Regression Discontinuity Design (RDD)

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The Identification Challenge

• Does X cause Y?
• Tempting to regress Y on X …
  \[ Y = a + b \times X + \text{controls} + e \]
  Unobservables?
• … but often X is endogenous with respect to Y
• Endogeneity is especially challenging in strategy research:
  ➢ By definition, firm strategies are endogenous decisions of companies.
How to Establish Causality?

- Ideally: need randomization of $X$.
- But: randomization is hard to get (except in controlled lab/field experiments).
- Second best: use quasi-natural experiments, i.e., look for an empirical setting in which $X$ varies exogenously.
- Importantly: to establish causality, you need a source of exogenous variation in $X$. 
Leaving aside controlled experiments, three main methods of causal inference:

1) IV (instrumental variables)
2) DID (difference-in-differences)
3) RDD (regression discontinuity design)

1) and 2) increasingly popular in strategy research.

3) is rarely used.

- Missed opportunity.
- RDD considered as the sharpest tool of causal inference since it is closest to ideal setting of randomized experiments (see, e.g., Lee and Lemieux, 2010).

This presentation: focus on 3) from applied perspective.
Regression Discontinuity Design (RDD)

Example:
Flammer and Bansal, “Does Long-Term Orientation Create Value? Evidence from a Regression Discontinuity”
Agenda

1. Discontinuity
2. Randomization Tests
3. Estimation
4. External Validity
5. Recap—RDD “Etiquette”
Context

- Do companies benefit from long-term orientation?

- “Naïve” OLS Regression:
  \[ \text{Performance} = \alpha + \beta \times \text{Long-term orientation} + \gamma'X + \varepsilon \]

  **Omitted Variables?**

  - **Alternative story #1**: “Deep pocket” story: Companies that perform better need to worry less about the short run and hence can more easily afford to be long-term oriented.
  - **Alternative story #2**: More talented CEOs may take a longer time perspective and, at the same time, show better financial results given their managerial ability.
  - ...
Ideal Experiment

Long-term orientation (random)

\[ \text{CEO}_A \quad \text{Firm}_A \]

- Shareholder value
- Operating performance

Short-term orientation (random)

\[ \text{CEO}_B \quad \text{Firm}_B \]

- Shareholder value
- Operating performance
Shareholder proposals on long-term executive compensation.

- Objective of long-term compensation: incentivize executives to create long-term value, thus fostering long-term orientation (e.g., Kole, 1997).

(Quasi-)random assignment of long-term incentives to companies:

- Long-term executive compensation shareholder proposals that pass or fail by small margin of votes.
  - Intuition: no systematic difference between company that passes proposal with, e.g., 50.1% of votes and company that rejects proposal with 49.9% of votes.
  - Minor difference in vote shares leads to discrete change (i.e., a discontinuity) in adoption of long-term compensation policies.
  - Regression Discontinuity Design (RDD).
  - Passage of such “close-call” proposals akin to random assignment of long-term incentives to companies → provides clean causal estimate.
Shareholder Proposals on LT Executive Compensation

• Source:
  ➢ RiskMetrics and SharkRepellent databases.

• Coverage:
  ➢ Information included:
    • Firm identifiers, proposal description, date of shareholder meeting, proposal’s sponsor, voting requirement, outcome of votes.

• Selection Criteria:
  ➢ Shareholder-sponsored proposals.
  ➢ Related to long-term executive compensation:
    • Restricted stocks (i.e., company shares that cannot be sold in short run);
    • Stock options with long-term vesting period;
    • Long-term incentive plans (LTIP).
Example of LT Compensation Proposal that was Closely Approved

Company: Lucent Technologies, Inc.
Meeting Date: February 16, 2005
Proposal Type: Restricted stocks
Support Statement: As long-term shareholders, we support compensation policies for senior executives that provide challenging performance objectives that motivate executives to achieve long-term shareholder value.
Voting result: Passed (50.1% Yes versus 49.9% No)
Source: SharkRepellent
Final Sample

- Final Sample:
  - 808 long-term executive compensation proposals.
    - 65 proposals within 5% of majority threshold.
    - 152 proposals within 10% of majority threshold.
  
  "close call"
Distribution of Vote Outcomes
Agenda

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Randomization Tests

• **Regression discontinuity design (RDD):**
  - Compare shareholder proposals that pass or fail by small margin of votes.

• **Identifying assumption** of the RDD:
  - Around majority threshold, outcome of vote is as good as random.

• **Two standard tests** of this assumption (akin to tests of randomization in randomized experiments):
  1) Distribution of votes is continuous around majority threshold.
  2) **No pre-existing differences** between companies that marginally pass and reject long-term compensation proposals.
Continuity around Majority Threshold

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Regression Discontinuity Design
McCrary Test

$p$-value (McCrary test) = 0.997

- Null of continuous distribution cannot be rejected.
## No Pre-Existing Differences around Majority Threshold

<table>
<thead>
<tr>
<th></th>
<th>Before meeting ((t - 1))</th>
<th>Change from ((t - 2)) to ((t - 1))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>((1))</td>
<td>((2))</td>
</tr>
<tr>
<td>Abnormal return</td>
<td>0.000</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>((0.002))</td>
<td>((0.005))</td>
</tr>
<tr>
<td>Market value</td>
<td>-0.533***</td>
<td>-0.207</td>
</tr>
<tr>
<td></td>
<td>((0.183))</td>
<td>((0.356))</td>
</tr>
<tr>
<td>Total assets</td>
<td>-0.491**</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>((0.192))</td>
<td>((0.374))</td>
</tr>
<tr>
<td>Total CEO compensation</td>
<td>0.220</td>
<td>0.254</td>
</tr>
<tr>
<td></td>
<td>((0.192))</td>
<td>((0.374))</td>
</tr>
<tr>
<td>Long-term CEO compensation</td>
<td>0.282</td>
<td>0.459</td>
</tr>
<tr>
<td></td>
<td>((0.850))</td>
<td>((1.623))</td>
</tr>
<tr>
<td>LT-index</td>
<td>-0.016</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>((0.016))</td>
<td>((0.031))</td>
</tr>
<tr>
<td>Capital expenditures</td>
<td>-0.004</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>((0.005))</td>
<td>((0.008))</td>
</tr>
<tr>
<td>R&amp;D expenditures</td>
<td>0.005</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>((0.007))</td>
<td>((0.014))</td>
</tr>
<tr>
<td>ROA</td>
<td>-0.007</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>((0.010))</td>
<td>((0.018))</td>
</tr>
</tbody>
</table>
Firms that marginally rejected proposals are very similar to firms that marginally accepted proposals, which supports the randomization assumption.
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Regression Discontinuity Design (RDD)

Objective: measure difference in outcome variable \( y \) around threshold.

\[
\Delta = \bar{y}_{\text{above}} - \bar{y}_{\text{below}}
\]
Objective: measure difference in outcome variable $y$ around threshold.
Regression Discontinuity Design

\[ y_{it} = \beta \times \text{Pass}_{it} + P_l(v_{it}, \gamma_l) + P_r(v_{it}, \gamma_r) + \varepsilon_{it} \]

- \( y_{it} \): dependent variable for firm \( i \) around proposal vote at time \( t \).
  - Abnormal return (AR) computed using the 4-factor model (i.e., stock return adjusted for market, size, book-to-market, and momentum).

- \( \text{Pass}_{it} \): dummy variable that equals
  - 1 for firms that pass proposal
  - 0 for firms that reject proposal.

- \( P_l(v_{it}, \gamma_l) \): polynomial in vote share on LHS of majority threshold.
- \( P_r(v_{it}, \gamma_r) \): polynomial in vote share on RHS of majority threshold.

- \( \varepsilon_{it} \): error term (standard errors clustered at firm level).
Abnormal Returns on Day of Vote

![Graph showing abnormal returns on the day of the vote versus victory margin.](image-url)
## Effect of LT Incentives on Firm Performance

<table>
<thead>
<tr>
<th></th>
<th>Full model</th>
<th>[−10%, +10%]</th>
<th>[−5%, +5%]</th>
<th>[−2.5%, +2.5%]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pass</strong></td>
<td>0.0114***</td>
<td>0.0068*</td>
<td>0.0142**</td>
<td>0.0228*</td>
</tr>
<tr>
<td></td>
<td>(0.0039)</td>
<td>(0.0041)</td>
<td>(0.0066)</td>
<td>(0.0134)</td>
</tr>
<tr>
<td><strong>Polynomial in vote share</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.013</td>
<td>0.019</td>
<td>0.064</td>
<td>0.055</td>
</tr>
<tr>
<td><strong>Observations</strong></td>
<td>808</td>
<td>152</td>
<td>65</td>
<td>19</td>
</tr>
</tbody>
</table>
Agenda

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External Validity

• Benefit of RDD: **internal validity**.
  - Variation in long-term incentives is quasi-random.
  - RDD methodology often seen as the “sharpest tool of causal inference since it approximates very closely the ideal setting of randomized controlled experiments” (Lee and Lemieux, 2010).

• Potential concern of RDD: **external validity**.
  - Identification is obtained from firms close to discontinuity.
  - Are those firms **representative** of firms far from discontinuity?

• Assessment of external validity:
  - Contrast firms close to discontinuity with firms far from discontinuity.
### External Validity

Companies at the threshold are likely representative of other companies in our sample.
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4. External Validity
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Recap—RDD “Etiquette”

• Steps to implement the RDD:
  ➢ Starting point: a “discontinuity”:
    • E.g., majority threshold for election/vote, merit threshold for award, etc.
    • Importantly, being marginally above or below the discontinuity should be “as good as random”.
  ➢ Randomization tests:
    • McCrary test.
    • Covariate balance.
  ➢ Estimation:
    • Non-parametric: compare means right above vs. right below discontinuity.
    • Parametric: polynomials.
  ➢ External validity:
    • Contrast firms close to discontinuity vs. firms far from discontinuity.
Literature

• Econometrics of RDD:

• Applications of RDD:
Thank You!