# 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.**

# Three Methods of Causal Inference

- 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:

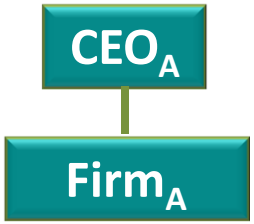
$$\text{Performance} = \alpha + \beta \times \text{Long-term orientation} + \boldsymbol{\gamma'X} + \varepsilon$$

**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.
- …

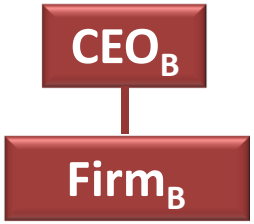
# Ideal Experiment

**Long-term orientation (random)**




- Shareholder value
- Operating performance

**Short-term orientation (random)**




- Shareholder value
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# RDD Approach

- 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:
  - U.S. publicly-traded companies from 1997–2012.
  - 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).

# Shareholder Proposals on LT Executive Compensation

*Example of LT Compensation Proposal that was Closely Approved*

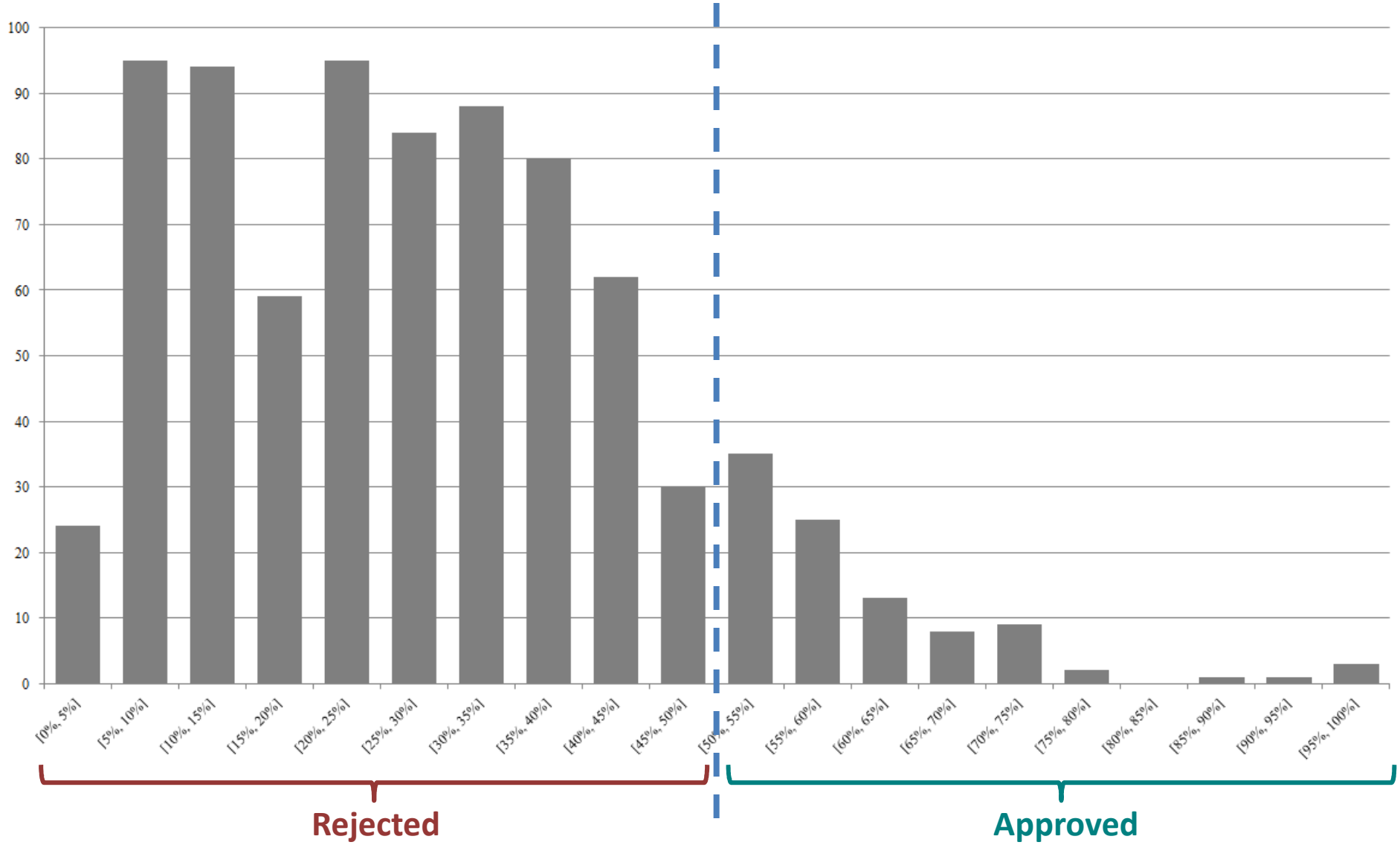
| | |
|---|---|
| Company: | Lucent Technologies, Inc. |
| Meeting Date: | February 16, 2005 |
| Proposal Type: | Restricted stocks |
| Support Statement: | As long-term shareholders, we support compensation policies for senior executives that provide challenging performance objectives that motivate 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



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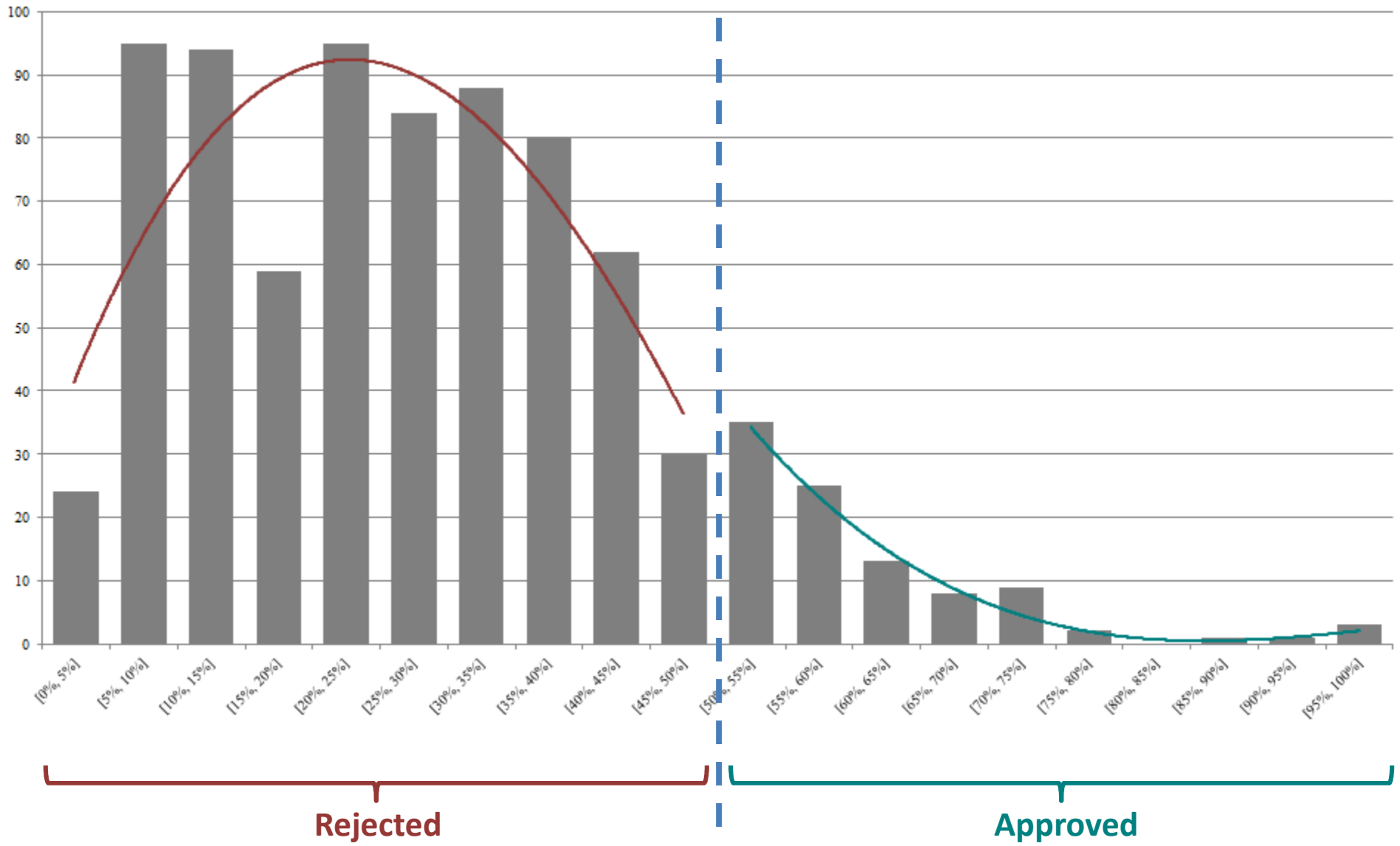
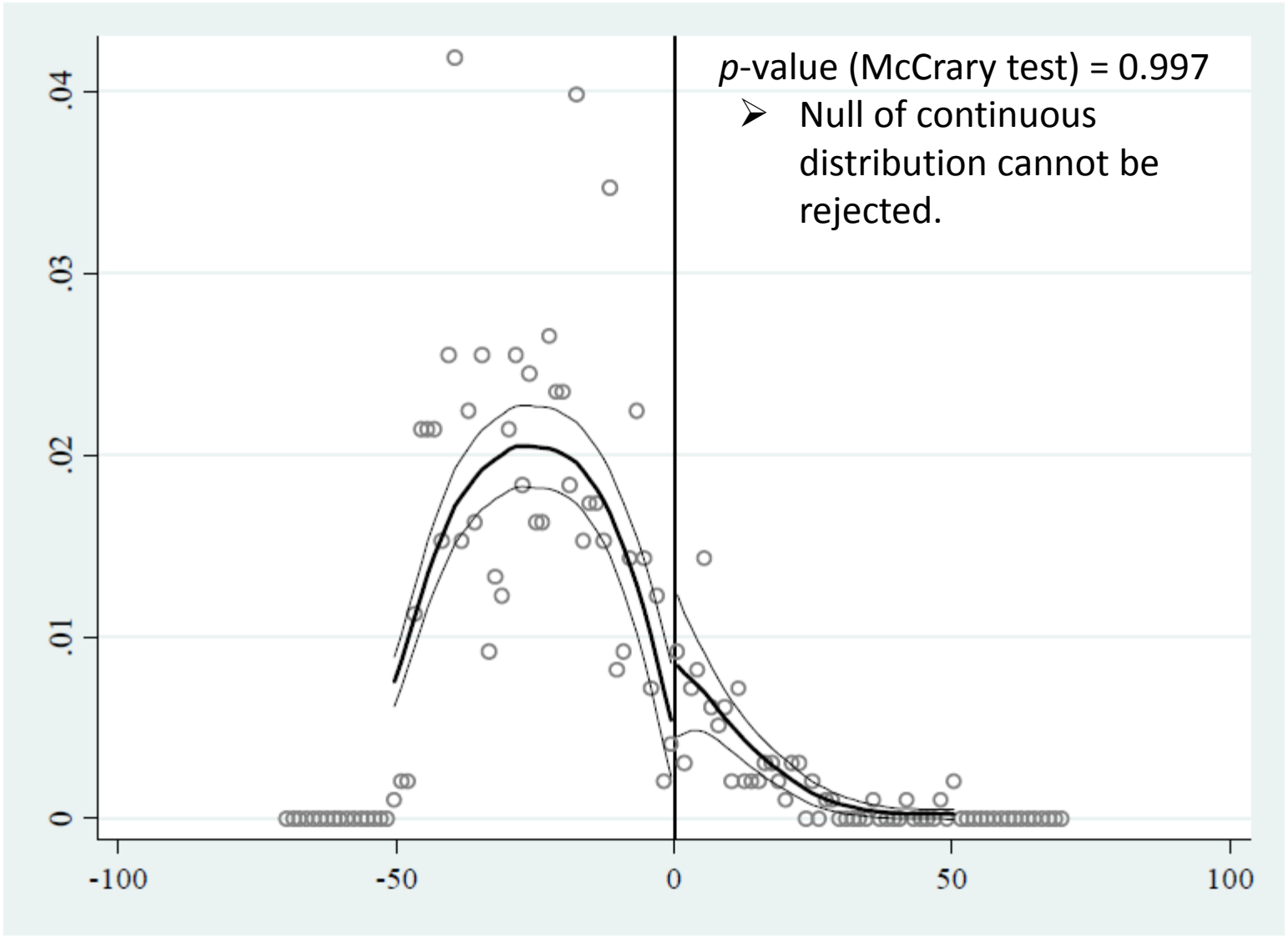
# Randomization Tests

- **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



# McCrary Test




*p*-value (McCrary test) = 0.997

- Null of continuous distribution cannot be rejected.

# No Pre-Existing Differences around Majority Threshold

| | Before meeting ($t-1$) | | Change from ($t-2$) to ($t-1$) | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Abnormal return | 0.000 | 0.003 | -0.001 | 0.003 |
| | (0.002) | (0.005) | (0.003) | (0.007) |
| Market value | -0.533*** | -0.207 | -0.043 | 0.044 |
| | (0.183) | (0.356) | (0.055) | (0.107) |
| Total assets | -0.491** | 0.087 | -0.026 | 0.012 |
| | (0.192) | (0.374) | (0.024) | (0.046) |
| Total CEO compensation | 0.220 | 0.254 | 0.128 | 0.529 |
| | (0.192) | (0.374) | (0.181) | (0.352) |
| Long-term CEO compensation | 0.282 | 0.459 | 0.195 | 0.249 |
| | (0.850) | (1.623) | (0.761) | (1.474) |
| LT-index | -0.016 | 0.047 | -0.000 | 0.010 |
| | (0.016) | (0.031) | (0.011) | (0.022) |
| Capital expenditures | -0.004 | 0.004 | -0.001 | -0.001 |
| | (0.005) | (0.008) | (0.002) | (0.004) |
| R&D expenditures | 0.005 | -0.001 | -0.003 | -0.001 |
| | (0.007) | (0.014) | (0.002) | (0.005) |
| ROA | -0.007 | -0.001 | -0.000 | -0.006 |
| | (0.010) | (0.018) | (0.006) | (0.011) |

# No Pre-Existing Differences around Majority Threshold

| | Before meeting $(t-1)$ | | Change from $(t-2)$ to $(t-1)$ | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| NPM | -0.002 | 0.002 | -0.005 | -0.001 |
| | (0.021) | (0.040) | (0.016) | (0.032) |
| Sales growth | 0.007 | -0.004 | 0.022 | 0.028 |
| | (0.022) | (0.043) | (0.030) | (0.058) |
| Tobin's Q | -0.199* | -0.176 | -0.002 | 0.088 |
| | (0.107) | (0.213) | (0.051) | (0.102) |
| Leverage | -0.008 | 0.007 | -0.004 | -0.001 |
| | (0.018) | (0.034) | (0.006) | (0.012) |
| KZ-index | 0.022 | 0.211 | -0.057 | -0.053 |
| | (0.087) | (0.174) | (0.039) | (0.079) |
| KLD-index | -0.949** | 0.122 | 0.010 | -0.172 |
| | (0.428) | (0.843) | (0.180) | (0.357) |
| G-index | 0.675** | 0.661 | -0.025 | -0.019 |
| | (0.262) | (0.507) | (0.056) | (0.109) |

- Firms that marginally rejected proposals are **very similar** to firms that marginally accepted proposals, which **supports** the **randomization assumption**.

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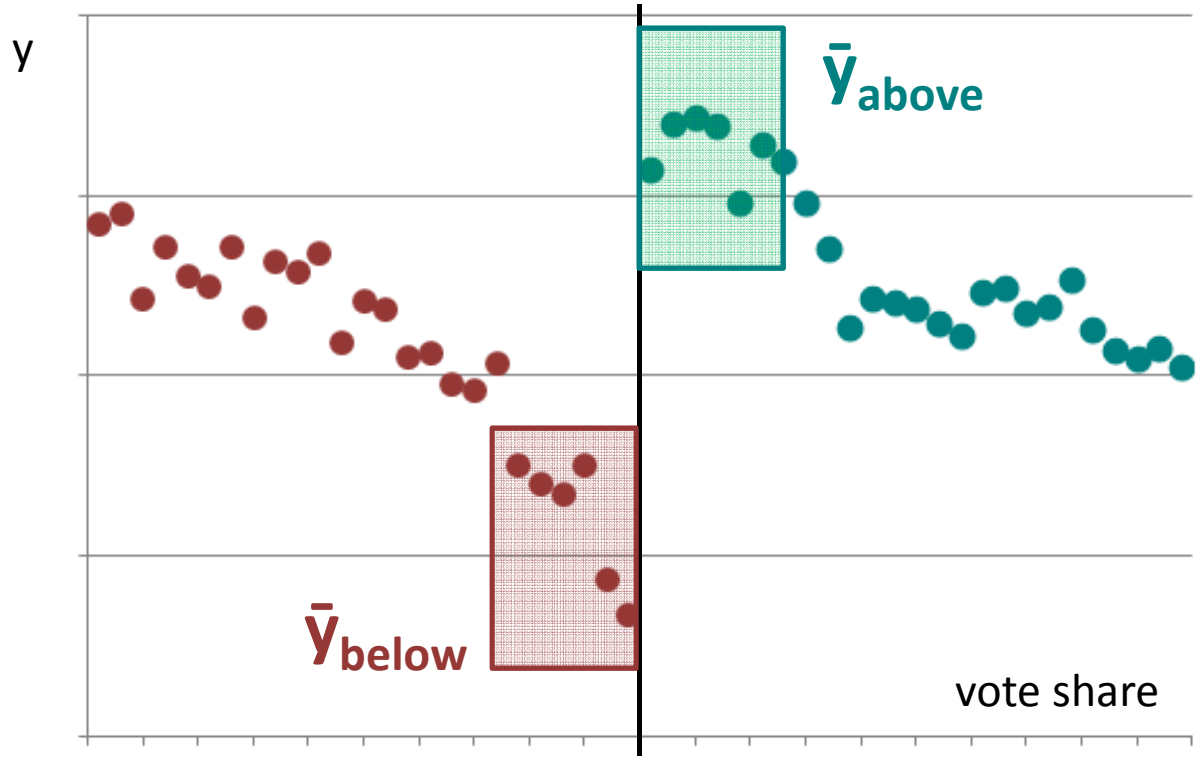
# Regression Discontinuity Design (RDD)

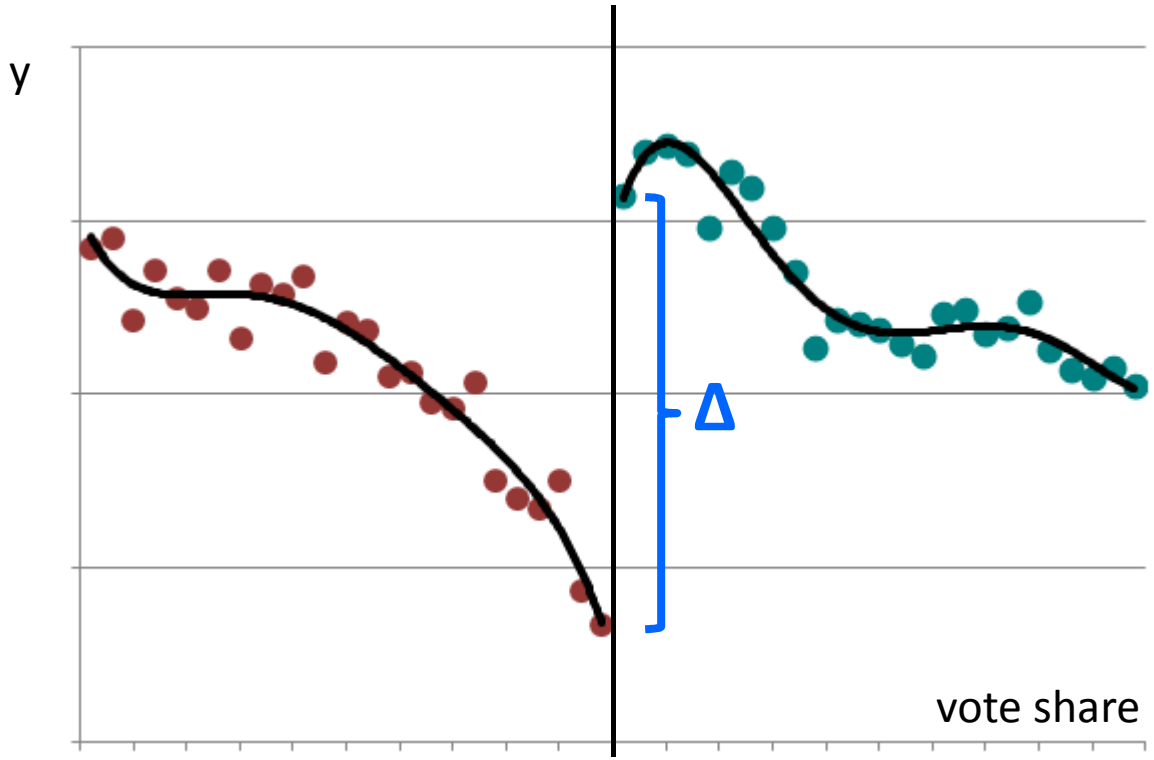
Objective: measure difference in outcome variable y around threshold.




$$\Delta = \bar{y}_{above} - \bar{y}_{below}$$

# Regression Discontinuity Design (RDD)

Objective: measure difference in outcome variable y around threshold.

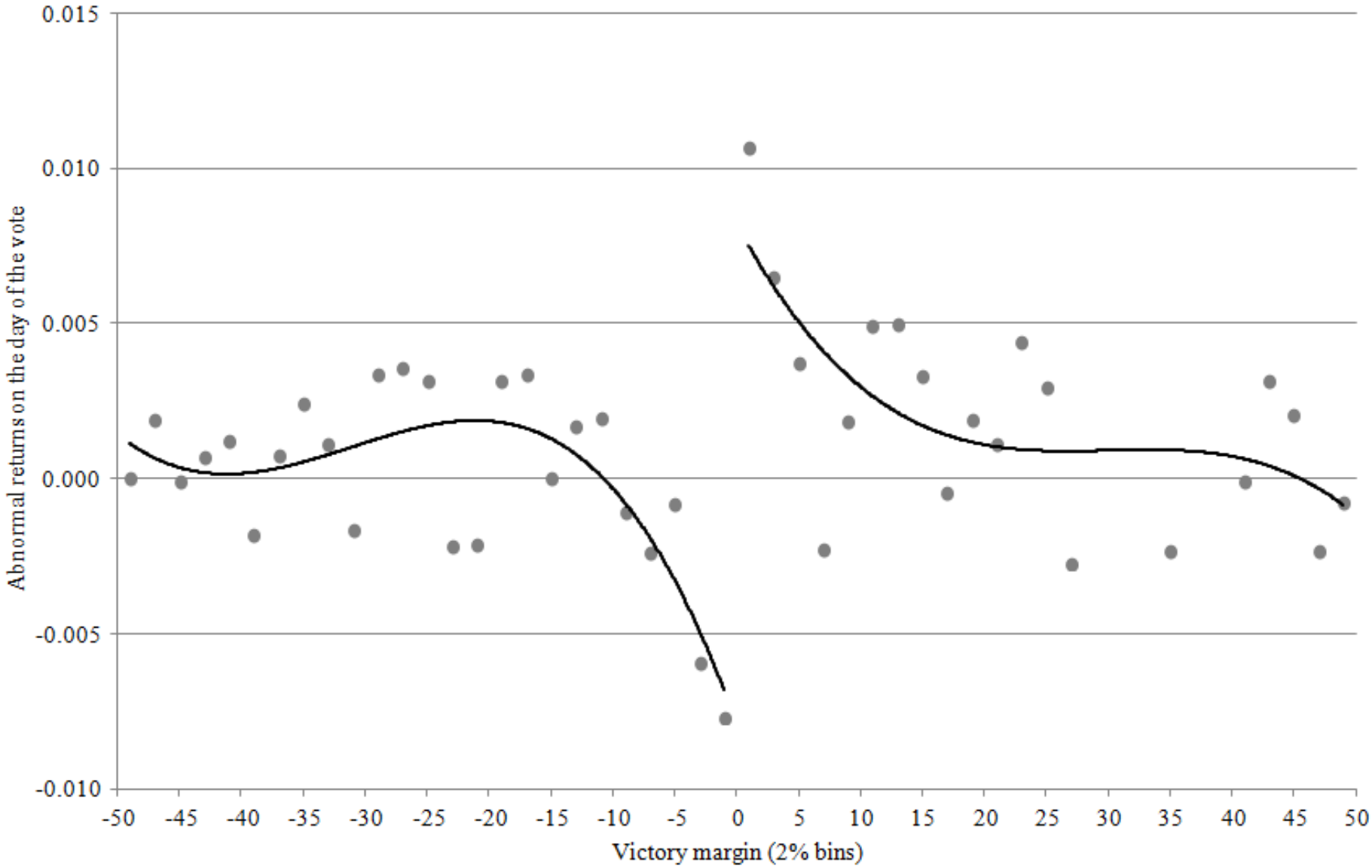


# Regression Discontinuity Design

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

- $y_{it}$ : 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).
- $Pass_{it}$: 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



# Effect of LT Incentives on Firm Performance

| | Full model | [–10%, +10%] | [–5%, +5%] | [–2.5%, +2.5%] |
|---|---|---|---|---|
| Pass | 0.0114*** | 0.0068* | 0.0142** | 0.0228* |
| | (0.0039) | (0.0041) | (0.0066) | (0.0134) |
| Polynomial in vote share | Yes | No | No | No |
| R-squared | 0.013 | 0.019 | 0.064 | 0.055 |
| Observations | 808 | 152 | 65 | 19 |

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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

| | [–5%, +5%] versus other proposals | | | [–10%, +10%] versus other proposals | | |
|---|---|---|---|---|---|---|
| | Mean [–5%, +5%] | Mean other proposals | *p* -value | Mean [–10%, +10%] | Mean other proposals | *p* -value |
| Abnormal return on meeting day | 0.001 | 0.001 | 0.900 | 0.000 | 0.001 | 0.325 |
| Market value ($ billion) | 41.088 | 37.595 | 0.715 | 37.157 | 38.043 | 0.872 |
| Total assets ($ billion) | 115.722 | 108.582 | 0.808 | 112.359 | 108.414 | 0.814 |
| Total CEO compensation ($ million) | 13.139 | 13.223 | 0.962 | 13.995 | 13.034 | 0.513 |
| Long-term CEO compensation ($ million) | 5.851 | 4.197 | 0.227 | 5.178 | 4.127 | 0.175 |
| LT-index | 0.732 | 0.751 | 0.262 | 0.731 | 0.753 | 0.088* |
| Capital expenditures | 0.045 | 0.046 | 0.906 | 0.043 | 0.046 | 0.371 |
| R&D expenditures | 0.050 | 0.038 | 0.208 | 0.045 | 0.038 | 0.306 |
| ROA | 0.095 | 0.114 | 0.064* | 0.108 | 0.114 | 0.363 |
| NPM | 0.181 | 0.190 | 0.660 | 0.192 | 0.189 | 0.840 |
| Sales growth | 0.078 | 0.070 | 0.734 | 0.097 | 0.064 | 0.070* |
| Tobin's Q | 1.503 | 1.680 | 0.146 | 1.611 | 1.679 | 0.409 |
| Leverage | 0.279 | 0.289 | 0.611 | 0.267 | 0.293 | 0.076* |
| KZ-index | 0.153 | 0.165 | 0.901 | 0.195 | 0.157 | 0.510 |

Companies at the threshold are likely **representative** of other companies in our sample.

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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:
  - Imbens GW, Lemieux T. 2008. Regression discontinuity designs: A guide to practice. *Journal of Econometrics* 142(2): 615–635.
  - Lee DS, Lemieux T. 2010. Regression discontinuity designs in economics. *Journal of Economic Literature* 48(2): 281–355.
- Applications of RDD:
  - Cuñat V, Giné M, Guadalupe M. 2012. The vote is cast: the effect of corporate governance on shareholder value. *Journal of Finance* 67(5): 1943–1977.
  - Flammer C. 2015. Does corporate social responsibility lead to superior financial performance? A regression discontinuity approach. *Management Science*, forthcoming.
  - Lalive R. 2007. Unemployment benefits, unemployment duration, and post-unemployment jobs: A regression discontinuity approach. *American Economic Review* 97(2): 108–112.

# Thank You!