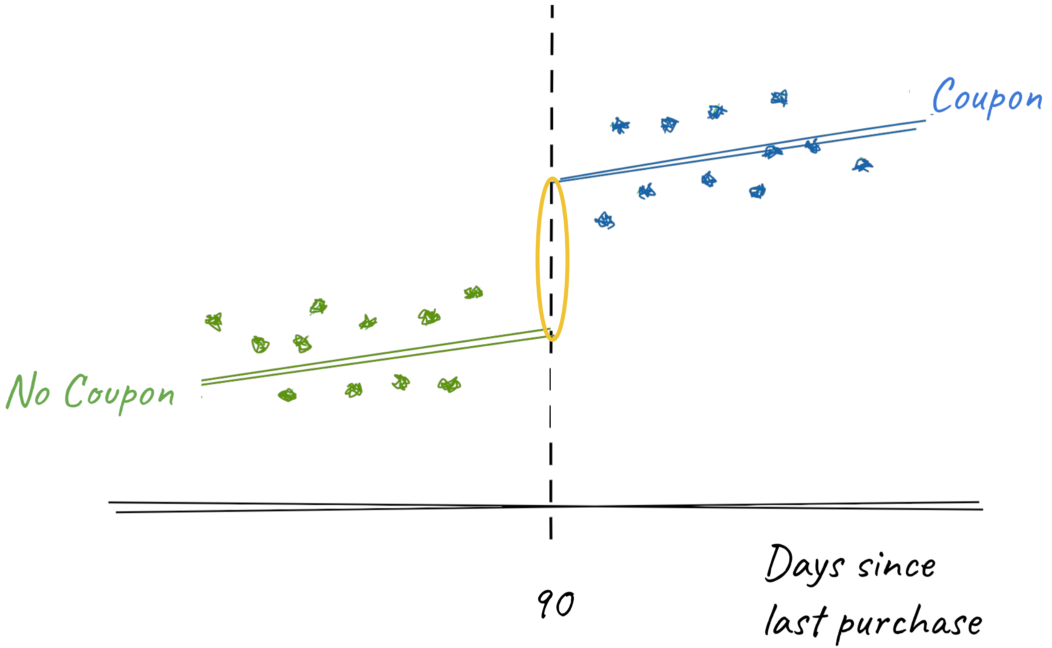
Regression Discontinuity application

Send coupon to customers who've not purchased in last 90 days



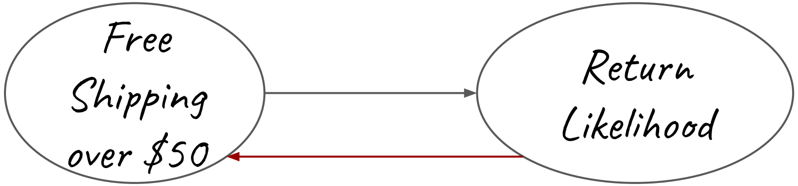
Recent engagement is predictive of future engagement

Regression Discontinuity application



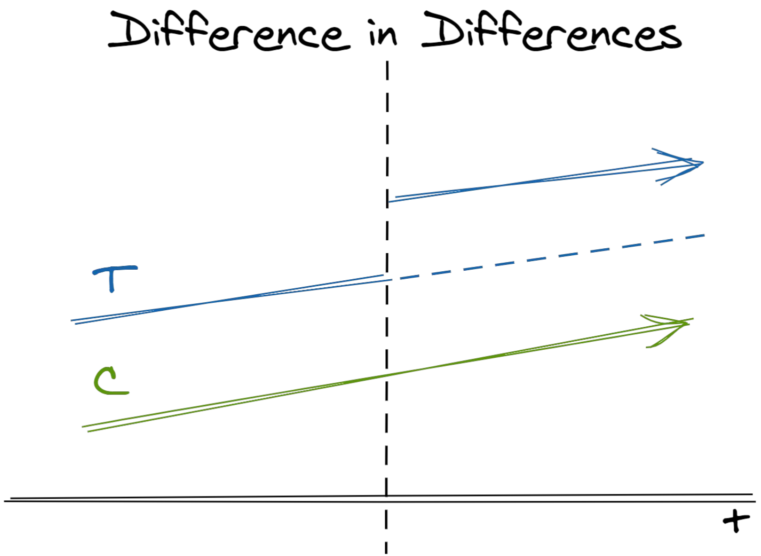
Regression Discontinuity breakdown

Offer free shipping and returns on purchases over $50



Customers anticipating returns can game a known policy

When we have pre-existing differences...



When you have:

- different baselines in comparison groups
- variation across time (pre/post)

Tries to:

Compare how difference in pre/post behavior differs across populations

⭐ Spark from treatment timing ⭐

Difference-in-Differences pattern

Recipe:

- Take the pre/post treatment difference within each group
- Find the difference in differences between groups
- Technically done as a fixed-effects regression

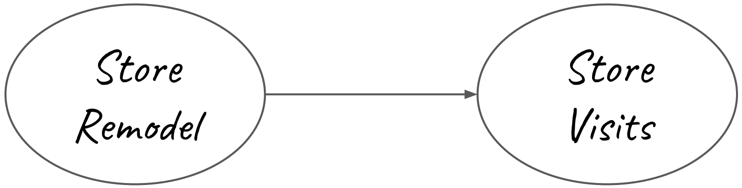
Assumption:

But-for the treatment, groups would have parallel trends

- Decision to treat not influenced by anticipated outcome
- No spill-over between groups

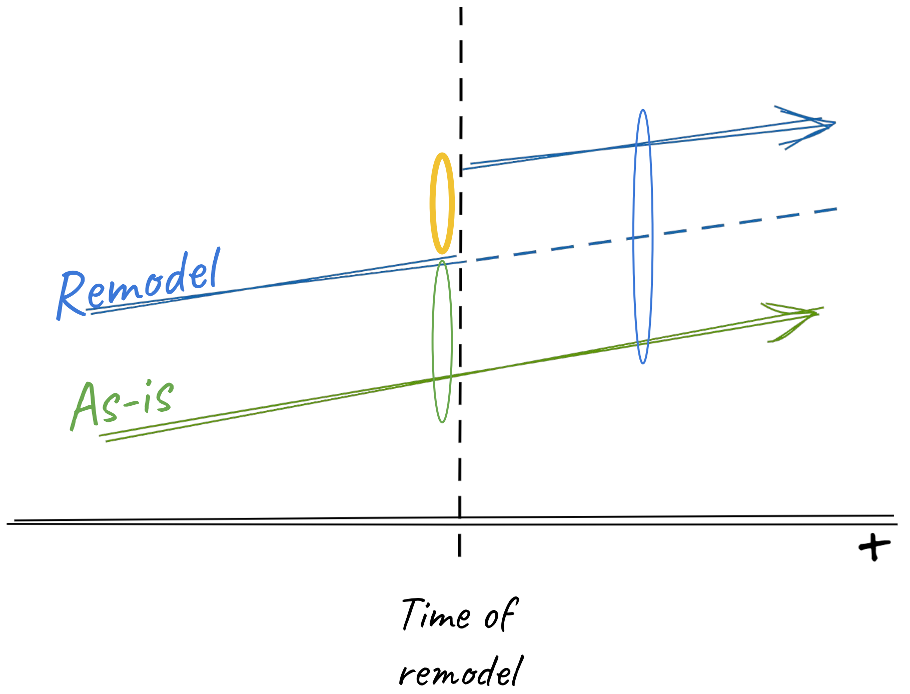
Difference-in-Differences application

Remodel store and want to measure effect on store traffic



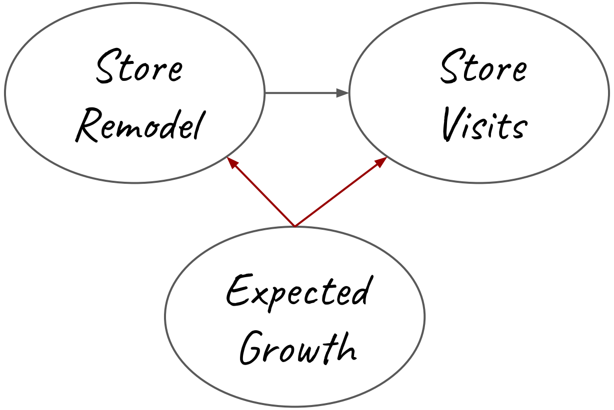
Too capital intensive
to experiment!

Difference-in-Differences application

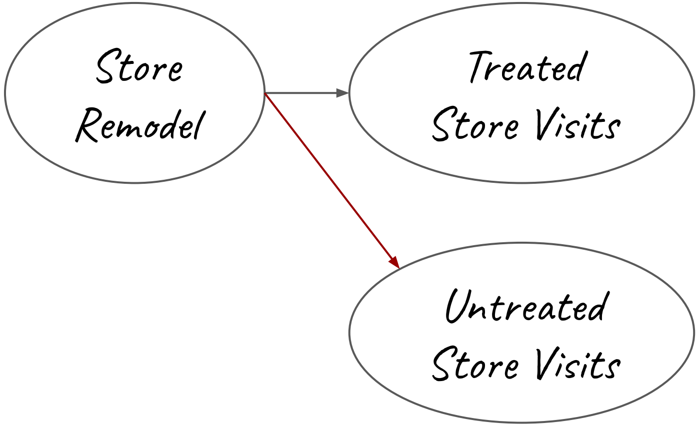


Difference-in-Differences breakdowns

Decision to Treat

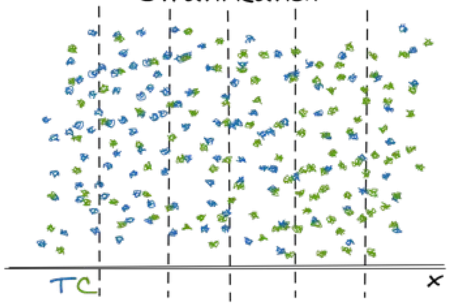


Spillover

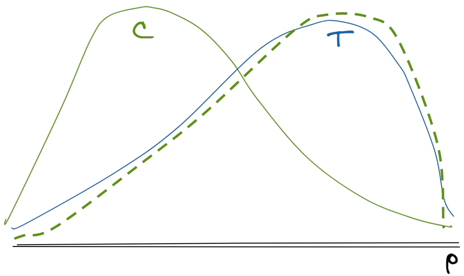


Four basic strategies for causal inference

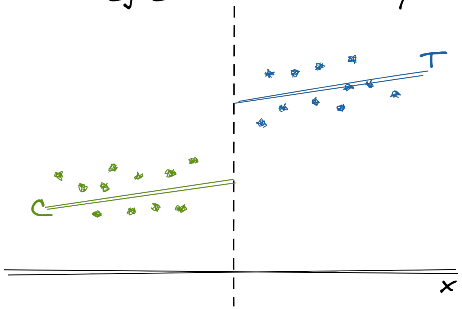
Stratification



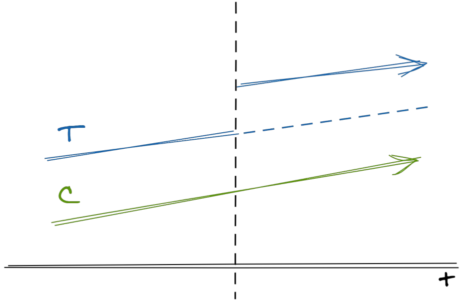
Propensity Score Weighting



Regression Discontinuity



Difference in Differences



Variation in treatment distribution within a population

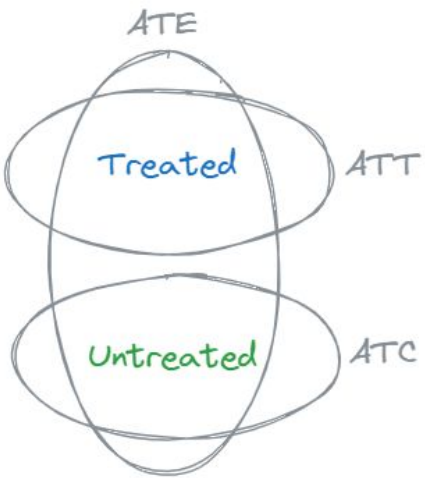
Variation across distinct groups

Variation across groups & time

Extensions

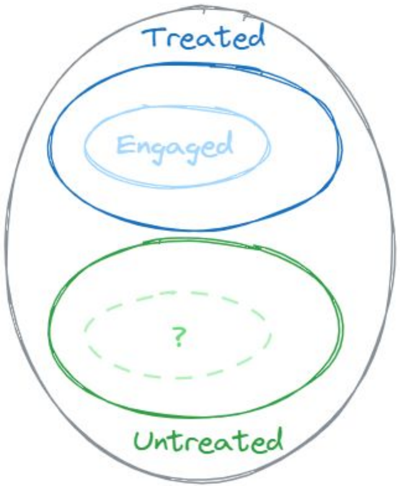
Propensity scores to measure different effects

Different Subgroups



Map propensity scores to different weights for different populations

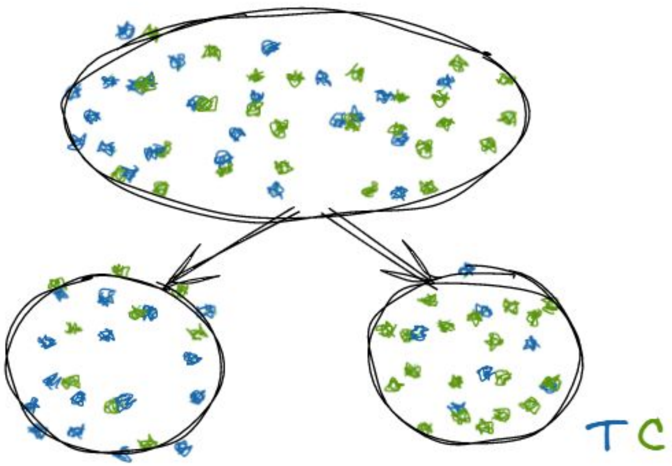
Different Points of Randomization



Create counterfactuals for narrower subgroups like campaign opt-ins

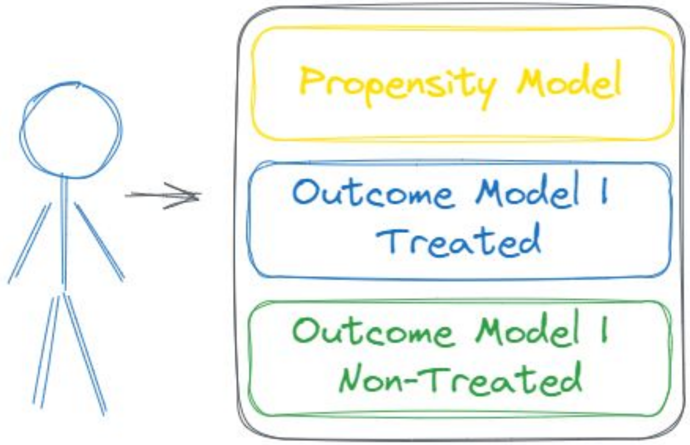
Propensity scores to estimate individual effects

Causal Forests



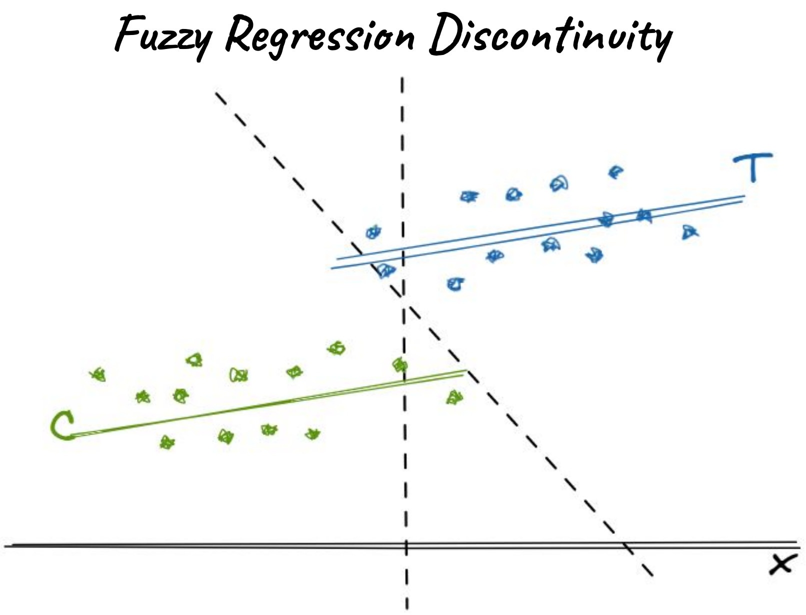
Create balanced experiment within tree nodes

Doubly Robust Methods (e.g. AIPTW)

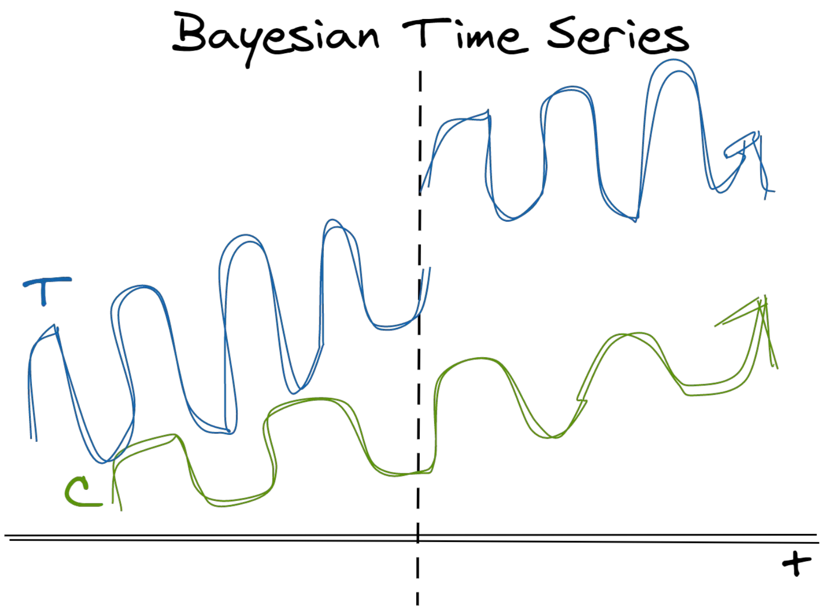


Combine treatment and outcome models- even if one is mis-specified!

Relaxing RD and Diff-in-Diff assumptions



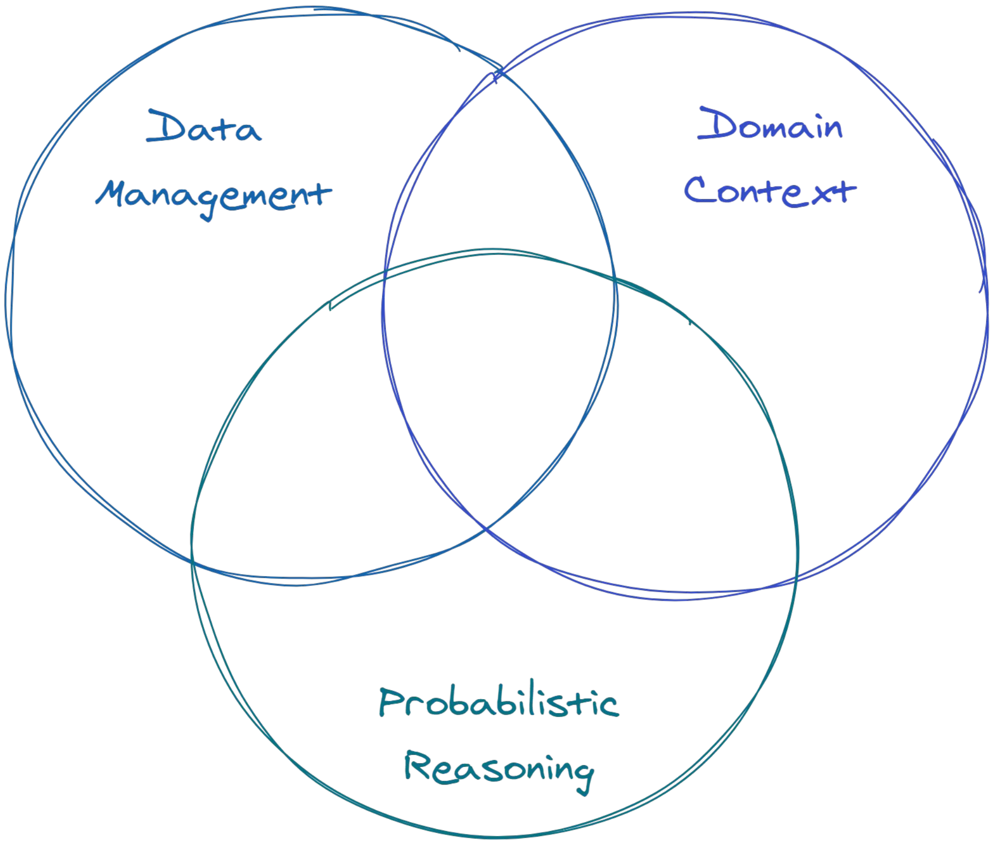
Regression discontinuity with imprecise cut-off



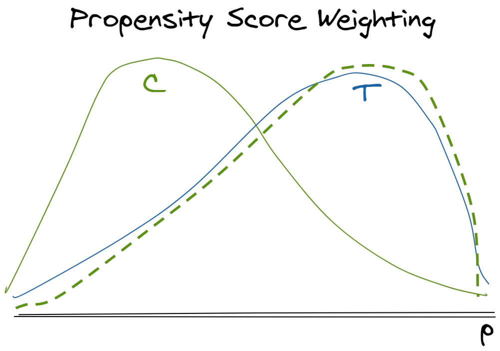
Diff-in-diff extension for richer time series

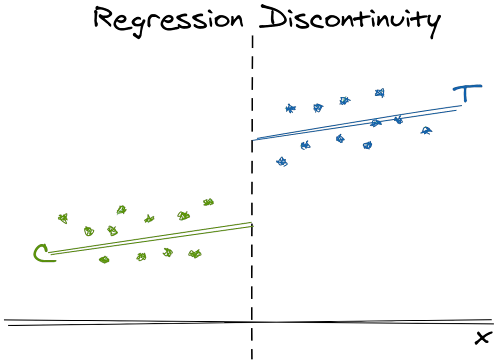
Org Implications

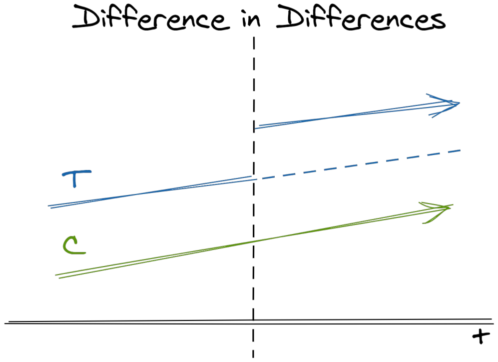
Successful causal inference requires a mix of skills & capabilities



Holistic data management can help us find the 'sparks' we need







Data Management

Behavioral data
Digital data
Operational data

Metadata Management

Segmentations
Strategies
Offers & Targeting

Knowledge Management

Decisions to enact policy
Rollout/launch dates

Resources

Questions?

↓ Get in touch ↓

@emilyriederer on Web / Twitter / GitHub / LinkedIn / Gmail

↓ Related blog posts ↓

Causal design patterns
Causal inference resource roundup

↓ Open access books ↓

The Effect: an Introduction to Research Design and Causality by Nick Huntington-Klein
Causal Inference: the Mixtape by Scott Cunningham
Causal Inference: What If? by Miguel Hernan
Introduction to Causal Inference by Brady Neal
Causal Inference for the Brave and True by Matheus Alves

Thank you!