Risk Management and Rating Segmentation in Credit Markets

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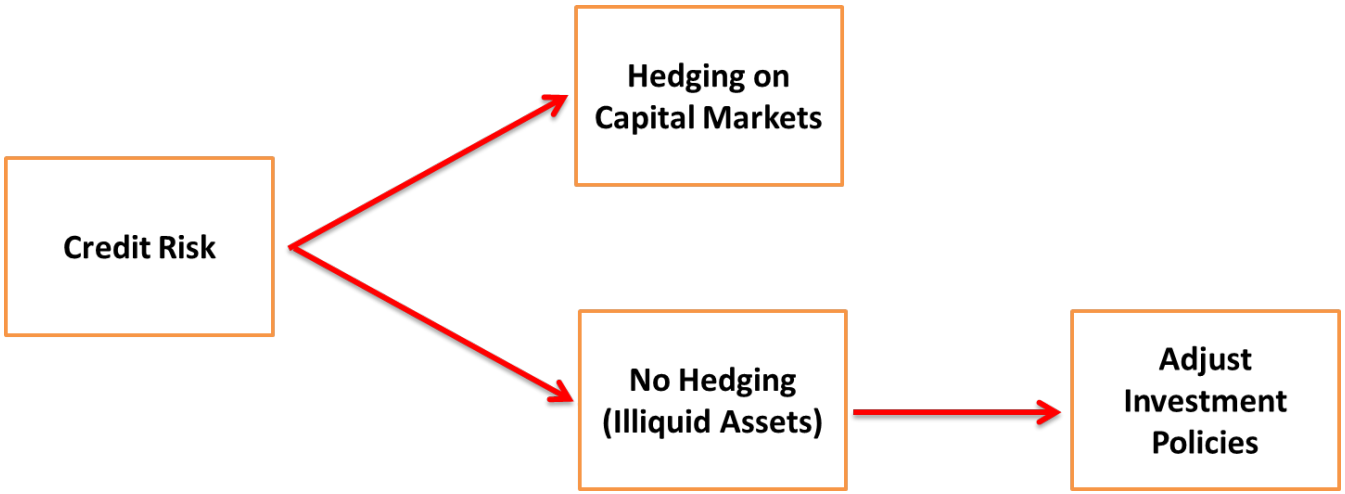
Risk Management

Defintion (Froot and Stein, 98): how banks control exposure to risk.



Therefore banks' risk management linked to:

- Lending policies (price and quantities) to SME firms.
- Efficient allocation of capital in the economy.

What We Do

We study how banks' risk management policies affected lending conditions to Italian SMEs between 2004 and 2011.

How? Exploit a discontinuity design arising in Italian credit markets:

- Allocation of SMEs into performing v. sub-standard categories based on continuous variable.
- Close to threshold: firms "as if" randomly allocated into different rating categories.

Combine with unique central bank data to compare financial contracts of similar firms at the threshold.

Main Results

	2004-2007	2008	2009	2010	2011
Interest Rate	+60 bp	≈ 0	≈ 0	+120 bp	+120 bp
Total Lending	≈ 0	-50 %	-50%	≈ 0	≈ 0
Production					

≈ 0 not significant, $+$ higher for sub-standard, $-$ lower for sub-standard.

Main Results

	2004-2007	2008	2009	2010	2011
INTEREST RATE	+60 bp	≈ 0	≈ 0	+120 bp	+120 bp
TOTAL LENDING	≈ 0	-50 %	-50%	≈ 0	≈ 0
PRODUCTION	≈ 0	-50%	-50%	-40%	≈ 0

≈ 0 not significant, $+$ higher for sub-standard, $-$ lower for sub-standard.

▸ Literature

Institutional and Empirical Framework

Institutional Framework

Italy: risk management wrt SMEs based on rating by *CEBI*:

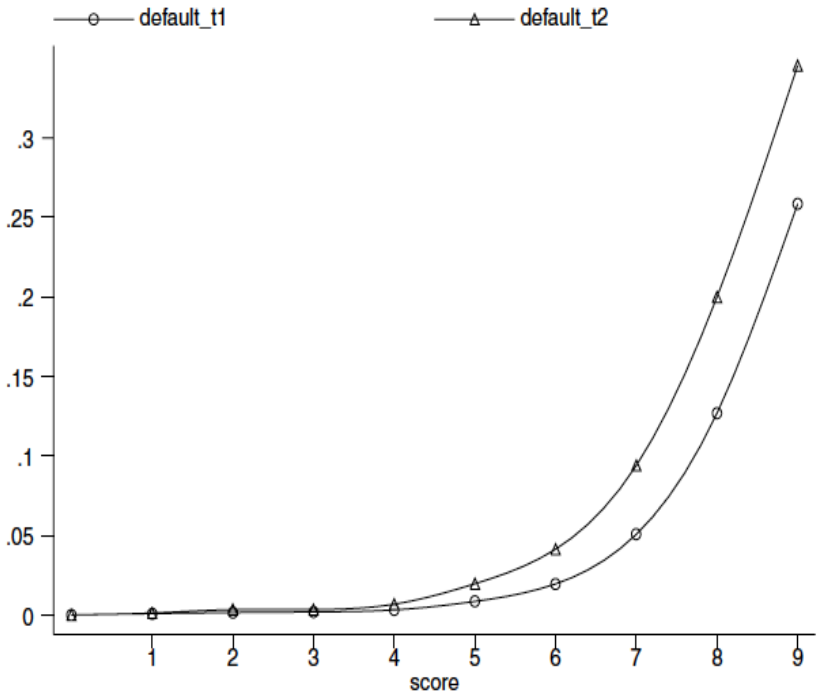
- Founded in 1983 jointly by Central Bank and Banking Association
- Centralize collection of balance sheets and compute rating.

Construction of rating:

- Multiple discriminant analyses of financial ratios (Altman (1968))
- Two step algorithm that produces continuous variables
- Continuous variables and thresholds determine assignment to 9 rating categories

▸ History of *CEBI* ▸ EL Formula ▸ Basel II

Characteristics of the Score Variable



▸ Figures Rating

Loan Officer Decision

What does loan officer observe?

Analisi del Rischio al 31/12/2006					
Categoria	6 - Vulnerabilità elevata	**Score F1**	-1,88	**Score F2**	0,26
	dettagli				

Schema: Società INDUSTRIALI - Importi espressi in MIGLIAIA DI EURO

- Both continuous and categorical value of *Score*
- However, loan officer receives lending limits per *Score* categories.

▸ Unicredit (2008) ▸ Risk Mgmt

Score Continuous and Categorical Value

Rating segmentation of firms into:

- *Score* between 1 and 6 $\rightarrow$ performing
- *Score* between 7 and 9 $\rightarrow$ sub-standard

Identification strategy exploits switch between performing and sub-standard:

- Range: $[-.75, 1.35]$
- Sharp assignment mechanism:

$$S = \begin{cases} 6 & \text{if} \quad 0 \leq s_i < 1.35 \\ 7 & \text{if} \quad -.75 \leq s_i < 0 \end{cases}$$

RDD Estimation

Estimate the jump in outcomes directly at the threshold:

$$y_i = \alpha + \beta S_i + f(s_i - \bar{s}) + S_i \cdot g(s_i - \bar{s}) + u_i \tag{1}$$

- y_i bank financing outcome for firm i
- S_i indicator taking value of 1 if $s_i \geq 0$ (*Score* is 6) and 0 if $s_i < 0$ (*Score* is 7)
- $f(\cdot)$ and $g(\cdot)$ are polynomials above and below the threshold
- β is the difference in intercepts at the threshold point

Identifying Ass.: local continuity of $E(u_i|s_i)$

RDD Interpretation

Implications of identifying assumption :

1. No manipulation — Mc Crary
2. Random sampling — balancing checks
3. Relevance of the threshold — placebo thresholds

Bonus: a panel RDD approach! ▸ First Differences RDD ▸ Fuzzy Panel RDD

Manipulation

Can firms select into better categories?

1. Rating unsolicited and secret algorithm.
2. Score in year t depends on balance sheet in year $t-1$.
3. Thresholds industry-specific and determined by ≈ 15 variables.

If manipulation, *systematic* discontinuity of firms' distribution at the threshold:

- Kernel local linear regression of log density $f(\cdot)$ on both sides of threshold
- Estimate:

$$\hat{\theta} = ln\hat{f}^{+} - ln\hat{f}^{-}$$

Mc Crary Self-Selection Test

Period	2004	2005	2006	2007	2008	2009	2010	2011
Mc Crary Density Estimate	.10 (.06)	.13 (.07)	.02 (.07)	.08 (.06)	.3*** (.07)	-.00 (.08)	.08 (.10)	.17 (.10)
N	5951	5876	6098	6514	5551	5360	4307	4110

▸ Figures McCrary

Manipulation

Exploit important feature of *Score*: resampling

- Rating computed on the basis of the yearly balance sheets.
- Share of new firms in the sample ranges between 46% and 51% of the same year's sample.

Why is this important?

1. No "attrition" in each CS.
2. If manipulation: no firm enters the sample just below the threshold.

▸ Figures Inflow

Data

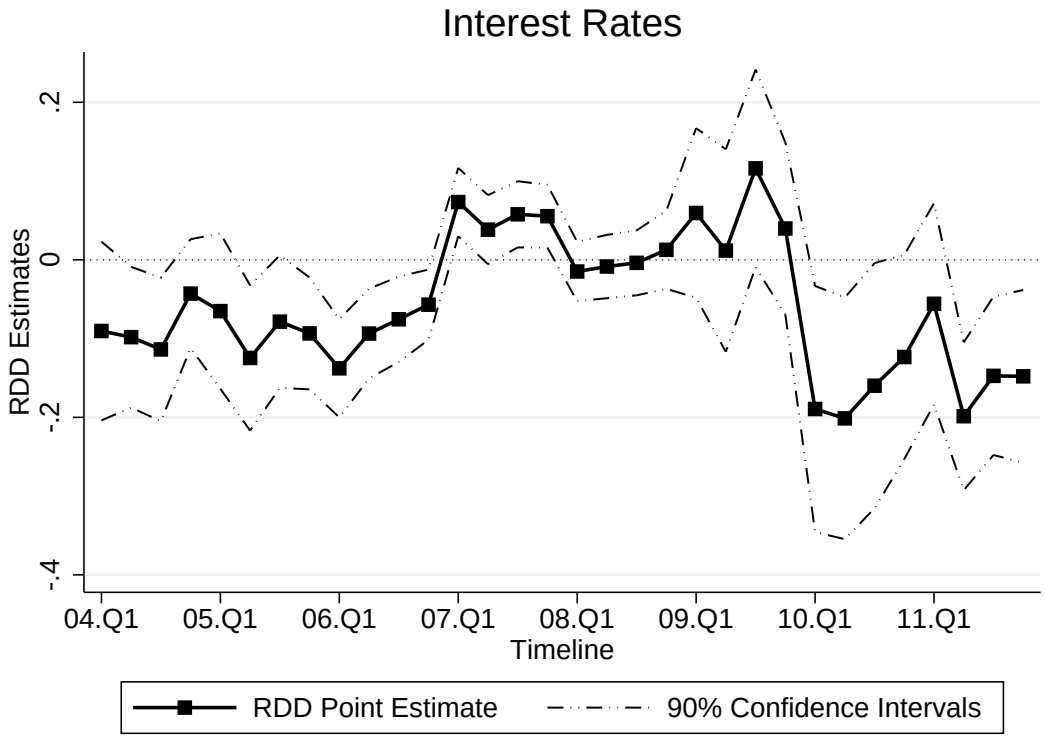
	All	Performing	Sub-Standard
Term Loans: Interest Rate	4.57 (1.62)	4.32 (1.56)	5.3 (1.6)
N	253502	188026	65475
All Bank Financing Granted	8503 (37200)	9237 (40600)	6167 (23100)
N	543855	414041	129754

Source: financial contracts from Italian central bank's credit registry for manufacturing firms.

▸ Detailled Descriptive Statistics

Results

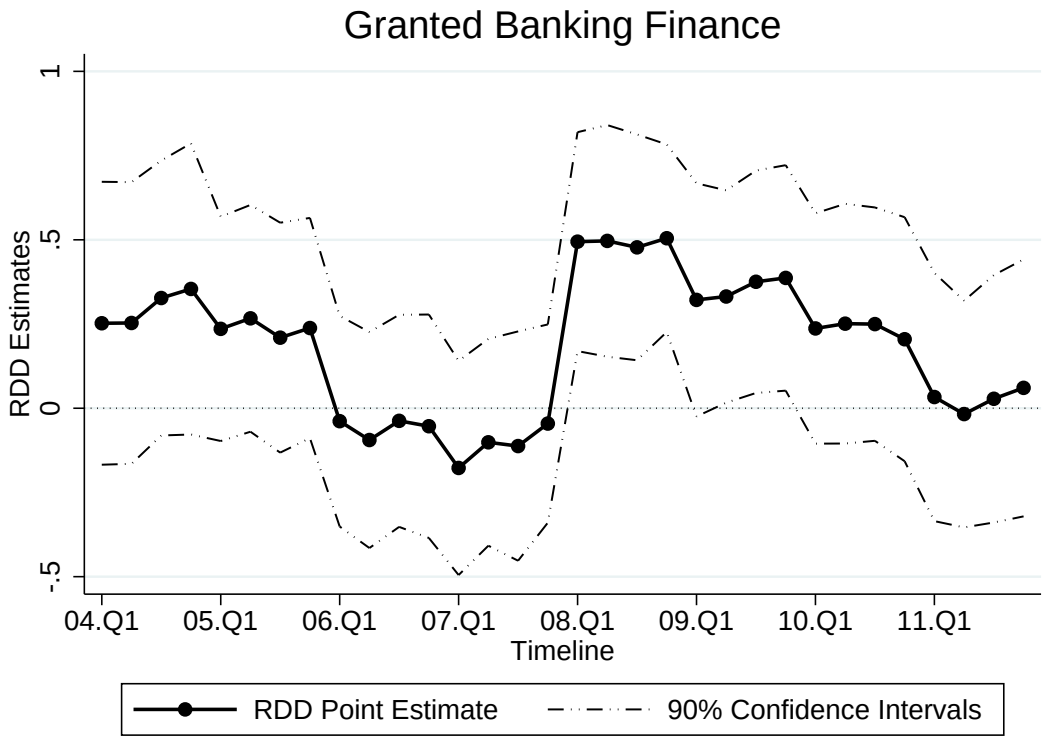
Interest Rates Across Time



2004-2007: firms in the sub-standard category are charged up to 10% higher interest rates than similar firms in the performing category.

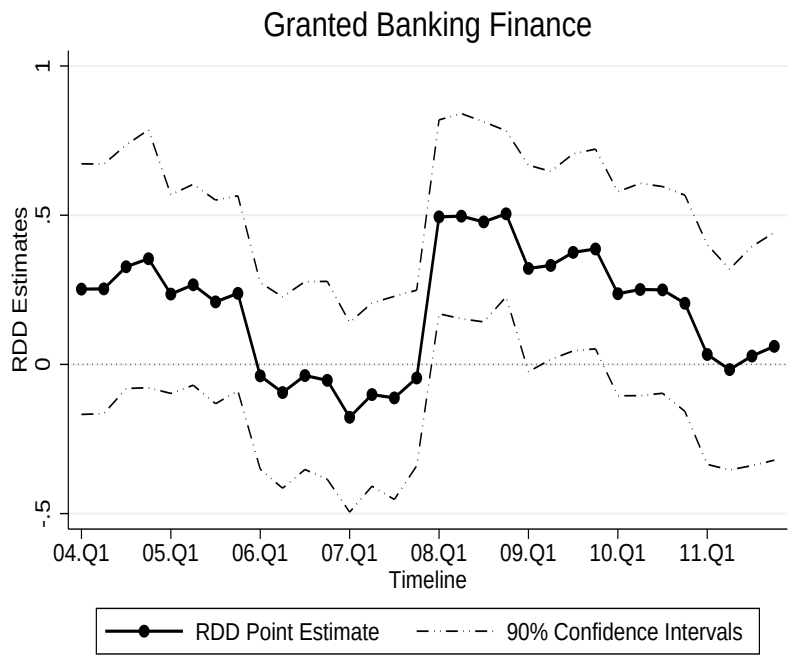
2010-2011: spread rises to 20%.

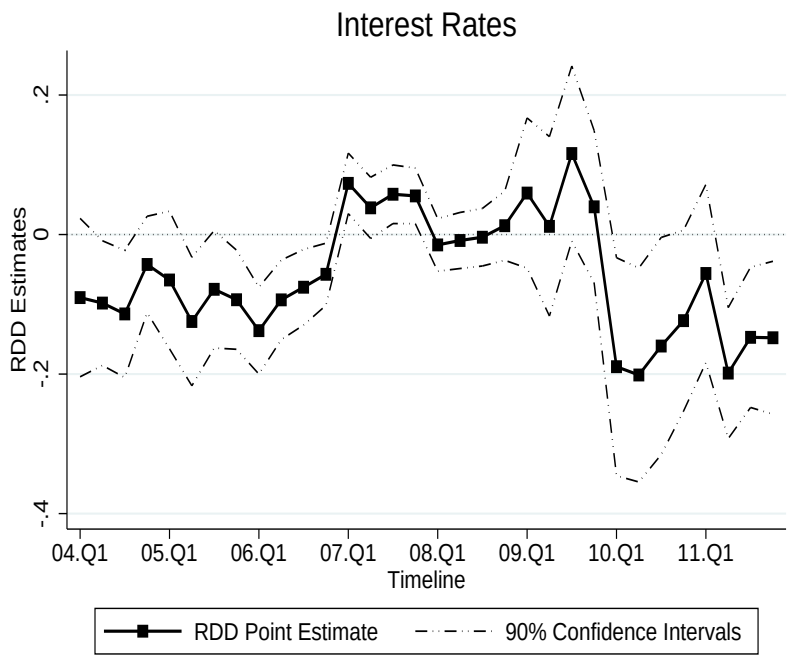
Quantity Across Time



2008-2009: firms in the sub-standard category obtain between 50% to 60% less credit than similar firms in the performing category

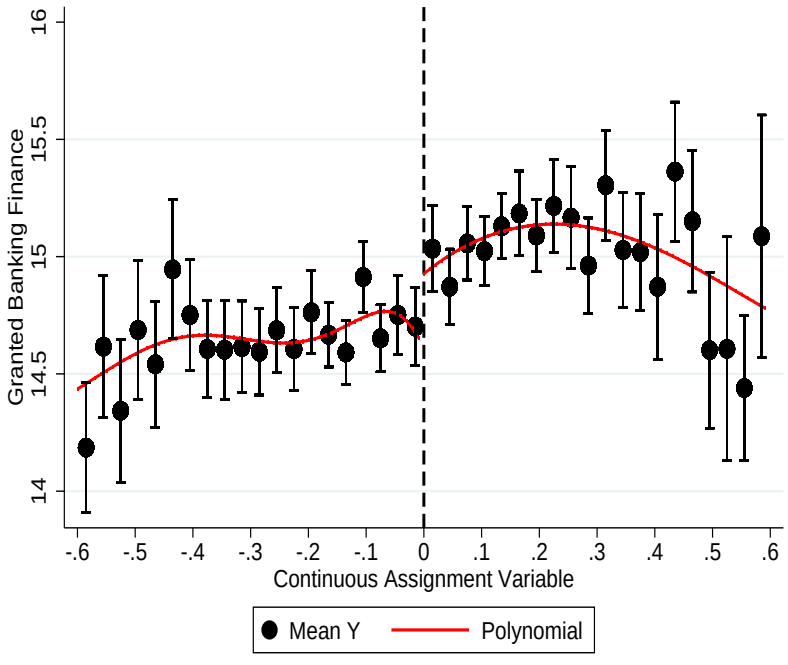
Quantities and Interest Rates Across Time

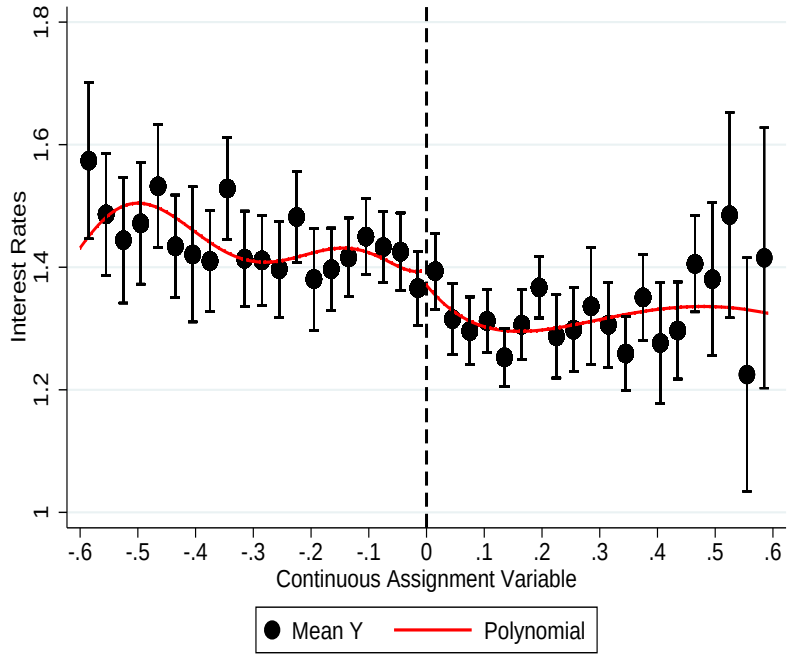




▸ Table ▸ Balancing Tests

Quantities and Interest Rates in Q2.2009

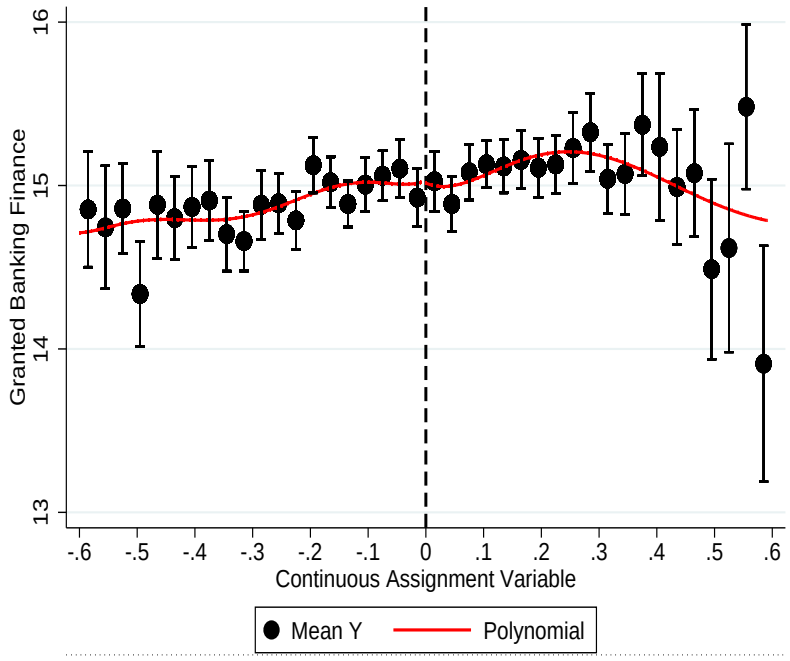


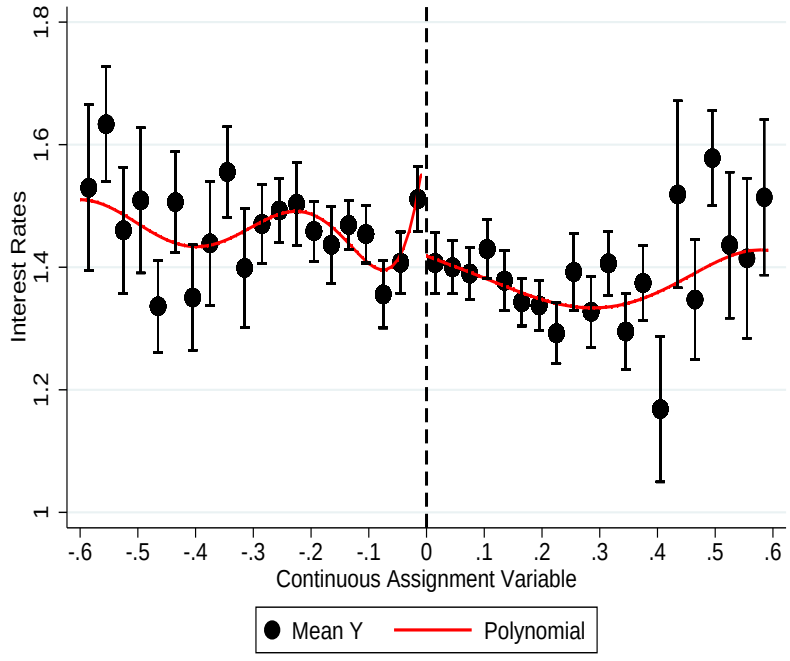


Plot: conditional regression function (bin of 0.03) and polynomial fit.

▸ More

Quantities and Interest Rates in Q2.2011

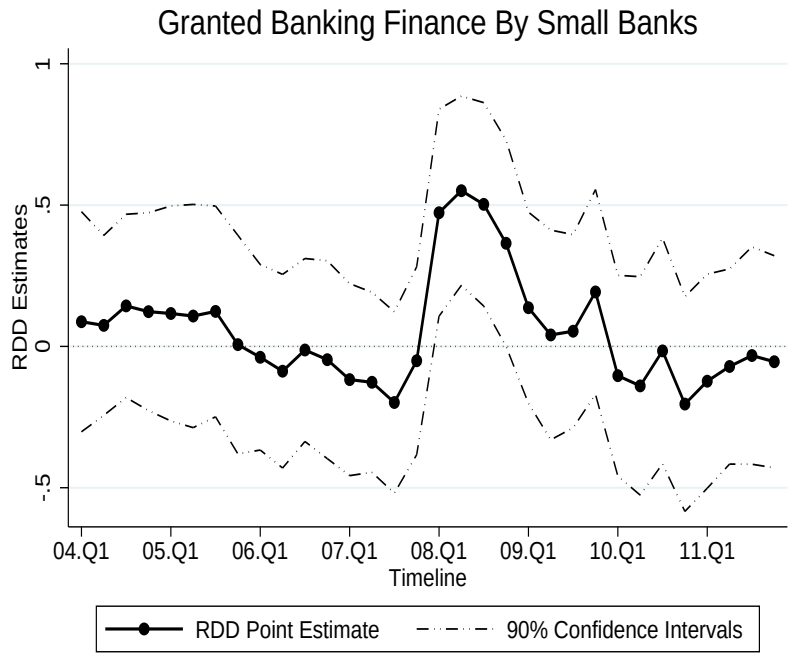


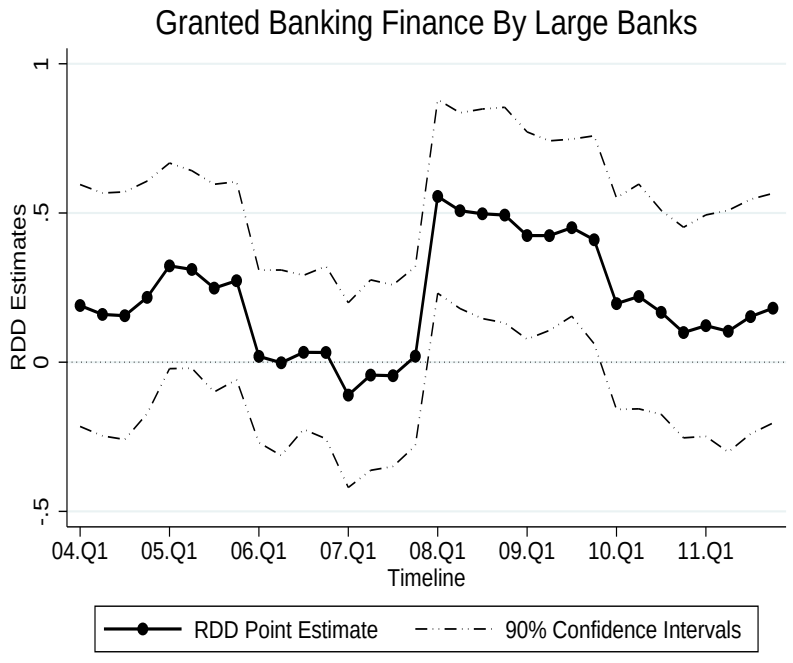


Plot: conditional regression function (bin of 0.03) and polynomial fit.

▸ More

Large and Small Banks Across Time





Real Effects

Period	2004	2005	2006	2007	2008	2009	2010	2011
Production	.21	.22	.23	.07	.51***	.42**	.40**	.13
	(.21)	(.18)	(.17)	(.17)	(.18)	(.18)	(.20)	(.21)
Investment	.31	.19	-.28	.43	.71**	.19	-.01	.2
	(.30)	(.30)	(.28)	(.31)	(.32)	(.32)	(.32)	(.35)
Intermediates	.15	.23	.15	.00	.54***	.29	.38*	.06
	(.22)	(.19)	(.18)	(.18)	(.19)	(.19)	(.21)	(.22)
Employment	-.01	-.14	.04	.14	.25	-.09	.4*	-.23
	(.22)	(.20)	(.19)	(.17)	(.22)	(.25)	(.23)	(.27)

2008-2010: firms in the sub-standard category sell up to 60% less than firms in the performing category.

Conclusions

- We identify the time-varying relationship between banks' risk management policies and credit conditions, exploiting rating segmentation.
- We find that comparable firms in the sub-standard and performing risk classes receive different credit conditions.
- Harsh differences in credit conditions give rise to significant differences in firms' expenditure in investment, employment and intermediates, thus causing firms to reduce production.

Unicredit Annual Report

A.2.2 Balance-sheet and off-balance sheet exposure by internal rating class (book values)

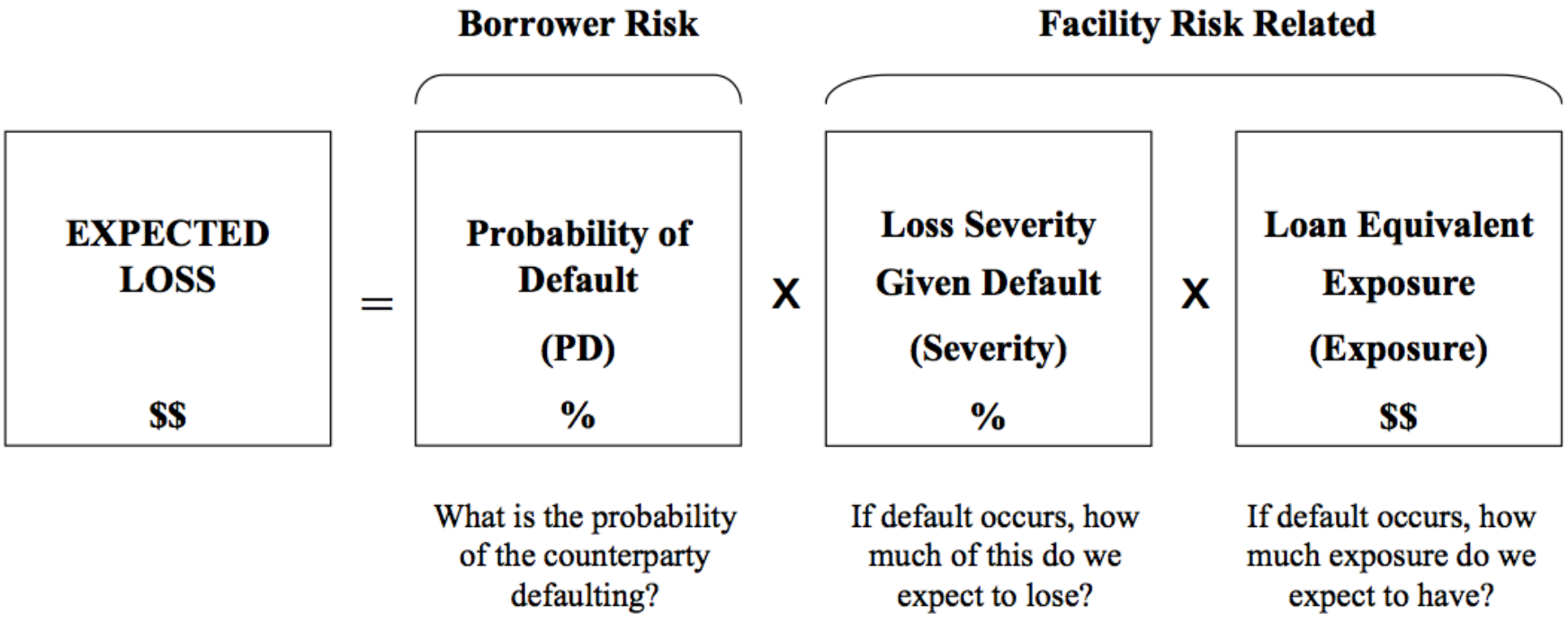
EXPOSURES	INTERNAL RATING CLASSES 1	2	3	4	5	6
A. On-balance-sheet exposures	126,021,087	4,633,994	2,817,825	658,281	221,906	15,531,788
B. Derivative contracts	2,823,785	286,258	42,845	1,876	-	3,388
B.1 Financial derivative contracts	2,823,737	286,258	42,845	1,876	-	3,388
B.2 Credit derivatives	48	-	-	-	-	-
C. Guarantees given	38,789,792	1,404,816	102,484	554,109	802,610	2,633,261
D. Otfher commitments to disburse funds	3,226,127	28,345	115,695	26,102	18,195	425,750
Total	170,860,791	6,353,413	3,078,849	1,240,368	1,042,711	18,594,187

A.2.2 Balance-sheet and off-balance sheet exposure by internal rating class (book values) continued

EXPOSURES	INTERNAL RATING CLASSES 7	8	9	10	IMPAIRED ASSETS	NO RATING	TOTAL
A. On-balance-sheet exposures	129,694	29,120	270,597	15,006	1,338,373	44,204,140	195,871,811
B. Derivative contracts	-	-	-	-	-	1,458,205	4,616,357
B.1 Financial derivative contracts	-	-	-	-	-	1,246,407	4,404,511
B.2 Credit derivatives	-	-	-	-	-	211,798	211,846
C. Guarantees given	916,725	127,966	429,707	7,907	133,191	4,960,386	50,862,954
D. Otfher commitments to disburse funds	110,749	8,707	-	-	-	4,185,278	8,144,948
Total	1,157,168	165,793	700,304	22,913	1,471,564	54,808,009	259,496,070

Back

Expected Loss Components



Back

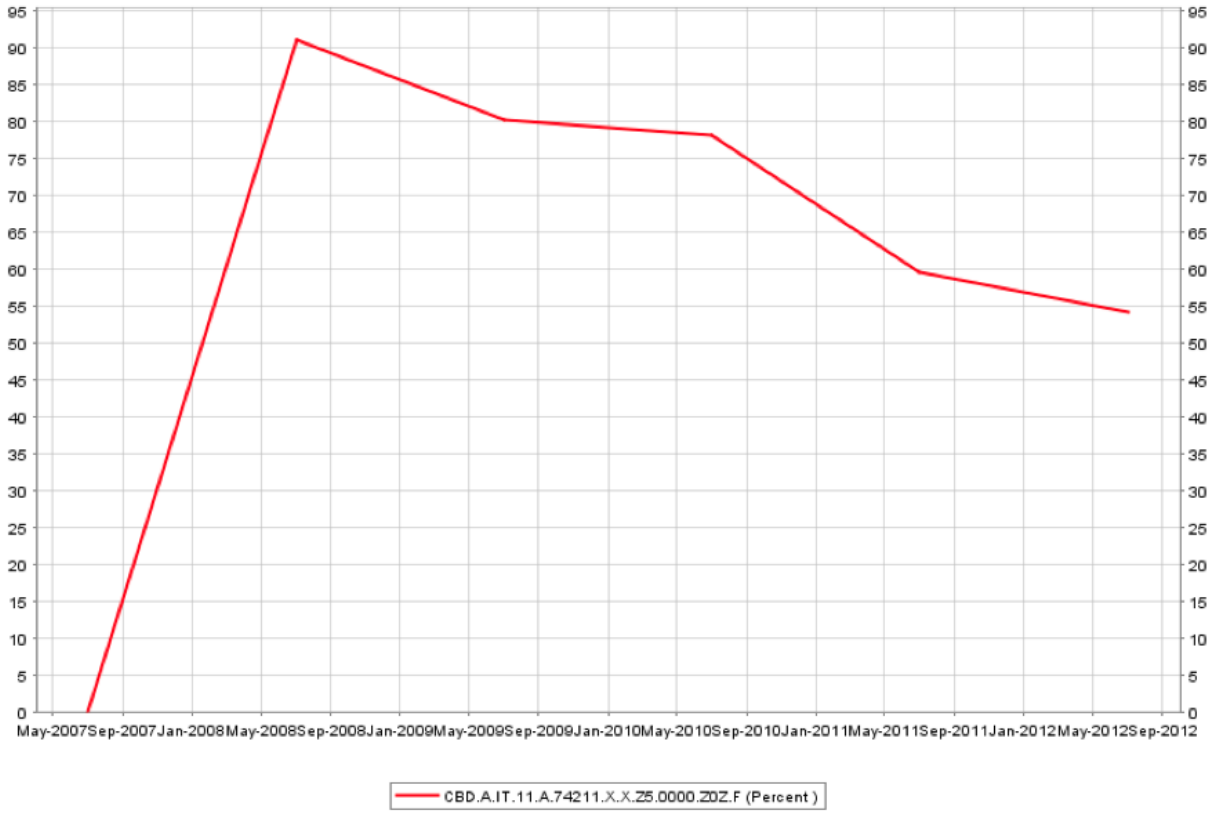
Basel II

- Basel II accord allows banks to use risk weights that depend on the credit quality of a counterpart
- Weights determined by rating systems developed externally (standardized approach) or internally (Internal Rating-Based approach)
- Standard approach (from early 2008): loans to SMEs were applied a 75% risk weight, rather than the 100% weight in Basel I
- SMEs likely to receive more lending under Basel II than under Basel I (Altman (2003))

Back

Standardized Approach by Italian Banks

Total capital requirements for credit risks - Standardised Approach (% of capital)



Back

Score and S&P's

	CREDIT GRADES	RISK LEVEL	PD (bp)	S&P
Performing	1	Minimal	0-1	AAA
	2	Modest	2-4	AA
	3	Average	5-10	A
	4	Acceptable	11-50	BBB
	5	Acceptable with care	51-200	BB
	6	Management Attention	201-1000	B
Substandard	7	Special Mention	1000+	CCC
	8	Substandard	Interest Suspense	CCC / CC
	9	Doubtful	Provision	CC / C
	10	Loss	Default / Loss	D

Back

Literature

Segmentation in financial markets: Kisgen (2007), Kisgen and Strahan (2010), Ellul, Jotikasthira, and Lundblad (2011), Chernenko and Sunderam (2012), Bruin, Fraisse and Thesmar (2013), Chen, Lookman, Schurhoff, and Seppi (2013)

=> We exploit rating segmentation driven by risk management policies

=> We find evidence of time-varying impact of risk management policies on SMEs' credit conditions and real decisions

Risk management practices: Smith and Stulz (1985) on corporate hedging decisions, Froot and Stein (1998) on financial intermediaries

=> We study banks' risk management policies in good and bad times

Back

Risk Management

What is management of credit risk?

- Amount and interest rate on loan(s) to a firm in a certain rating category
- Important: accounts for 70% of bank capital allocation (Altman (2003))
- Top mgmt decides yearly lending limits based credit ratings (Degryse, Ioannidou and von Schedvin (2012)).

Why segmentation?

1. Value of credit rating determines probability of default, thus Expected Loss (EL)
2. Investors observe banks' exposure into credit rating classes

Back

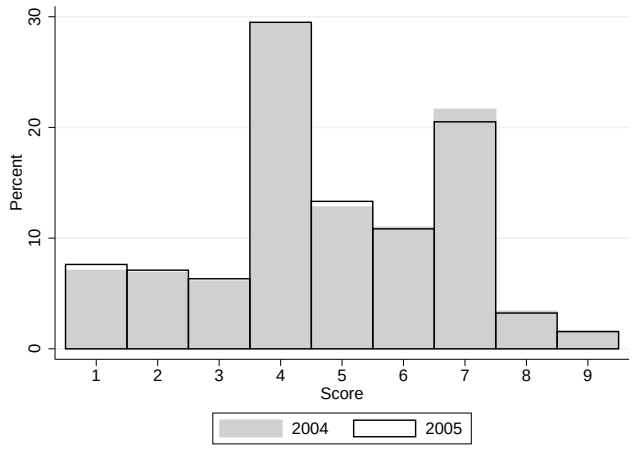
The *CEBI* System

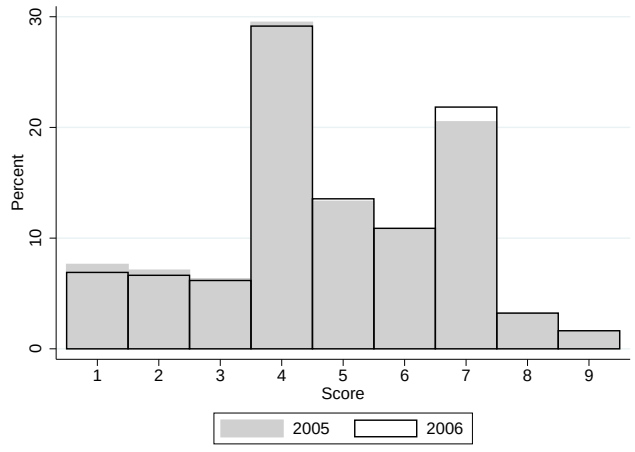
- Founded in 1983 jointly by Central Bank and Banking Association
- Objective to record and process firms' financial statements and risk-assessment tool of SME credit risk, or *Score*
- In 2004, 73% credit granted to SMEs using *Score*
- Anecdotal evidence, Banca Popolare di Vicenza (2005):

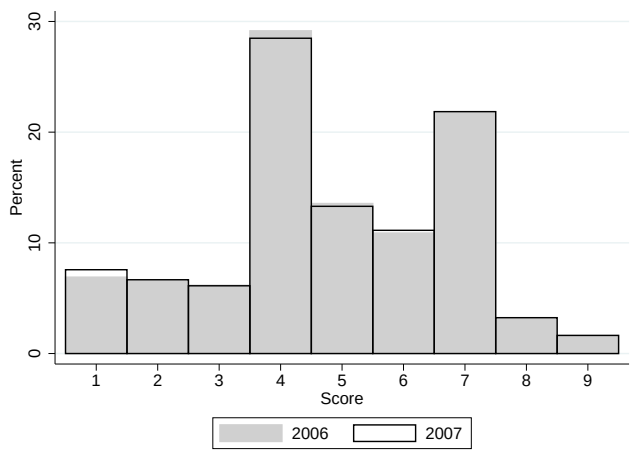
> *"CEBI is the leading provider of risk management tools to the quasi totality of Italian credit institutions."*

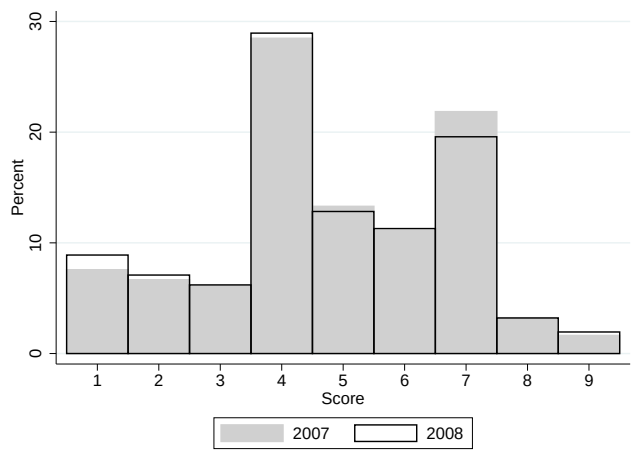
Back

Rating Distribution Across Time

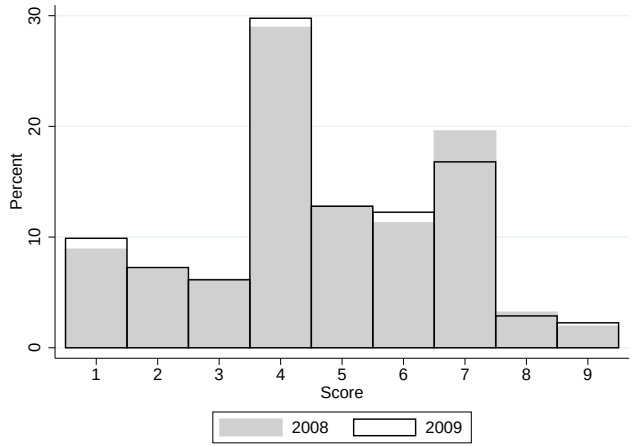


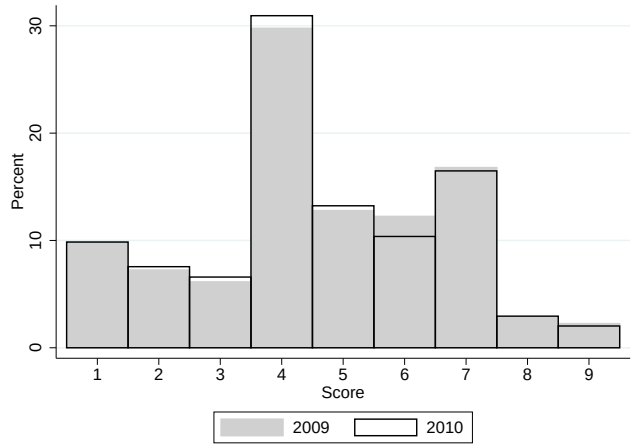


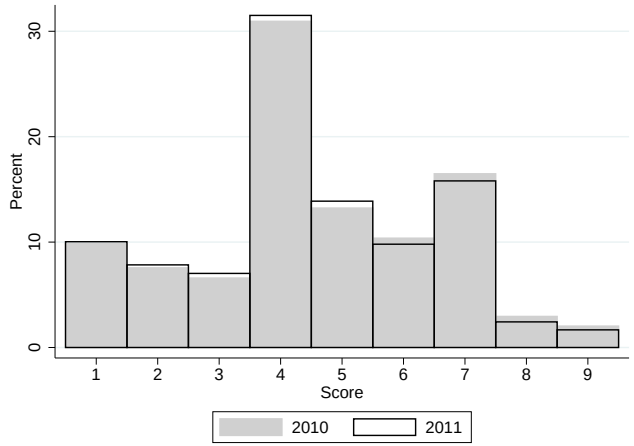




Rating Distribution Across Time

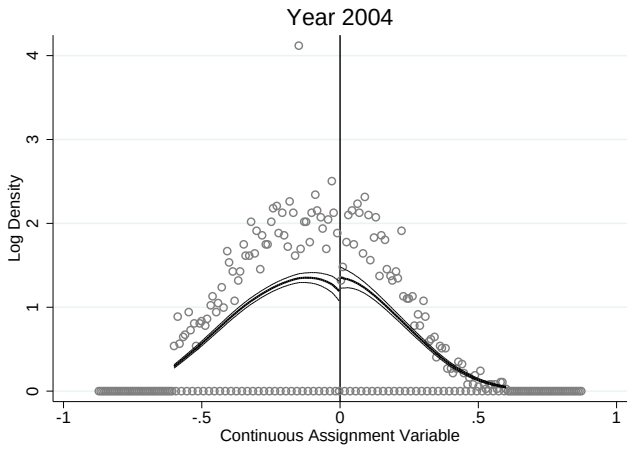


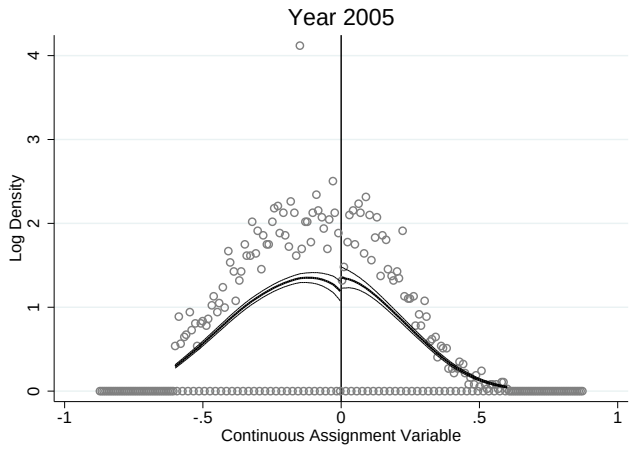


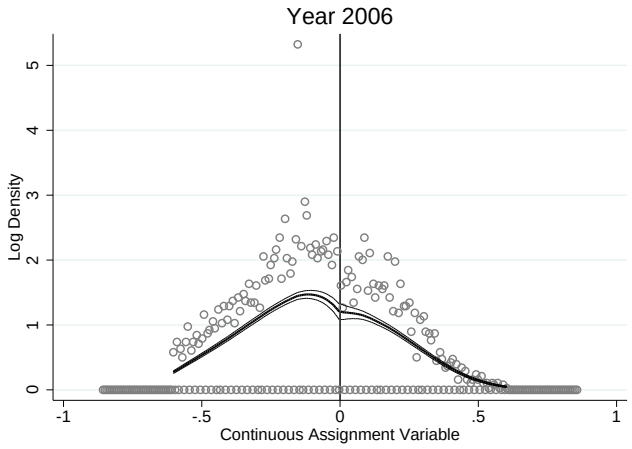


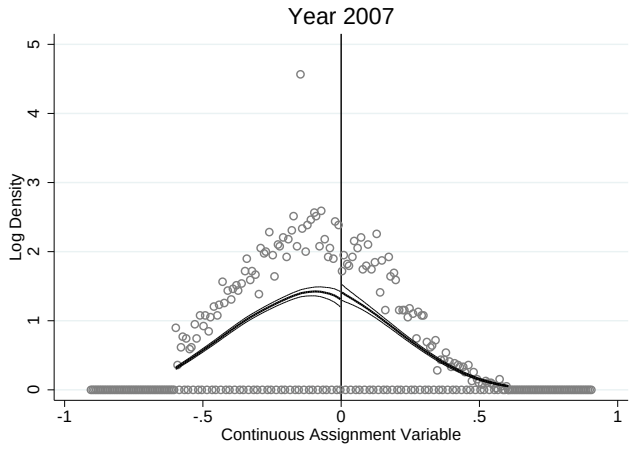
Back

Mc Crary Self-Selection Test

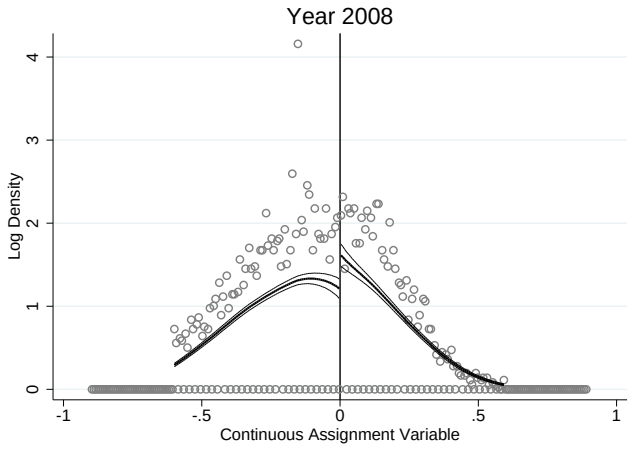


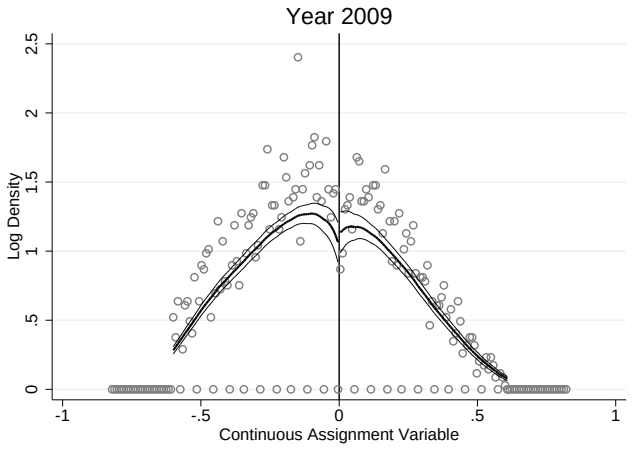


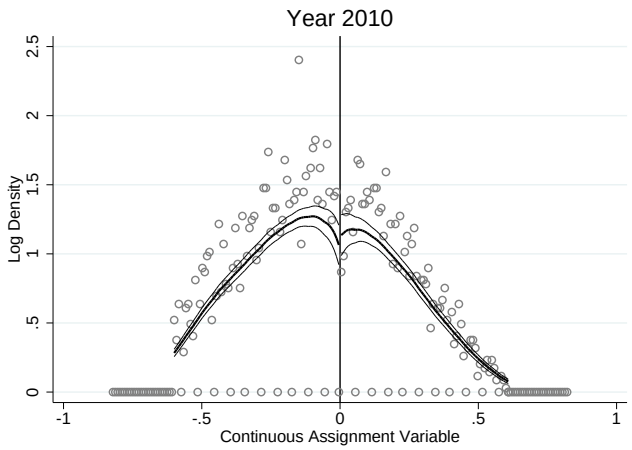


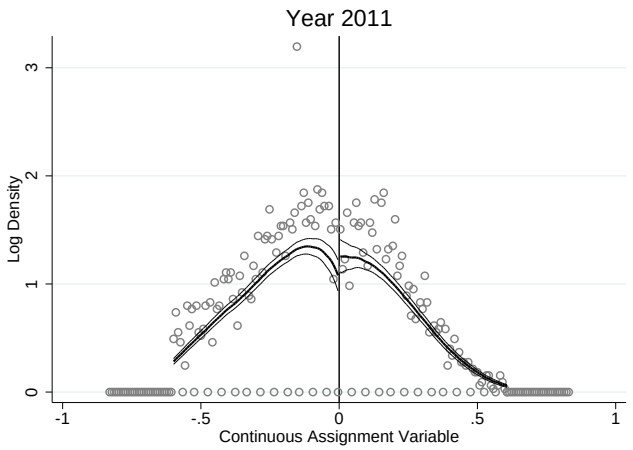


Mc Crary Self-Selection Test









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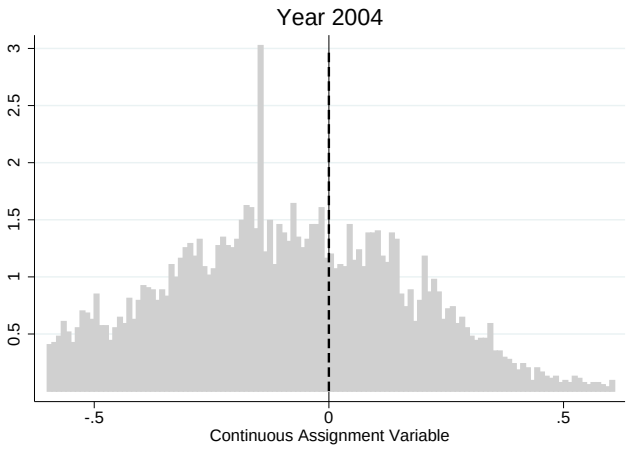
Resampling


Year 2004
0.5
1
1.5
2
2.5
3
-.5
0
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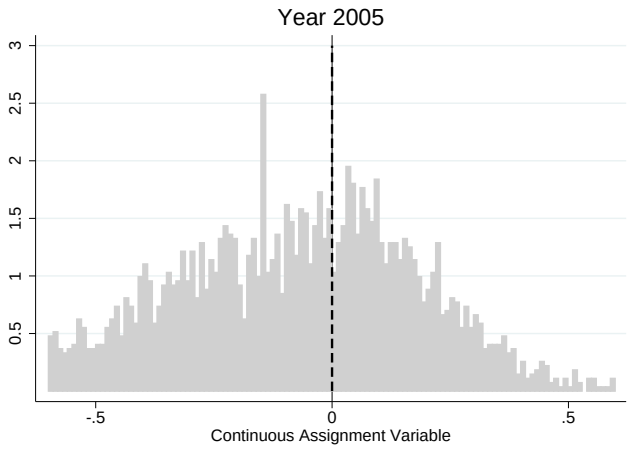
Continuous Assignment Variable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2
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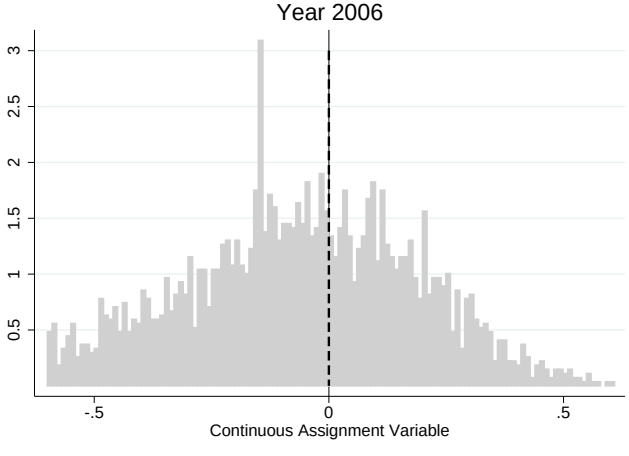
Continuous Assignment Variable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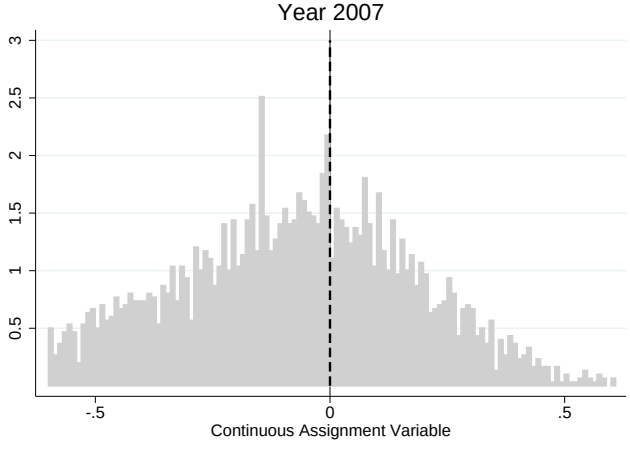
2
2.5
3
-.5
0
.5
Continuous Assignment Variable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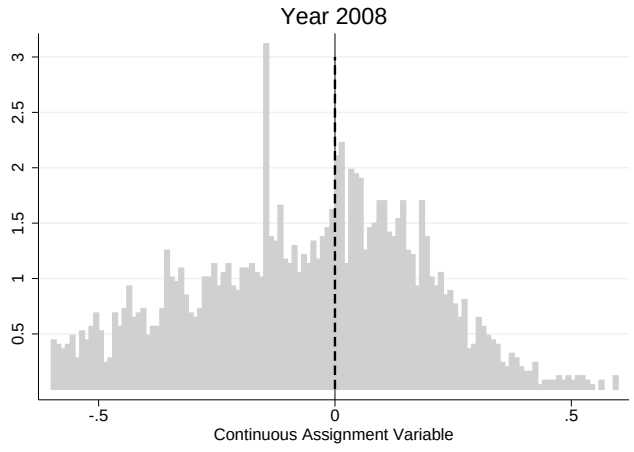
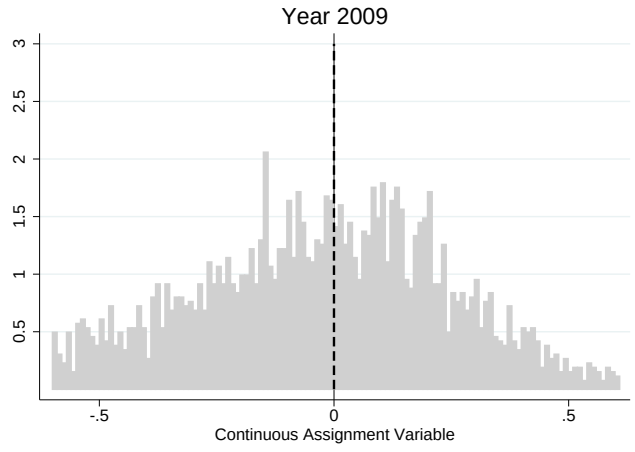
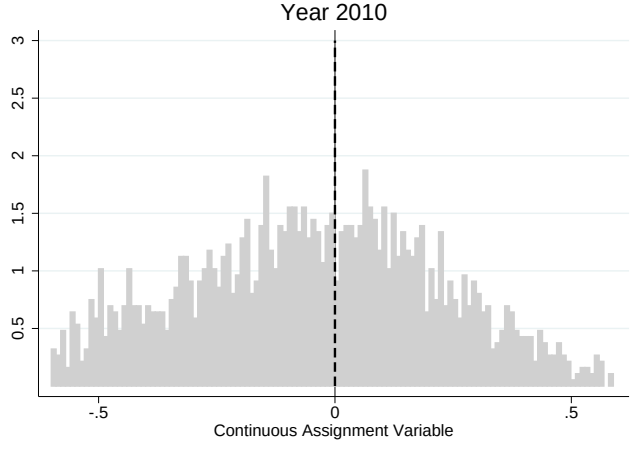
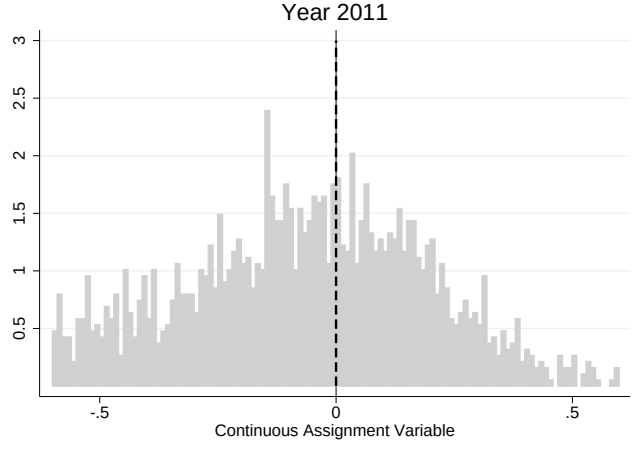
1.5
2
2.5
3
-.5
0
.5
Continuous Assignment Variable

Resampling









Back

Descriptive Statistics — Cross Section

	All	Performing	Sub-Standard	Score 6	Score 7
Employment	92	95	76	73	72
	(294)	(295)	(290)	(170)	(207)
Investment to Assets	.24	.24	.24	.23	.24
	(.23)	(.22)	(.24)	(.23)	(.24)
Return to Assets	.05	.07	.00	.05	.03
	(.10)	(.08)	(.13)	(.07)	(.07)
Leverage	.67	.61	.86	.79	.85
	(.19)	(.18)	(.10)	(.10)	(.09)
N	143953	108353	35600	16432	27350

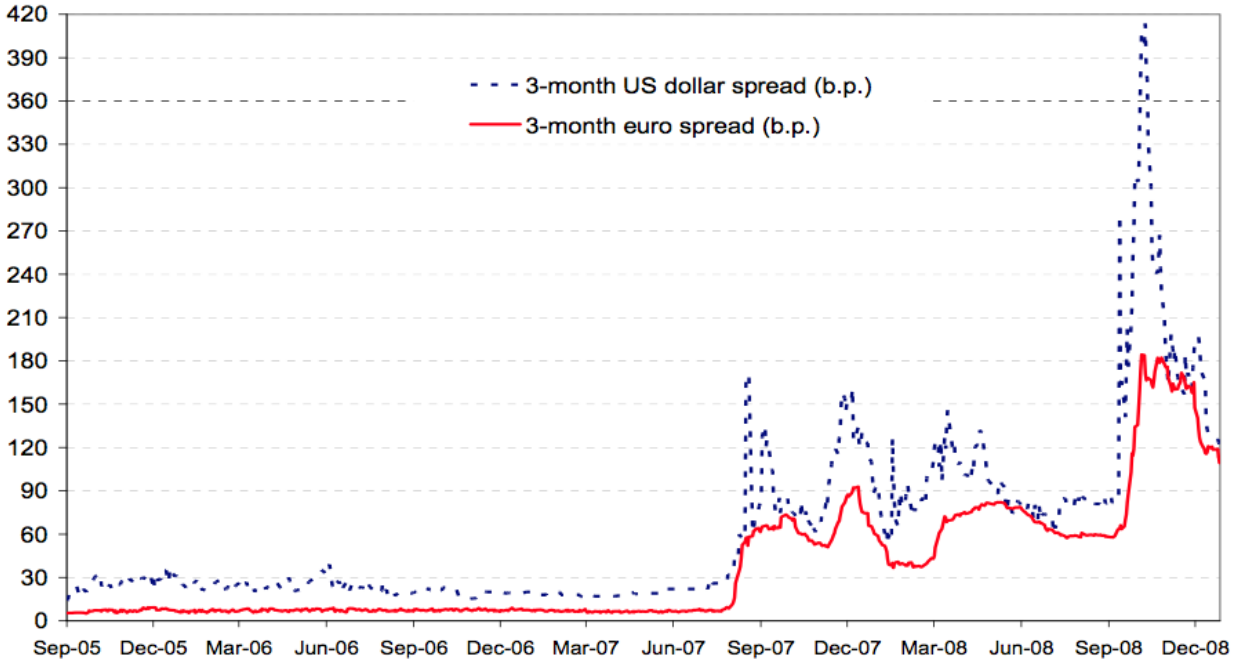
Descriptive Statistics — Cross Section

	All	Performing	Sub-Standard	Score 6	Score 7
Term Loans: Interest Rate	4.57 (1.62)	4.32 (1.56)	5.3 (1.6)	4.79 (1.58)	5.29 (1.59)
Term Loans: Amount	816 (9850)	885 (5156)	617 (17300)	451 (1623)	569 (17700)
Term Loans: Maturity	.66 (.47)	.66 (.47)	.65 (.48)	.73 (.44)	.65 (247)
N	253502	188026	65475	49265	60326

Descriptive Statistics — Cross Section

	All	Performing	Sub-Standard	Score 6	Score 7
All Bank Financing Granted	8503 (37200)	9237 (40600)	6167 (23100)	7542 (24600)	6392 (21100)
Share of Used to Granted Financing	.55 (.27)	.50 (.25)	.74 (.22)	.66 (.20)	.74 (.21)
Share of Term Loans Granted	.35 (.25)	.35 (.25)	.36 (.25)	.33 (.21)	.35 (.25)
Share of Write-downs	.01 (.09)	.01 (.04)	.03 (.17)	.00 (.05)	.01 (.09)
N	543855	414041	129754	63722	104253

Descriptive Statistics Across Time

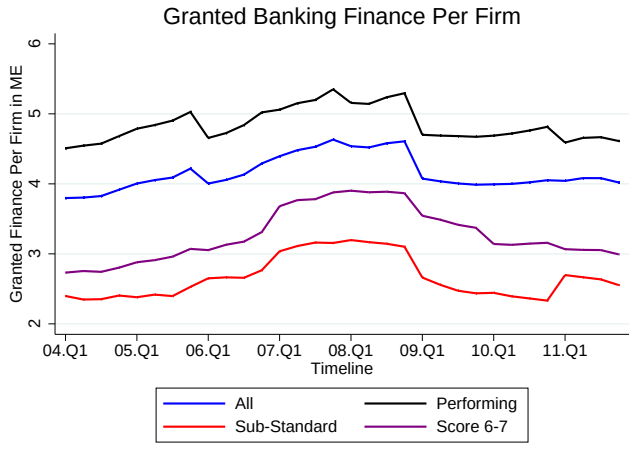


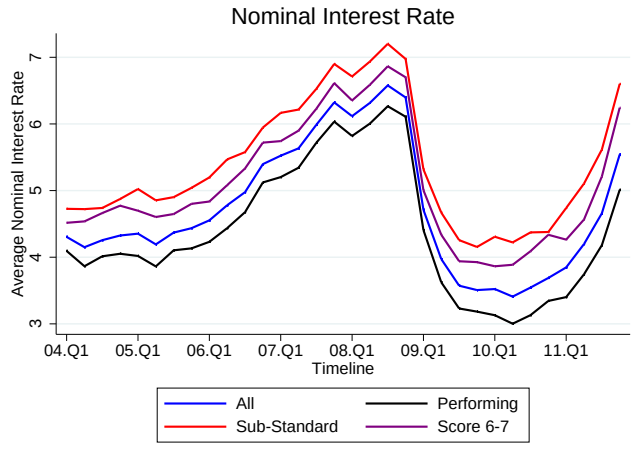
Source: Reuters, Datastream.

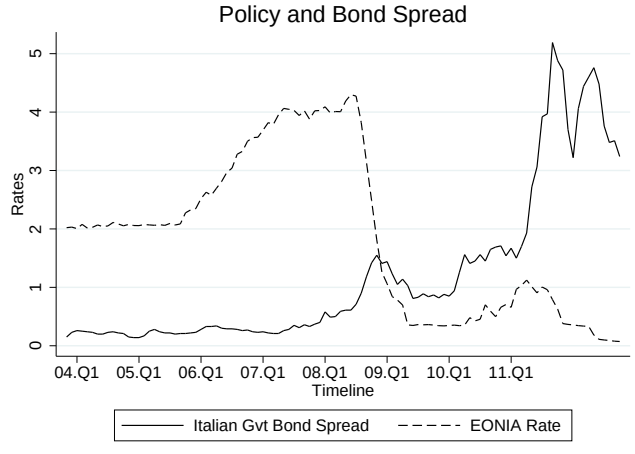
From Angelini, Nobili and Picillo (2009)
Spreads between interest rates on unsecured (EURIBOR) and secured (EUREPO) deposits rises in August 2007

Back

Descriptive Statistics Across Time







Back

Balancing Characteristics Test

Assumption: close to the threshold firms are as if randomly sampled

- If not true: firm characteristics differ systematically across the threshold.
- Estimate:

$$\bar{X}_{i.} = \alpha + \gamma S_i + f(s_i - \bar{s}) + S_i \cdot g(s_i - \bar{s}) + u_i \qquad (2)$$

H0: $\hat{\gamma} \neq 0$

Characteristics $\bar{X}_{i.}$:

- Logically unaffected by the threshold
- But plausibly related to outcome

Balancing Characteristics Test

Period	2004	2005	2006	2007	2008	2009	2010	2011
Activity: Automobile Industry	.01	.015	.00	.00	-.03	.00	.01	-.02
	(.02)	(.02)	(.01)	(.00)	(.03)	(.02)	(.02)	(.02)
Pooled Mean	.02	.02	.02	.02	.02	.02	.02	.02
Activity: Food Industry	.03	-.04	.03	-.01	.05	.04	.06	-.06
	(.04)	(.05)	(.04)	(.04)	(.04)	(.04)	(.06)	(.06)
Pooled Mean	.10	.10	.10	.11	.11	.10	.12	.11
	(.21)	(.19)	(.19)	(.17)	(.23)	(.26)	(.22)	(.25)
N	5951	5876	6098	6514	5551	5360	4307	4110

No statistically and economically significant evidence of clustering of firms into sector of activities (automobile or food industries)

Balancing Characteristics Test

Period	2004	2005	2006	2007	2008	2009	2010	2011
Location: Top 5 Cities	.06	.03	.05	-.06	.02	-.01	.07	.05
	(.06)	(.06)	(.06)	(.06)	(.06)	(.06)	(.08)	(.07)
Pooled Mean	.27	.27	.27	.28	.26	.26	.27	.28
Location: Top 10 Cities	.05	.01	.02	-.04	.02	-.02	.11	.07
	(.07)	(.07)	(.07)	(.07)	(.07)	(.07)	(.09)	(.08)
Pooled Mean	.39	.39	.40	.40	.39	.38	.39	.41
Location: Firm Clusters	.07	.06	.09	.03	.01	.06	.05	.01
	(.07)	(.07)	(.07)	(.06)	(.07)	(.07)	(.08)	(.08)
Pooled Mean	.40	.40	.40	.40	.37	.38	.39	.38
N	5951	5876	6098	6514	5551	5360	4307	4110

No statistically and economically significant evidence of slection in terms of geographical location.

▸ Back

RDD Estimates Table

Period	04.Q1	04.Q2	04.Q3	04.Q4	05.Q1	05.Q2	05.Q3	05.Q4	06.Q1	06.Q2	06.Q3	06.Q4	07.Q1	07.Q2	07.Q3	07.Q4
Quantity	.25	.25	.33	.35	.24	.27	.21	.24	-.04	-.09	-.04	-.05	-.18	-.10	-.11	-.04
	(.24)	(.25)	(.25)	(.26)	(.20)	(.21)	(.19)	(.19)	(.20)	(.18)	(.21)	(.20)	(.20)	(.18)	(.19)	(.19)
R-squared	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.03	.03	.02	.02	.02	.02
N	5614	5621	5621	5599	5601	5608	5604	5605	5822	5822	5815	5829	6224	6230	6237	6234
Price	-.09	-.10**	-.11**	-.04	-.07	-.13***	-.08*	-.09**	-.14***	-.09***	-.07***	-.06**	.07**	.04	.06**	.05**
	(.07)	(.05)	(.06)	(.05)	(.06)	(.05)	(.05)	(.04)	(.04)	(.04)	(.03)	(.03)	(.03)	(.03)	(.03)	(.02)
R-squared	.17	.18	.18	.16	.15	.17	.17	.19	.17	.15	.14	.15	.14	.14	.13	.12
N	1758	1922	2229	3522	3048	3177	3459	4002	3318	3922	4204	5123	4808	4680	4921	5853

Period	08.Q1	08.Q2	08.Q3	08.Q4	09.Q1	09.Q2	09.Q3	09.Q4	10.Q1	10.Q2	10.Q3	10.Q4	11.Q1	11.Q2	11.Q3	11.Q4
Quantity	.49**	.50***	.48***	.51***	.32	.33*	.37*	.39**	.23	.25	.25	.21	.03	-.02	.03	.06
	(.19)	(.18)	(.18)	(.19)	(.21)	(.20)	(.20)	(.20)	(.21)	(.22)	(.22)	(.20)	(.25)	(.22)	(.23)	(.23)
R-squared	.02	.02	.02	.02	.02	.03	.03	.03	.02	.02	.02	.02	.01	.01	.01	.01
N	5328	5323	5330	5316	5108	5106	5102	5093	4105	4104	4102	4098	3955	3952	3942	3943
Price	-.02	-.01	-.00	.01	.06	.01	.11	.04	-.19*	-.20**	-.16*	-.12	-.06	-.20***	-.15***	-.15**
	(.02)	(.02)	(.02)	(.03)	(.06)	(.07)	(.08)	(.07)	(.10)	(.10)	(.09)	(.08)	(.08)	(.06)	(.06)	(.08)
R-squared	.13	.10	.13	.12	.09	.07	.08	.09	.08	.11	.10	.13	.14	.15	.13	.10
N	3845	3633	3431	3466	2918	2884	2783	3407	2542	2762	2911	3299	3019	2957	3120	2699

Back

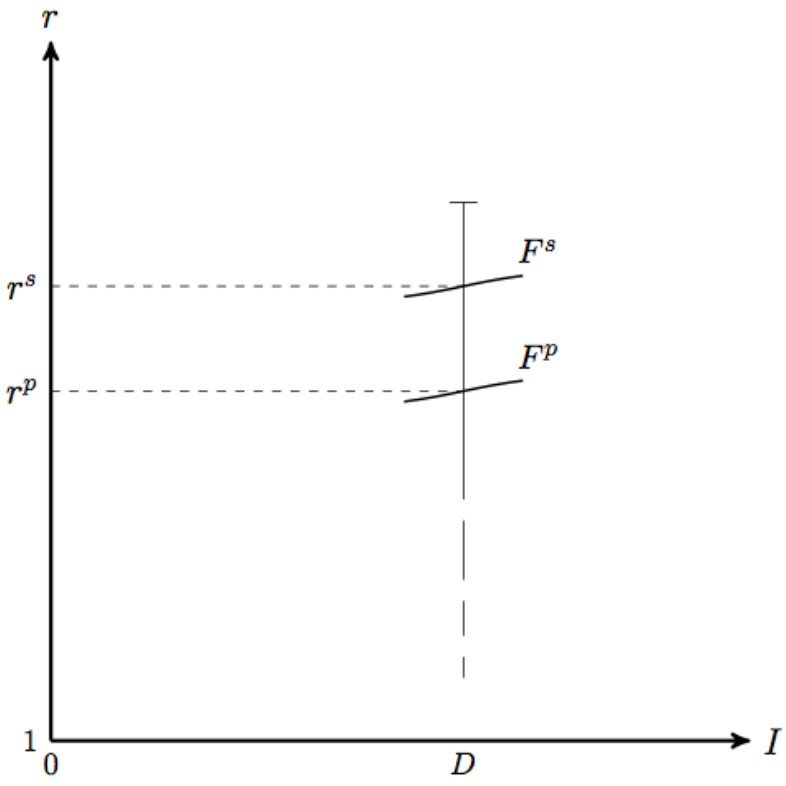
RDD Estimates Table — Collateral And Late

Period	04.Q1	04.Q2	04.Q3	04.Q4	05.Q1	05.Q2	05.Q3	05.Q4	06.Q1	06.Q2	06.Q3	06.Q4	07.Q1	07.Q2	07.Q3	07.Q4
Guaranteed Loans	.63	.88	.55	.47	.00	.03	-.03	-.61	-.00	-.25	-.45	-.76	-.55	-.16	-.27	-.23
	(.93)	(.95)	(.93)	(1)	(.97)	(.94)	(.97)	(1.04)	(.85)	(.84)	(.85)	(.74)	(.91)	(.79)	(1)	(.83)
R-squared	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
N	5653	5661	5662	5647	5629	5643	5639	5642	5854	5854	5845	5861	6528	6267	6280	6279

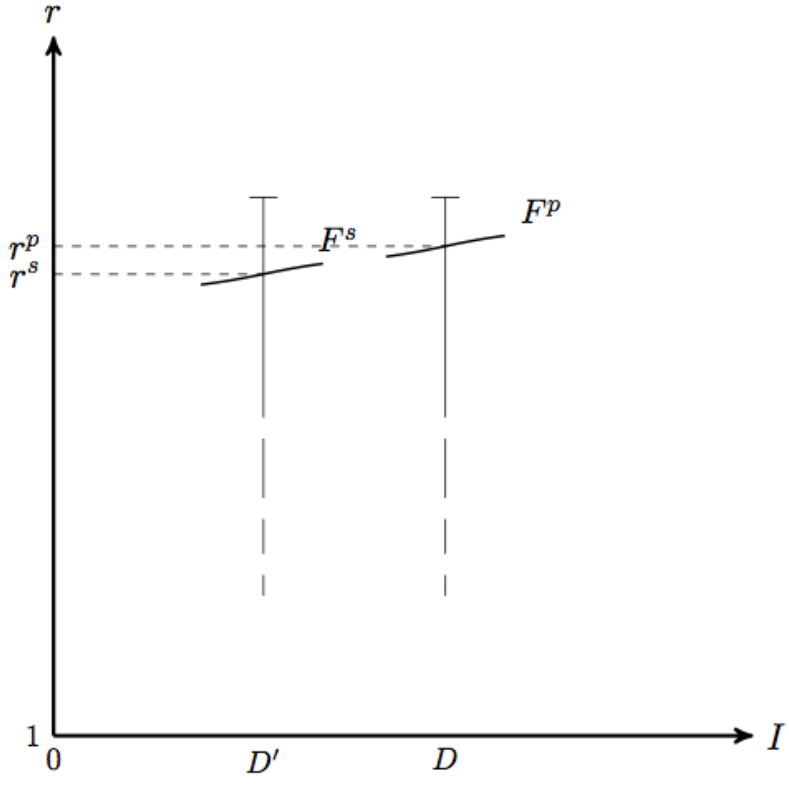
Period	08.Q1	08.Q2	08.Q3	08.Q4	09.Q1	09.Q2	09.Q3	09.Q4	10.Q1	10.Q2	10.Q3	10.Q4	11.Q1	11.Q2	11.Q3	11.Q4
Guaranteed Loans	2.42***	2.37**	2.51***	2.34***	.63	.62	.76	1.19	1.22	1.07	.63	.68	.23	.35	.63	.38
	(.83)	(.99)	(.92)	(.89)	(1.06)	(.91)	(.93)	(1.08)	(1.18)	(1.14)	(1.19)	(1.24)	(1.2)	(1.25)	(1.34)	(1.18)
R-squared	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.02	.02	.02	.02
N	5346	5347	5352	5345	5108	5106	5102	5095	4105	4104	4102	4098	3955	3952	3942	3943

Back

Demand-Supply Framework



(a) Price Discrimination



(b) Quantity Discrimination

Back

Placebo Threshold Estimates

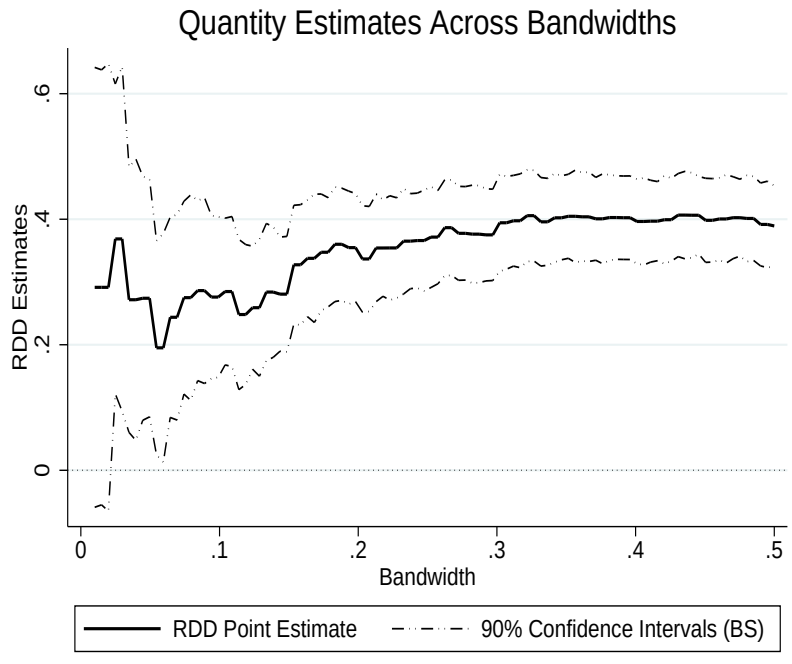
We draw 100 randomly distributed "fake" thresholds along support of *Score* categories 6 and 7, and re-run the baseline specification

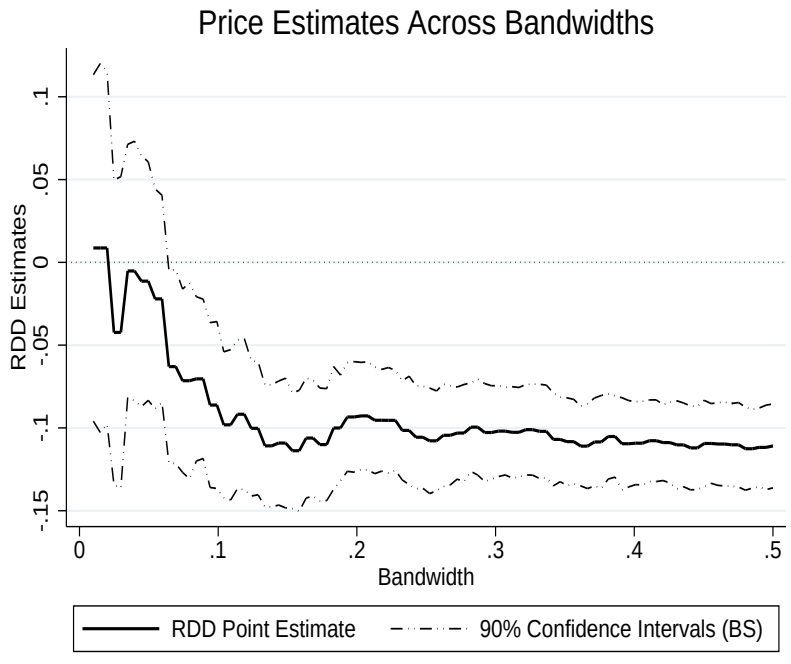
Period	04.Q1	04.Q2	04.Q3	04.Q4	05.Q1	05.Q2	05.Q3	05.Q4	06.Q1	06.Q2	06.Q3	06.Q4	07.Q1	07.Q2	07.Q3	07.Q4
True Threshold: Quantity Estimates	.25	.25	.33	.35	.24	.27	.21	.24	-.04	-.09	-.04	-.05	-.18	-.10	-.11	-.04
Mean of Placebo Estimates	.08	.11	.10	.11	-.09	-.09	-.09	-.03	.011	.03	.01	.03	-.09	-.09	-.09	-.08
Median of Placebo Estimates	.07	.09	.09	.06	-.06	-.02	-.06	-.03	.00	.03	.04	.08	-.03	-.02	-.01	.00
Fraction Significant Placebo Estimates	.10	.10	.12	.11	.12	.15	.14	.11	.04	.08	.06	.08	.04	.06	.07	.07
Fraction Opposite Sign Placebo Estimates	.04	.03	.03	.03	.08	.08	.08	.06	.01	.02	.01	.02	.01	.02	.03	.03
Number of Placebos	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
True Threshold: Price Estimates	-.09	-.10**	-.11**	-.04	-.07	-.13***	-.08*	-.09**	-.14***	-.09***	-.07***	-.06**	.07**	.04	.06**	.05**
Mean of Placebo Estimates	-.03	.00	-.01	-.01	-.01	.02	-.20	.07	-.01	-.13	1.03	-.01	-.00	.02	-.00	.02
Median of Placebo Estimates	-.00	.02	-.01	-.00	.00	.01	.00	.01	.00	.00	.00	.00	-.00	.01	.00	.00
Fraction Significant Placebo Estimates	.13	.14	.11	.16	.25	.15	.20	.15	.24	.21	.26	.22	.23	.23	.15	.20
Fraction Opposite Sign Placebo Estimates	.05	.00	.00	.08	.15	.00	.11	.00	.00	.00	.00	.00	.12	.10	.07	.10
Number of Placebos	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133

Period	08.Q1	08.Q2	08.Q3	08.Q4	09.Q1	09.Q2	09.Q3	09.Q4	10.Q1	10.Q2	10.Q3	10.Q4	11.Q1	11.Q2	11.Q3	11.Q4
True Threshold: Quantity Estimates	.49**	.50***	.48***	.51***	.32	.33*	.37*	.39**	.23	.25	.25	.21	.03	-.02	.03	.06
Mean of Placebo Estimates	.06	.07	.07	.10	-.00	-.00	.00	.01	.05	.04	.02	.03	-.04	-.04	-.07	-.07
Median of Placebo Estimates	.04	.03	.03	.03	-.02	-.02	.00	-.01	.03	.03	.03	.01	-.04	-.03	-.02	-.02
Fraction Significant Placebo Estimates	.11	.12	.10	.08	.06	.07	.06	.10	.09	.08	.06	.08	.12	.08	.06	.09
Fraction Opposite Sign Placebo Estimates	.02	.02	.01	.00	.04	.05	.04	.05	.04	.03	.02	.03	.05	.04	.03	.04
Number of Placebos	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
True Threshold: Price Estimates	-.02	-.01	-.00	.01	.06	.01	.11	.04	-.19*	-.20**	-.16*	-.12	-.06	-.20***	-.15***	-.15**
Mean of Placebo Estimates	.05	.01	-.02	.07	-.02	-.01	.00	-.02	-.02	-.13	-.05	.01	-.00	.02	-.05	-.04
Median of Placebo Estimates	.00	.00	.00	.00	-.01	-.01	-.01	-.01	-.02	-.02	-.01	.01	-.00	.01	.00	-.00
Fraction Significant Placebo Estimates	.20	.17	.20	.21	.21	.20	.23	.16	.23	.26	.23	.20	.24	.17	.11	.21
Fraction Opposite Sign Placebo Estimates	.09	.04	.11	.09	.14	.10	.11	.09	.00	.00	.00	.11	.11	.00	.00	.00
Number of Placebos	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133	133

Back

Quantities and Interest Rates in Q2.2009

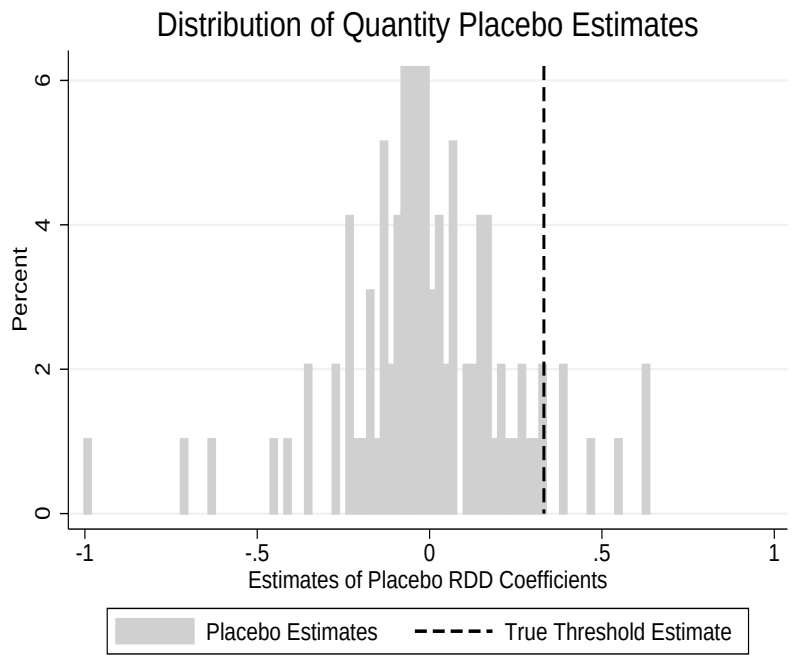


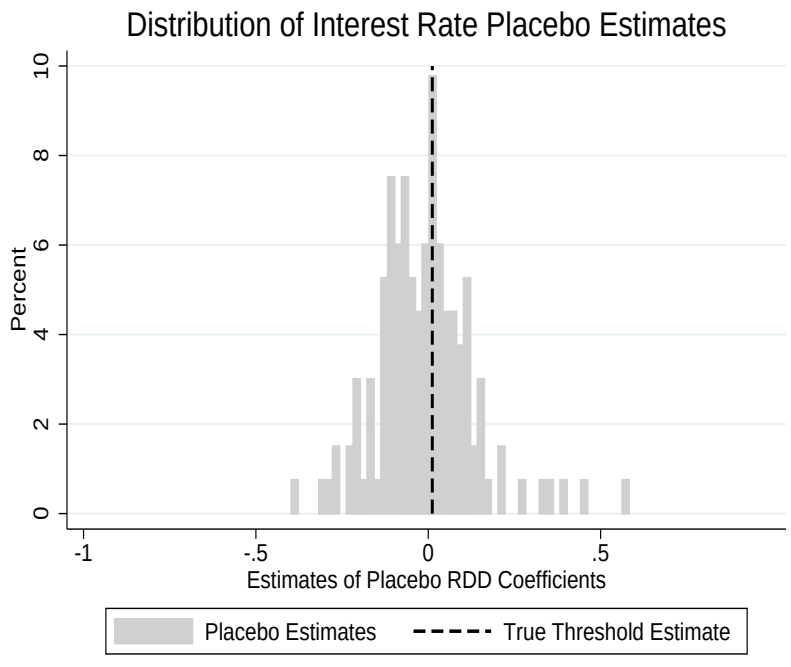


Plot of $\hat{\gamma}$ for different windows h around the threshold:

$$y_i = \delta + \gamma S_i + u_i \quad \text{for} \quad \bar{s} - h \leq s_i \leq \bar{s} + h$$

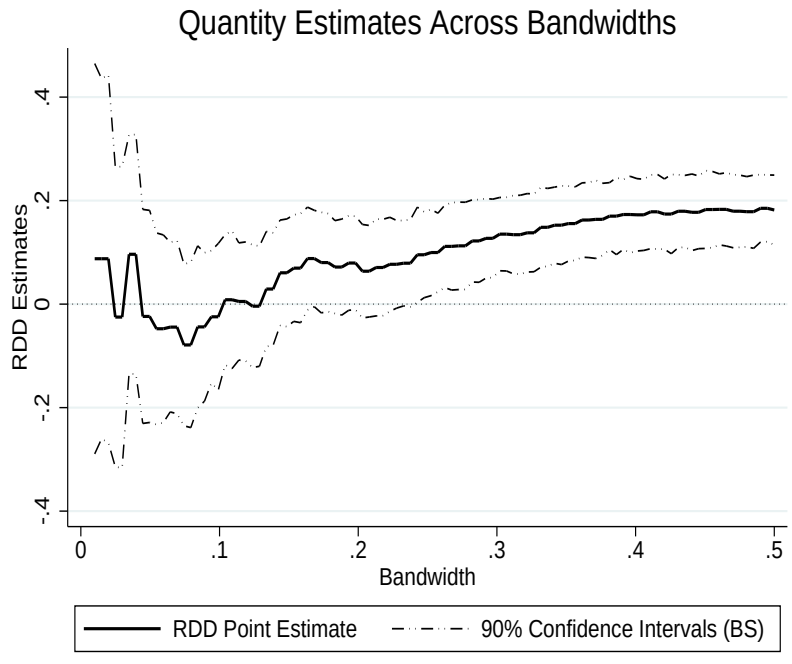
Quantities and Interest Rates in Q2.2009

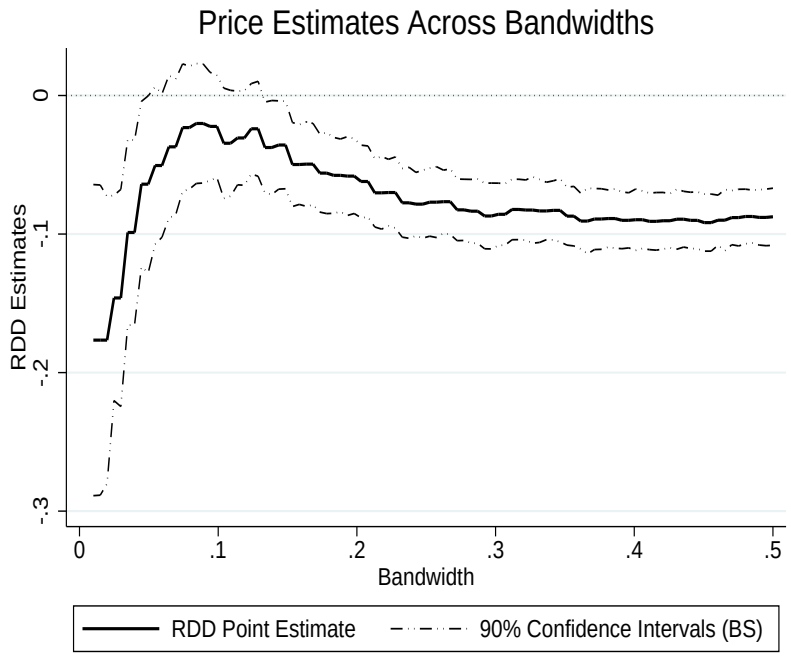




Back

Quantities and Interest Rates in Q2.2011

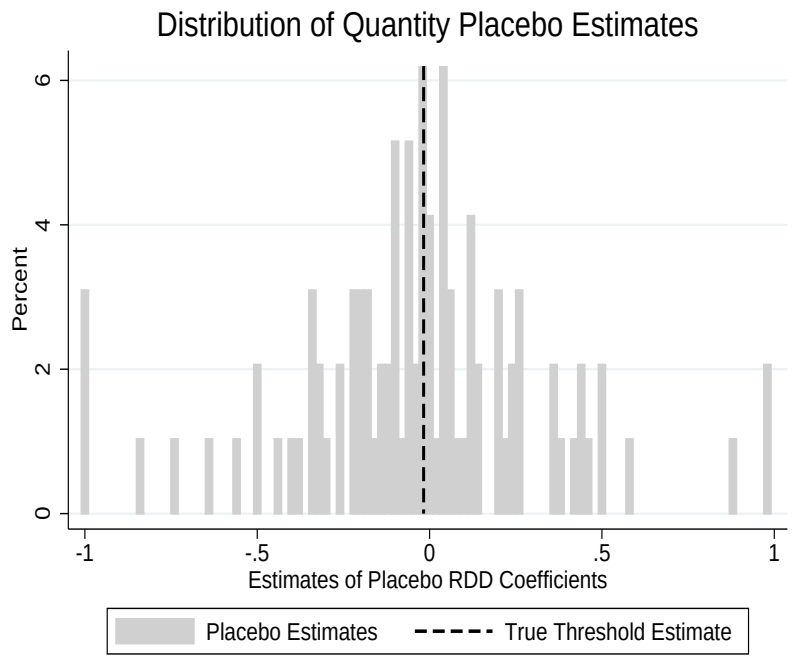


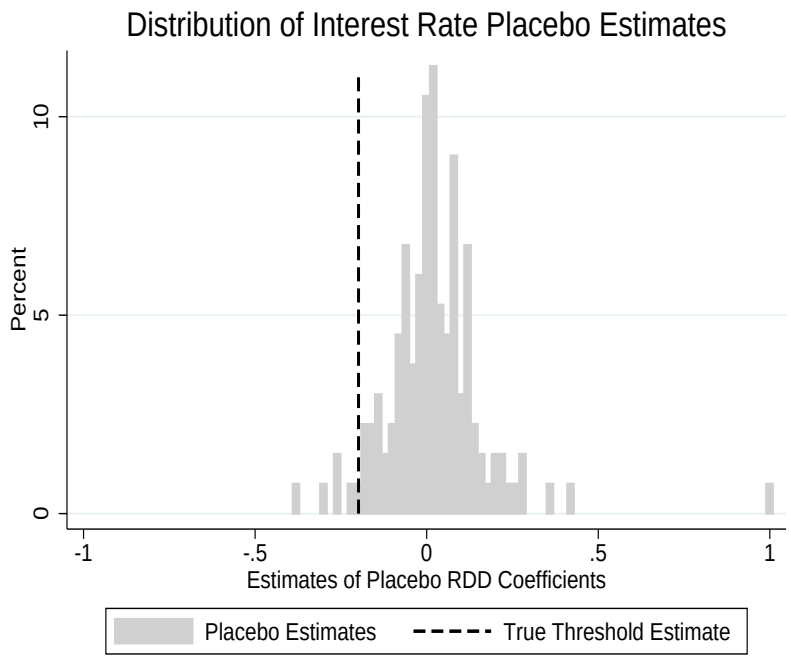


Plot of $\hat{\gamma}$ for different windows h around the threshold:

$$y_i = \delta + \gamma S_i + u_i \quad \text{for} \quad \bar{s} - h \leq s_i \leq \bar{s} + h$$

Quantities and Interest Rates in Q2.2011





Back

First Differences

Intuition: exploit variation from downgrades.

Procedure:

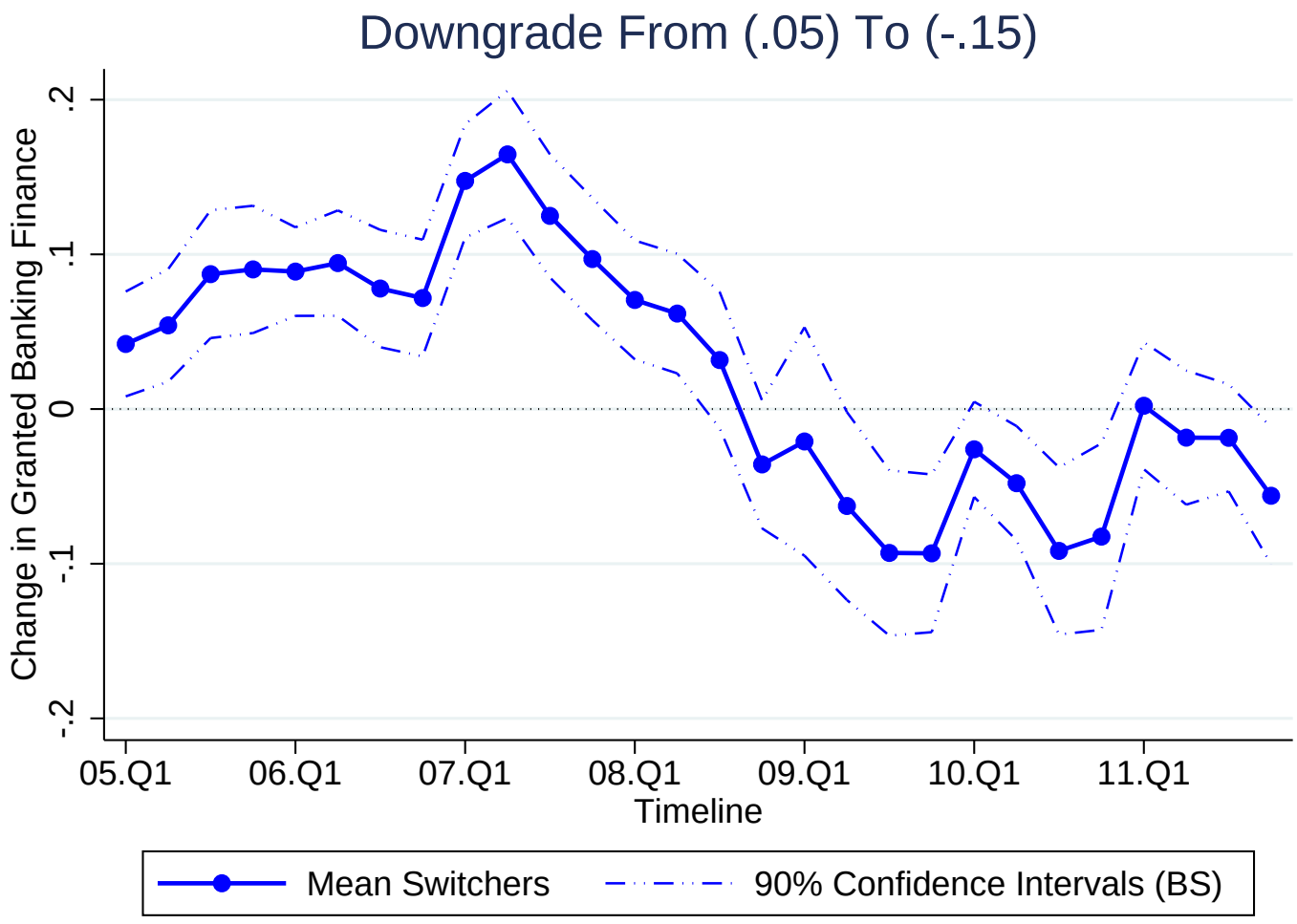
1. Write all variables (y, S, s) in first differences;
2. Fix starting point in s_{t-1};
3. Fix arrival point in s_{t-1};
4. Plot mean Δy across time conditional on starting and arriving point.

Example for $(T = 1, 2)$, first difference estimate:

$$E[Y_0|\bar{s}_2^-, \Delta S = -1] - E[Y_0|\bar{s}_1^+, \Delta S = -1] + E[\beta]$$

Back

First Differences



Discontinuities in Differences

Intuition: exploit differences in small changes of the assignment variable.

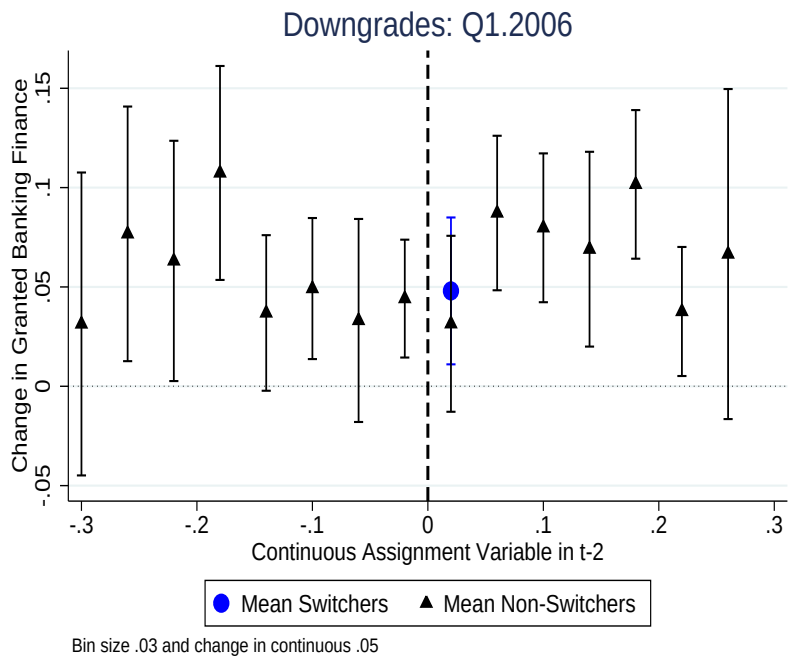
Procedure:

1. Write all variables (y, S, s) in first differences;
2. Fix Δs very small;
3. Plot mean Δy as a function of starting point s_{t-1};
4. Close to the threshold, plot mean Δy as a function of ΔS ;

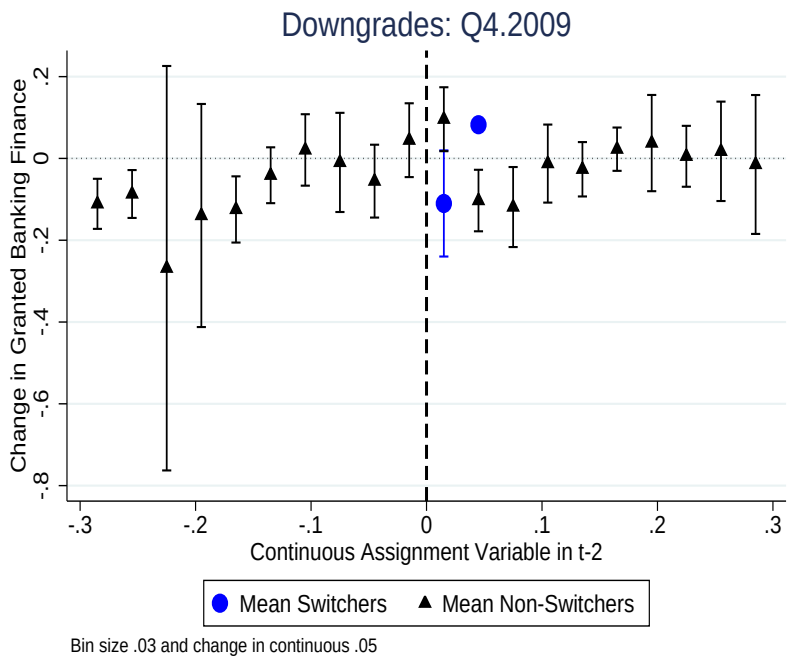
The mean impact on participants is identifed by:

$$E[\beta|\Delta S = 1] = E[\Delta Y_1|\bar{s}^+_{t-1}, \Delta S = 1] - E[\Delta Y_0|\bar{s}^+_{t-1}, \Delta S = 1]$$

Discontinuities in Differences



Bin size .03 and change in continuous .05



Bin size .03 and change in continuous .05

Back

RDD Estimation - Time Variation

Exploiting across time variation: a discontinuity in differences approach!
Define:

- $\Delta s = s_{t,i} - s_{t-1,i}$
- $\Delta S = S_{t,i} - S_{t-1,i}$
- $\Delta y = y_{t,i} - y_{t-1,i}$
- $\bar{s}^{+}$ and $\bar{s}^{-}$ refer to units marginally above or below $\bar{s}$.

RDD Estimation - Time Variation

The usual continuity assumption implies that:

$$E[Y_0|\bar{s}^+] = E[Y_0|\bar{s}^-]$$

Fixing ($-m \leq \Delta s \leq 0$) and therefore focusing on downgrades, the continuity assumption becomes:

$$E[\Delta Y_0|\Delta s, \bar{s}^+_{t-1}] = E[\Delta Y_0|\Delta s, \bar{s}^-_{t-1}]$$

RDD Estimation - Time Variation

The LHS expression can be decomposed into:

$$E[\Delta Y_0 | \Delta s, \bar{s}^+_{t-1}] = \phi E[\Delta Y_0 | \Delta s, \bar{s}^+_{t-1}, \Delta S = 1] + (1-\phi) E[\Delta Y_0 | \Delta s, \bar{s}^+_{t-1}, \Delta S = 0]$$

where $\phi = E\Delta S | \bar{s}^+_{t-1}$ is the probability of the downgrade conditional on marginal eligibility.

RDD Estimation - Time Variation

Combining these expressions:

$$E[\Delta Y_0|\Delta s, \bar{s}^+_{t-1}, \Delta S = 1] = \frac{1}{\phi} E[\Delta Y_0|\Delta s, \bar{s}^-_{t-1}] + \frac{(1-\phi)}{\phi} E[\Delta Y_0|\Delta s, \bar{s}^+_{t-1}, \Delta S = 0]$$

The mean impact on participants is identifed by:

$$E[\beta|0 \leq \Delta s \leq m, \Delta S = 1] = E[\Delta Y_1|\Delta s, \bar{s}^+_{t-1}, \Delta S = 1] - E[\Delta Y_0|\Delta s, \bar{s}^+_{t-1}, \Delta S = 1]$$