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:

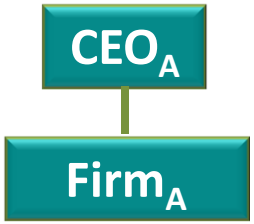
$$\text{Performance} = \alpha + \beta \times \text{Long-term orientation} + \boldsymbol{\gamma'X} + \varepsilon$$

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.
- …

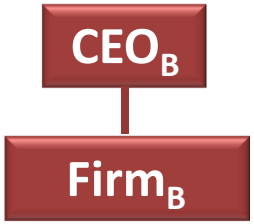
Ideal Experiment

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

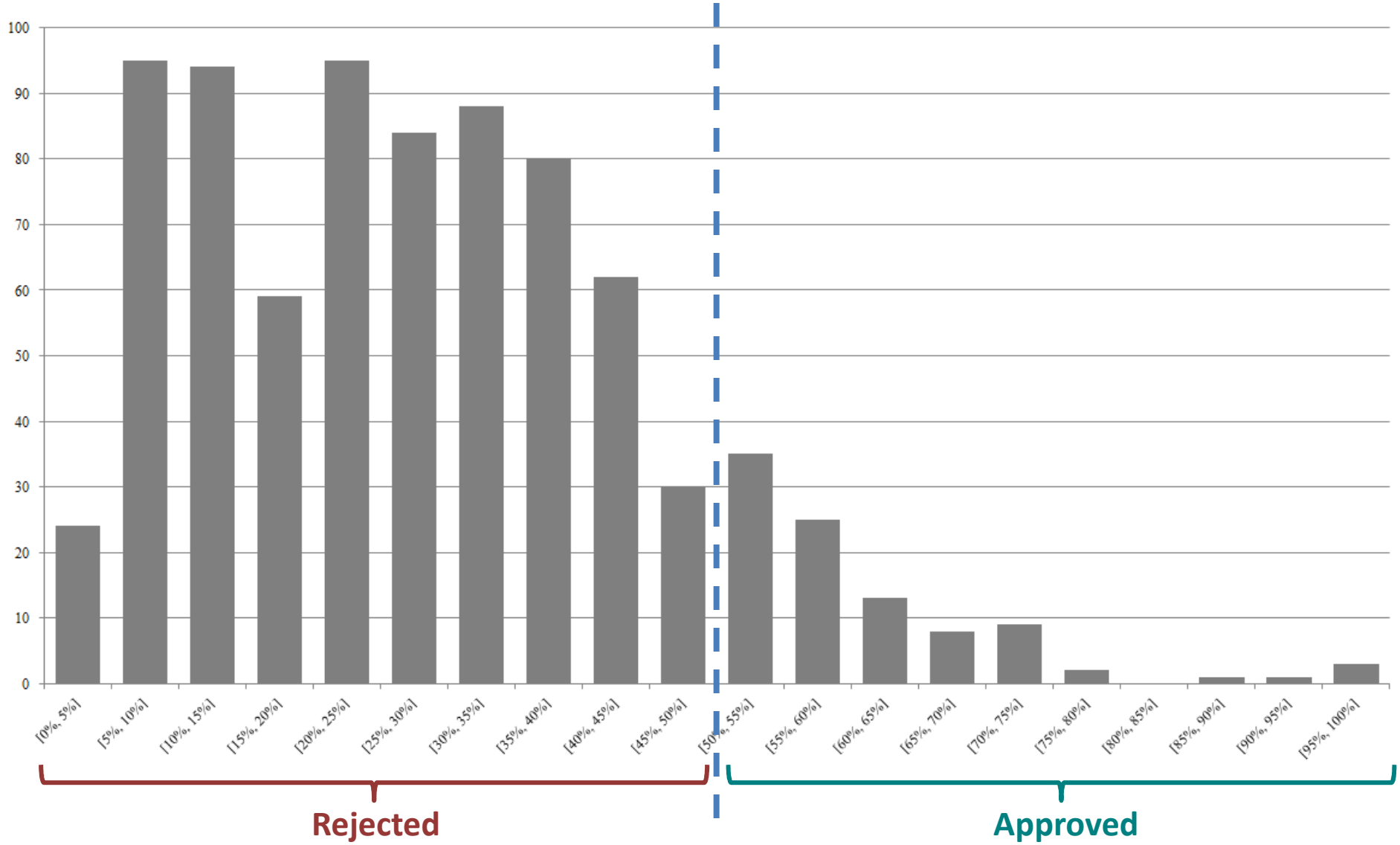
Company:	Lucent Technologies, Inc.
Meeting Date:	February 16, 2005
Proposal Type:	Restricted stocks
Support Statement:	As long-term shareholders, we support compensation policies for senior executives that provide challenging performance objectives that motivate executives to achieve long-term shareholder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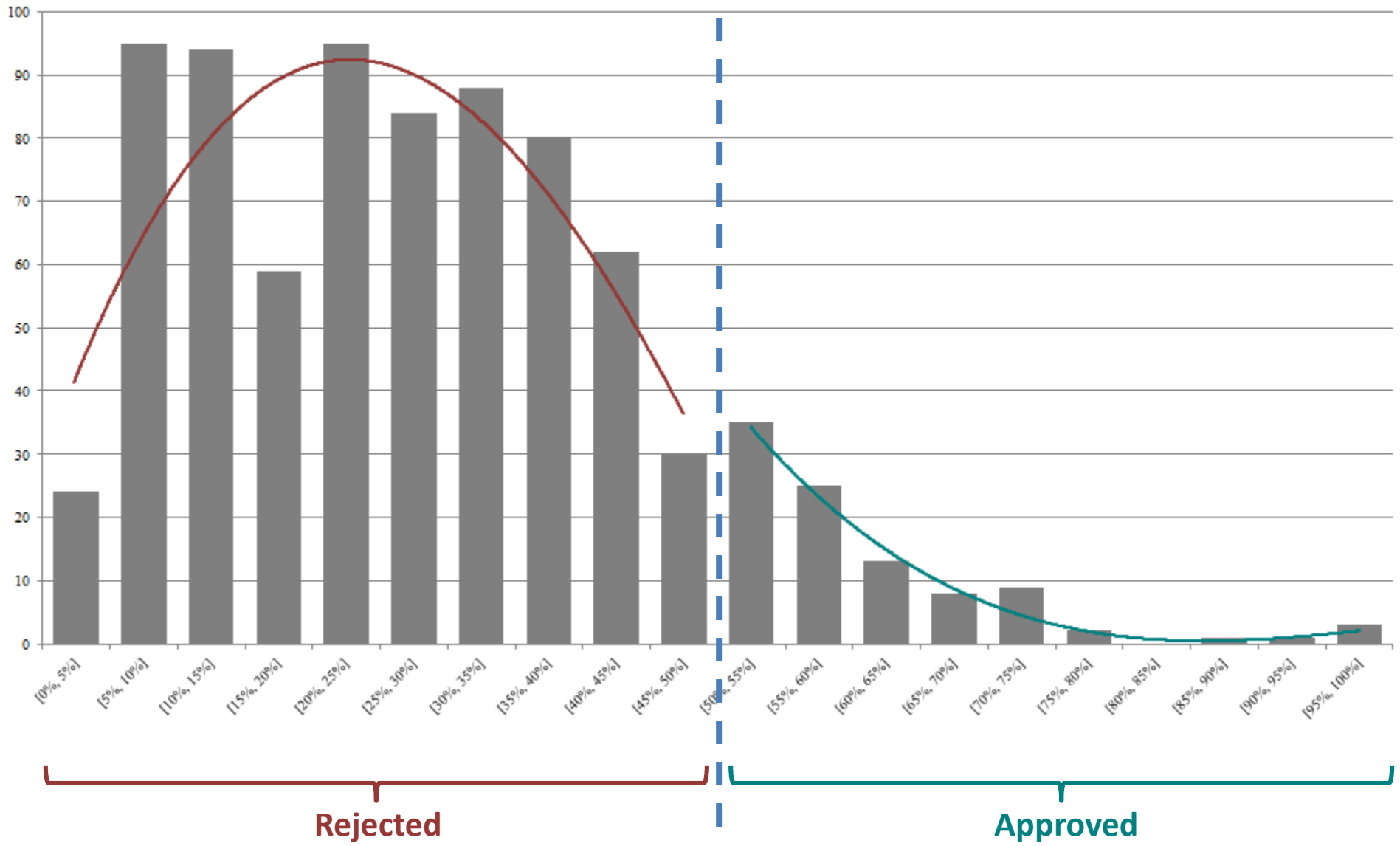
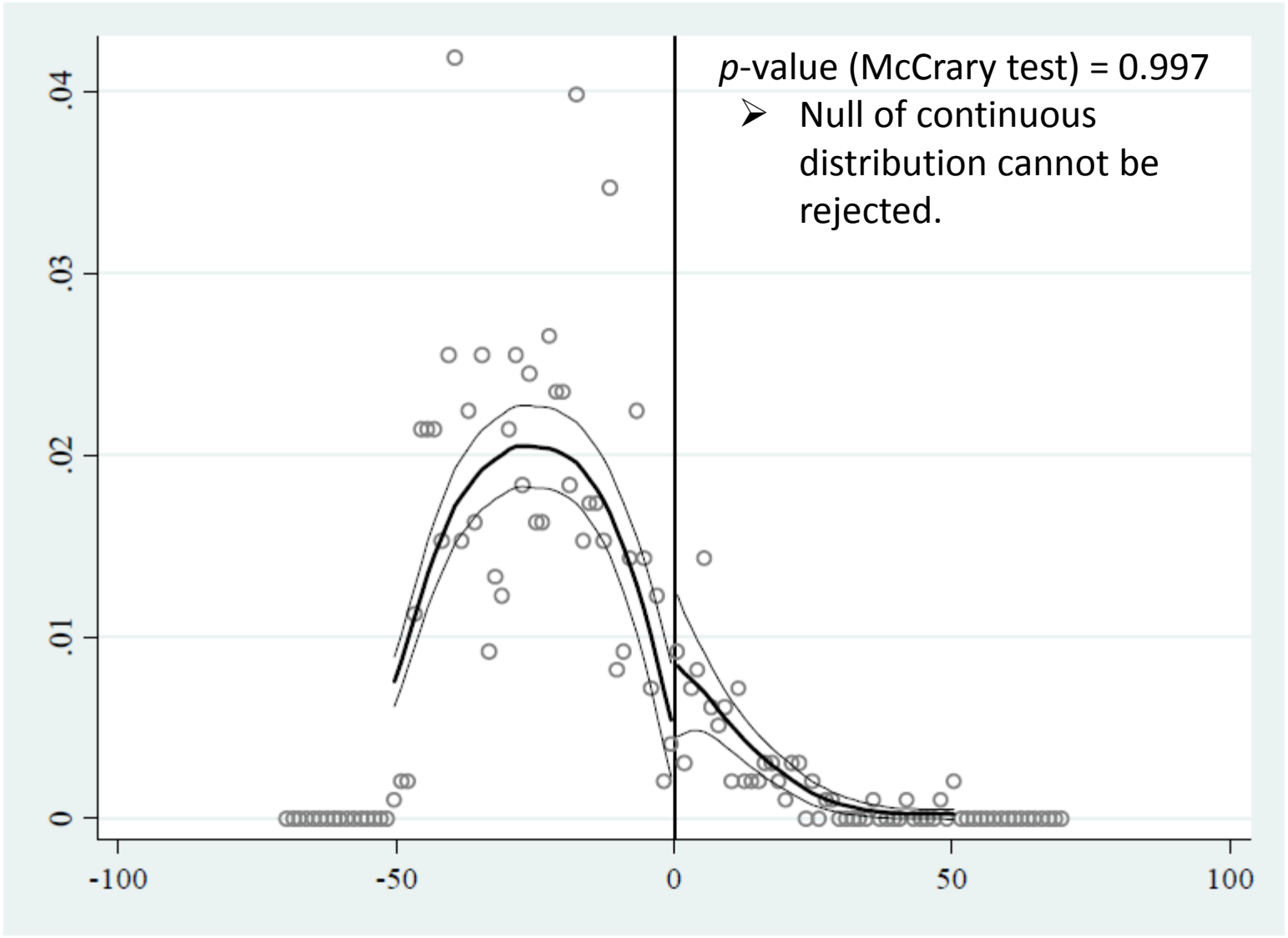
Randomization Tests

- **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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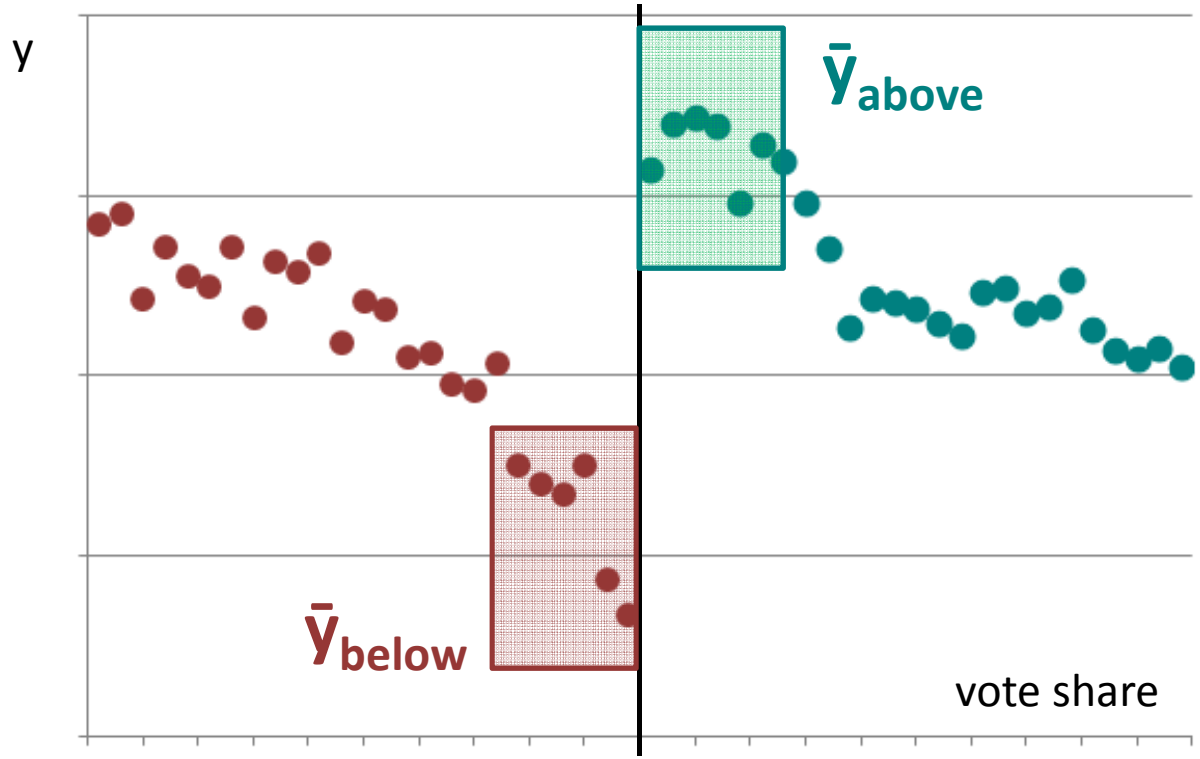
Regression Discontinuity Design (RDD)

Objective: measure difference in outcome variable y around threshold.



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

Regression Discontinuity Design (RDD)

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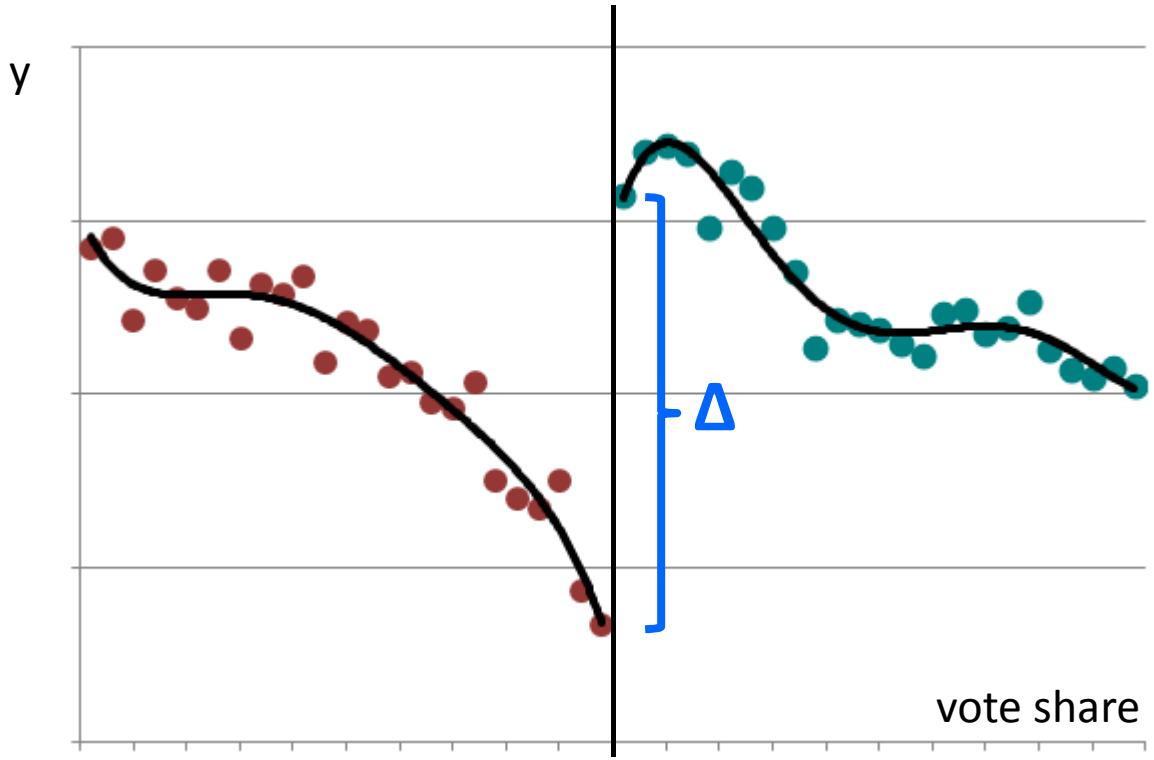
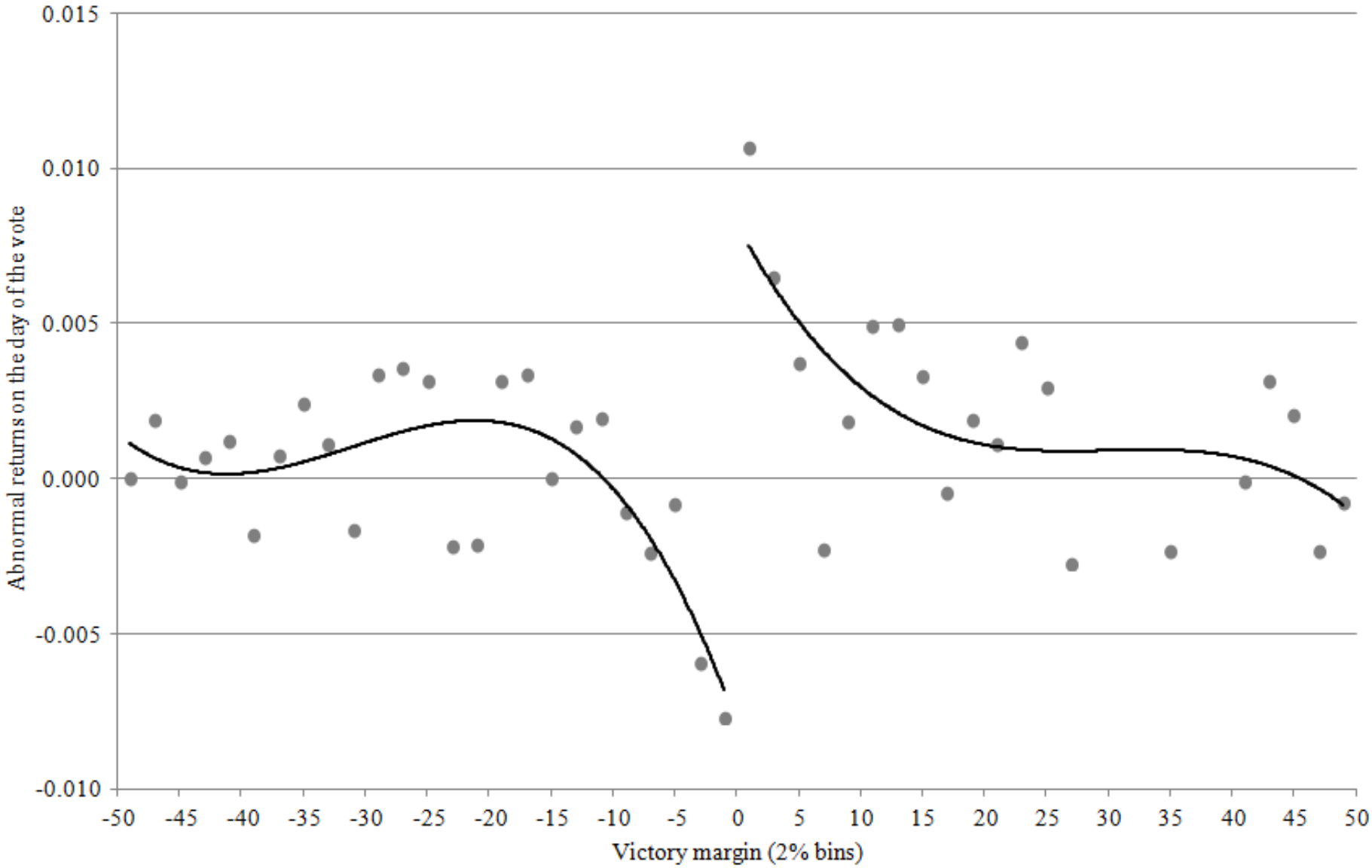


Regression Discontinuity Design

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

- 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.
- ε_{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!