The Effect of DOE SBIR Grants on Firm Outcomes

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Census Bureau, NYU Stern & NBER

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Outline

Introduction

DOE SBIR Data

Innovation

Census Data

Firm Growth

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DOE SBIR Data
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Innovation
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Disclosure

Any opinions and conclusions expressed herein are those of the
authors and do not necessarily reflect the views of the U.S. Census
Bureau. No confidential information on individual firms is disclosed.

Plan for Talk

- 1) From Howell, S. T. (2017), "Financing Innovation: Evidence from R&D Grants," *American Economic Review* 107(4), 1136–64.

  - a) Summary of DOE SBIR data

  - b) Effect of grants on innovation

- 2) Summary of Census work to date

  - a) Preliminary effects of grants on payroll, employment, wages, and revenue

  - b) Summary of ongoing work

Outline

Source: Howell (2017)

The Small Business Innovation Research Program

- Lump sum grants fund R&D in small, privately held, for-profit firms ($2.4 bill in FY12 at 11 federal agencies)

  - Phase 1

      $150,000

      Early-stage testing

  - Phase 2

      $1 million

      May apply 1 yr after winning Phase 1

      Later-stage demonstration

- Analog to small end of standard financing model: seed $\rightarrow$ series A

- No cost sharing, equity, IP rights, monitoring, or future procurement potential

Source: Howell (2017)

Summary of key results

- Phase 1 grants have large positive impacts on VC and patents

  - Effects much stronger (and sometimes exist only) for first-time winners

  - Effects stronger for younger firms and firms in emerging sectors

- Phase 2 grants have small effect on patents, no effect on VC

- Mechanism

  - Appears to be a funding effect $\rightarrow$ equity or proof-of-concept channel

  - Not certification

Source: Howell (2017)

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SBIR Application Data

- 1983-2013: Basic info about all 14,522 applications to 2 main applied offices

  - Energy Efficiency and Renewable Energy (EERE)
  - Fossil Energy (FE)

- Ranks from 1995-2013 (RD starts in 1995)

  - 5,021 applications
  - 4,545 firms
  - 428 Phase 1 competitions

- Per competition ave 10.6 applicants, 1.7 awards

Source: Howell (2017)

# Key Points about Ranking and Award Process

- Firms funded in rank order, so rank maps directly to the award

- Cutoff exogenous to ranking process

    - # awards does not vary systematically by any covariate

- Ranks & losers secret
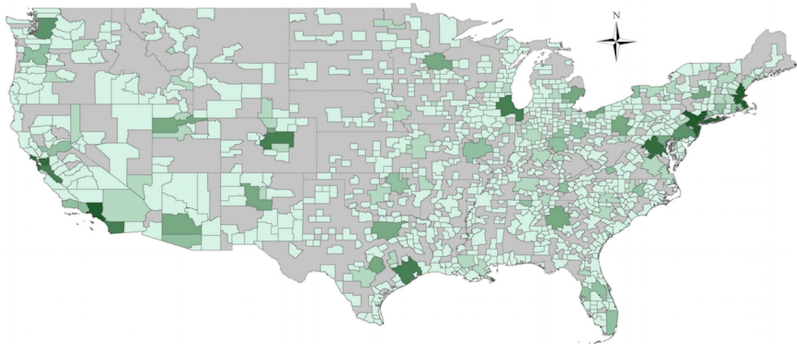
▸ Criteria   ▸ Applicant Sum Stats   ▸ Politicization

Source: Howell (2017)

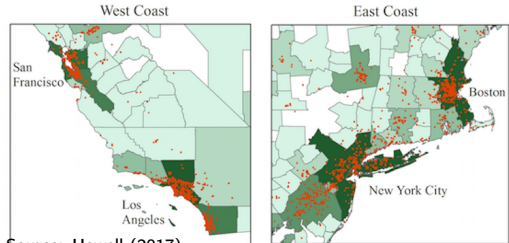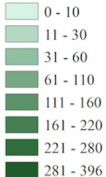DOE SBIR Phase 1 Applicants
to Energy Efficiency & Renewable Energy & Fossil Energy Program Offices
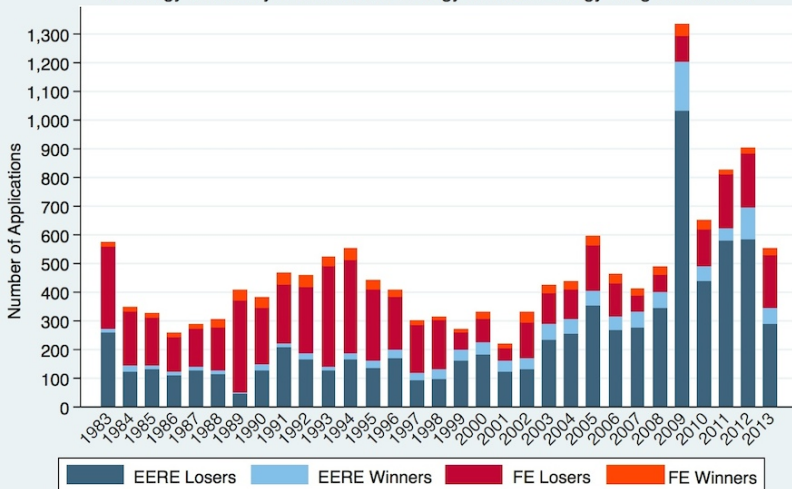
Note: Phase 1 Grant size increased from $50,000 to $150,000 over life of program. Firms may appear more than once.

Source: Howell (2017)

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Applicant Locations

Legend

Number of Firms in Metro Area (MSA)

	0 - 10
	11 - 30
	31 - 60
	61 - 110
	111 - 160
	161 - 220
	221 - 280
	281 - 396

Source: Howell (2017)

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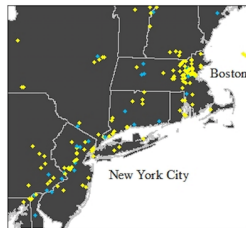oo

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Wind and Solar Applicants

Legend

Firm Sector
- Solar
- Wind

West Coast

East Coast

San Francisco

Los Angeles

Boston

New York City

Source: Howell (2017)

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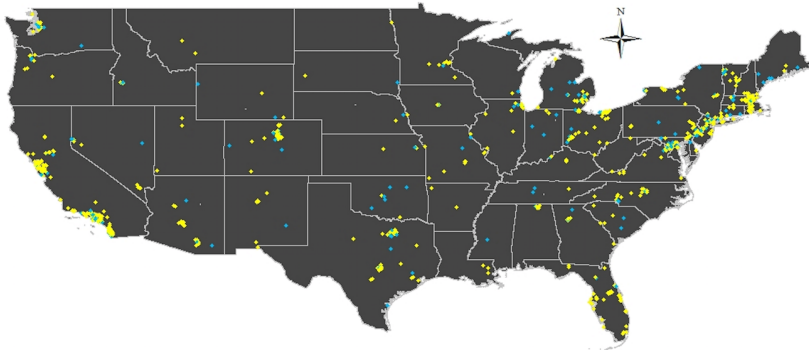
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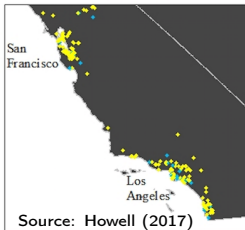
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Coal, Oil, and Natural Gas Applicants
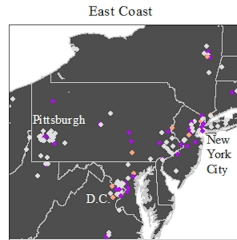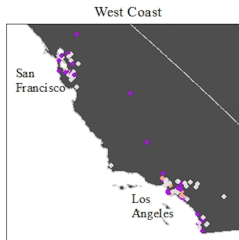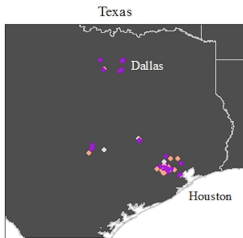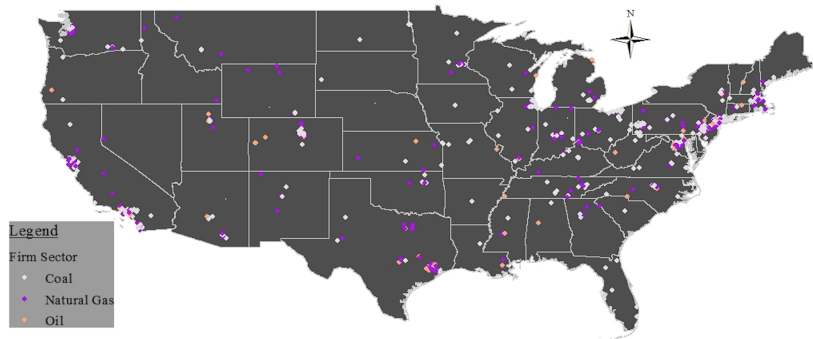
Source: Howell (2017)

Outline

Outcomes

- VC investment

    - Tests for crowding out

    - Indicates company is privately profitable investment opportunity

    - Proxy for market/innovation success

    - *Data: Cleantech Group i3, ThompsonOne, Preqin, CapitalIQ, Crunchbase* ▸ Summary Stats

- Innovation

    - Cite-weighted patents

    - *Data: All patents 1976-2014 from Berkeley Fung Institute* ▸ Summary Stats

Source: Howell (2017)

Sharp RD approximates local randomized experiment

- Compare firms ranked just above the cutoff (winners) with firms just below the cutoff (losers)

- Center ranks within each competition around zero $\rightarrow R_{ic}$

$$Y_{ic}^{\text{Post}} = \alpha + \tau \left[\mathbf{1} \mid R_{ic} > 0\right] + f\left(R_{ic}\right) + \gamma_1 Y_{ic}^{\text{Prev}} + \gamma_2 X_{ic} + \delta_c + \varepsilon_{ic}$$
$$\text{where} -r \leq R_{ic} \leq r$$

- Assumption: Cutoff in rating variable (rank) separates otherwise very similar firms, who cannot precisely manipulate rank

    - Tests indicate no sorting around the cutoff

Source: Howell (2017)

Cite-Weighted Patents Before and After Phase 1 Grant by Rank

Panel A. Before the award decision   Panel B. After the award decision
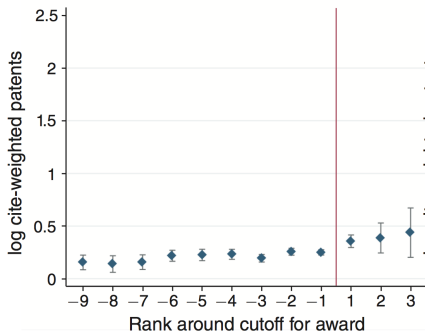
• No information in rank at arbitrary distances from the cutoff

Phase 1 grant impact on subsequent cite-weighted patents

Panel 1: Negative binomial model; dependent variable is $Cites_i^{post}$

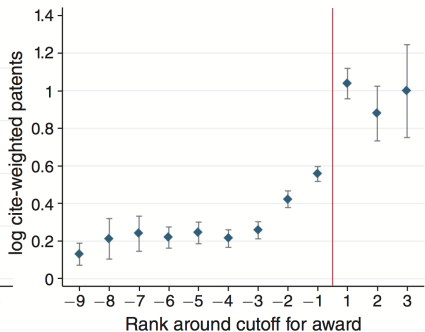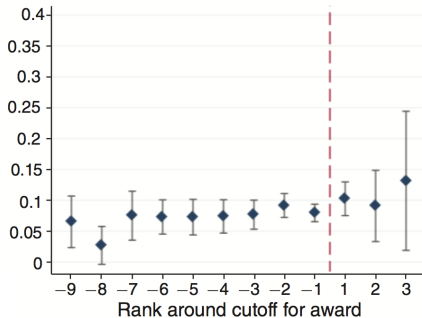| Sample:	No previous winners				All	No prev. apps	>2 prev. wins
Bandwidth:	1	1	All	All	1	1	1
	I.	II.	III.	IV.	V.	VI.	VII.
Award	.93***	.91***	.92***	.94***	.82***	2.1***	.40***
	(.21)	(.19)	(.33)	(.26)	(.13)	(.34)	(.14)
Normalized rank			.052				
			(.074)				
Normalized rank^2			-.0072				
			(.0045)				
Rank quintiles	N	N	N	Y	N	N	N
Controls†	N	Y	N	N	N	N	N
Sector-year f.e.††	Y	Y	Y	Y	Y	Y	Y
N	1871	1871	5021	5021	2714	972	1477
R^2	0.056	0.084	0.053	0.053	0.034	0.080	0.035

Panel 2: OLS models; dependent variable is $\ln\left(1 + Cites_i^{post}\right)$

Sample:	No previous winners				All	No prev. apps	>2 prev. wins
Bandwidth:	1	1	All	All	1	1	1
	I.	II.	III.	IV.	V.	VI.	VII.
Award	.33**	.27**	.29***	.22**	.29***	.49**	.22*
	(.15)	(.13)	(.11)	(.087)	(.087)	(.21)	(.13)
Normalized rank			-.026				
			(.02)				
Normalized rank^2			.00078				
			(.0011)				
Rank quintiles	N	N	N	Y	N	N	N
Controls†	N	Y	N	N	N	N	N
Competition f.e.	Y	Y	Y	Y	Y	Y	Y
N	1872	1872	5021	5021	2714	972	1477
Pseudo-R^2	0.46	0.60	0.53	0.351	0.63	0.71	0.75

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Probability of Venture Capital Before and After Grant by Rank

Panel A. Before the award decision
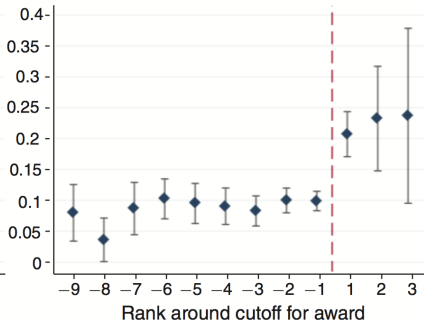
Panel B. After the award decision

- No information in rank at arbitrary distances from the cutoff

Phase 1 grant impact on subsequent VC

Panel 1

Dependent variable:	VC_i^{post}						$\ln\left(1 + \text{VC Amt}_i^{post}\right)$
Bandwidth:	1		3		All		1
	I.	II.	III.	IV.	V.	VI.	VII.
Award	.098***	.10***	.12**	.094***	.072**	.10***	1.4***
	(.032)	(.033)	(.058)	(.033)	(.033)	(.028)	(.5)
Normalized rank			-.029		.0086		
			(.033)		(.0071)		
Normalized rank^2			.012		-7.4e-5		
			(.0088)		(.00043)		
Rank quintiles	N	N	N	Y	N	Y	N
Controls†	Y	N	Y	Y	Y	Y	N
Competition f.e.	Y	Y	Y	Y	Y	Y	Y
N	1872	1872	3368	3368	5021	5021	1843
R^2	0.47	0.42	0.35	0.35	0.27	0.27	0.42

Panel 2

Dependent variable:	VC_i^{post}						VC Deals$_i^{post}$
Sample:	All applicants		No prev. apps		>2 prev. wins		No prev. wins
Bandwidth:	1	All	2	All	1	All	1
	I.	II.	III.	IV.	V.	VI.	VII.
Award	.11***	.075***	.11***	.10**	.080*	.074	.93***
	(.023)	(.026)	(.037)	(.048)	(.048)	(.053)	(.19)
Normalized rank, normalized rank^2	N	Y	N	Y	N	Y	N
Competition f.e.	Y	Y	Y	Y	Y	Y	N∓
N	2714	6400	1514	2951	1246	2322	1872
R^2	0.37	0.19	0.50	0.28	0.51	0.35	0.051 (Pseudo-R^2)

Firms with >100 SBIR awards from DOE

Company Name	DUNS	# of Awards
Aerodyne Research, Inc.	030817290	102
ELTRON RESEARCH & DEVELOPMENT, INCORPORATED	029303690	115
Omega-P, Inc.	084736651	118
PHYSICAL OPTICS CORPORATION	153865951	159
Physical Sciences Inc.	073800062	125
Radiation Monitoring Devices, Inc.	073804411	260
TDA Research, Inc.	181947730	172
TECH-X CORPORATION	806486692	216

Source: SBIR.gov (public data)

Source: Howell (2017)

Phase 1 grant's effect is strongest for most constrained firms

Effect on VC is....

- ...much larger for firms with no previous patents (also true for patents) than firms with at least one cite-weighted patent

- ...larger for hardware than software firms

- ...largest for youngest firms; declines with age (also true for patents)

- ...larger for firms in riskiest/immature/clean sectors

Source: Howell (2017)

Impact of Phase 1 Grant by Technology

Dependent Variable:	VC_i^{post}	$\ln\left(1 + Cites_i^{post}\right)$	$In\ Bus_i^{post}$	N
	I.	II.	III.	
Geothermal	.56* (.24)	–.58 (.30)	.14 (.13)	51
Hydropower, Wave & Tidal	.51** (.19)	.50** (.20)	.26*** (.025)	236
Solar	.25** (.11)	.15 (.13)	.20** (.077)	421
Carbon Capture & Storage	.20** (.091)	.73** (.34)	.25* (.13)	211
Building & Lighting Efficiency	.14** (.057)	.39** (.16)	.21*** (.048)	370
Vehicles, Motors, Engines, Batteries	.12** (.060)	.23* (.12)	.16*** (.059)	726
Wind	.11** (.039)	.030 (.10)	.15 (.093)	194
Advanced Materials	.11 (.071)	–.081 (.18)	.23*** (.077)	435
Biomass Production/Generation	.085 (.067)	.036 (.29)	.21** (.079)	308
Fuel Cells & Hydrogen	.077 (.0723)	.17 (.18)	.27*** (.10)	400
Natural Gas	.060 (.074)	.54 (.45)	–.15 (.17)	255
Recycling, Waste-to-energy & Water	.045 (.053)	.094 (.21)	.061 (.08)	549
Smart Grid, Sensors, Converters	.045 (.053)	.36* (.21)	.056 (.069)	634
Air & Emission Control	.025 (.035)	.20 (.24)	.20* (.11)	300
Coal	.024 (.053)	.79 (.51)	.11 (.41)	108
Biofuels & Biochemicals	.014 (.054)	.036 (.29)	.051 (.13)	176

Source: Howell (2017)

Grant Use Survey Results

Panel 1: Phase 1 (94 respondents)

Survey Response:	Fraction			Frequency		
	Yes	No	If random	Yes	No	χ^2 p-value[†]
	I.	II.	III.	IV.	V.	VI.
(a) Basic R&D on new tech.	.71	.29	.40	67	27	.00***
(b) Patent applications	.08	.92	.40	8	86	.00***
(c) Testing existing tech.	.65	.35	.40	61	33	.00***
(d) Overhead/salaries	.47	.53	.40	44	50	.18
(e) Something else	.10	.90	.40	9	85	.00***
Only (a)	.32	.68	.088	30	64	.00***
Only (c)	.26	.74	.088	24	70	.00***
Neither (a) nor (c)	.032	.97	.36	3	91	.00***

Panel 2: Phase 2 (38 respondents)

Survey Response:	Fraction			Frequency		
	Yes	No	If random	Yes	No	χ^2 p-value[†]
	I.	II.	III.	IV.	V.	VI.
(a) Basic R&D on new tech.	.42	.58	.50	16	22	.33
(b) Patent applications	.21	.79	.50	8	30	.00***
(c) Testing existing tech.	.79	.21	.50	30	8	.00***
(d) Overhead/salaries	.63	.37	.50	24	14	.11
(e) Something else	.18	.82	.50	7	31	.00***
Only (a)	.026	.97	.042	1	37	.00***
Only (c)	.16	.84	.042	6	32	.00***
Neither (a) nor (c)	.11	.89	.25	4	34	.04**

Source: Howell (2017)

Phase 2 grant ($1 million) much less useful

- Phase 2 doubles a firm's cite-weighted patents

  - Effect exists only for first-time winners

- On a public dollar basis, much smaller effect than Phase 1

  - E.g. in 2012 DOE spent $38 million on 257 Phase 1 grants and $112 million on 111 Phase 2 grants

  - If reallocated all 2012 Phase 2 money to Phase 1, 750 add'l firms could have gotten Phase 1 grants, increasing by 2.5x program's impact on cite-weighted patents

- No effect of Phase 2 on VC

  - Seems to reflect adverse selection in applying (e.g., ineligible if outside investor owns >50%)

Source: Howell (2017)

Outline

Data sources

- SBIR linked to the Census Bureau's Business Register by EIN (when available) or probabilistic matching on name, address, and zip code.

- Business Register-linked firms are then linked to Longitudinal Business Database (LBD) and W-2s

- LBD is universe of non-farm, non-public administration business establishments with paid employees

Data structure

- Annual data, 1976-2015

- Employment in pay period including March 12th, as well as other quarters starting in 2005

- Quarterly Payroll

- Annual Revenues

- W-2 data contain annual earnings for each employee, 2005-2015

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Estimating equations

- Use variety of estimating equations in a panel data setting

- All applicants included in baseline models

    - Show main results robust to a bandwidth of one rank on either side of award cutoff

- Some models restrict time period to 3 years before and 5 years after application year

- Fixed effects

    - Competition

    - Firm-application (obviating need for rank or competition controls)
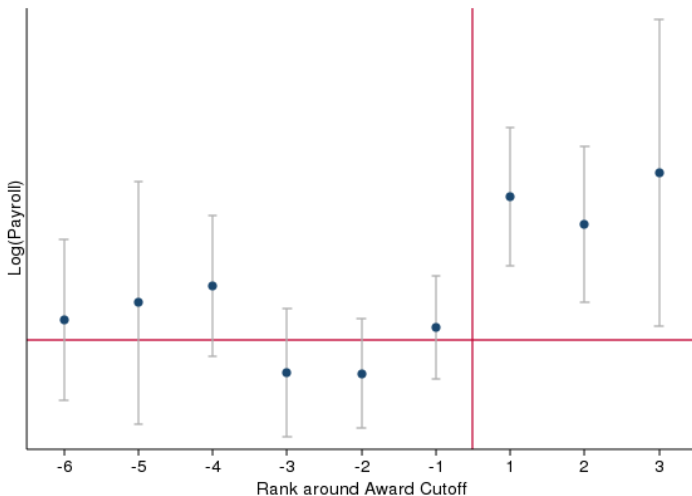
Estimating equations for figures

- Effect by rank around award cutoff:

$$\ln\left(\frac{Y_{i,t}}{Y_{i,t=-1}}\right) = \sum_{x=-6}^{x=3} \beta_x \left(PostAward_{i,j}\right)\left(Rank_{i,j} = x\right)$$
$$+ \eta_1 Age_i + \eta_2 Age_i^2 + \tau_t + \theta_j + \varepsilon_{i,j,t}$$

- Quarterly effect:

$$\ln Y_{i,t} = \sum_{x=-13}^{x=13+} \left[\beta_x \left(Award_{i,j} = 1\right)\left(q = x\right) + \delta_x \left(q = x\right)\right]$$
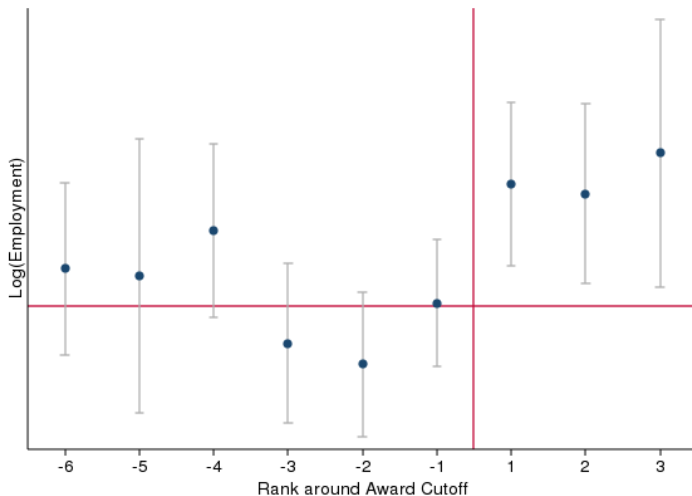$$+ \tau_t + \lambda_i + \varepsilon_{i,j,t}$$

Effect of grant on payroll (2010$) by rank around award cutoff

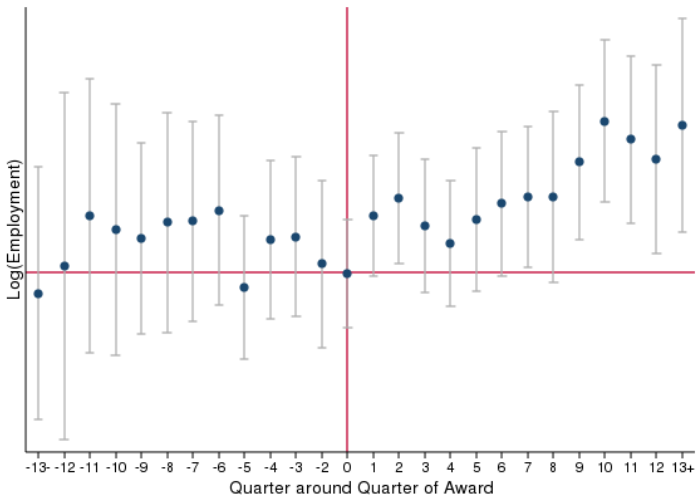## Effect of grant on payroll (2010$) by quarter around grant application
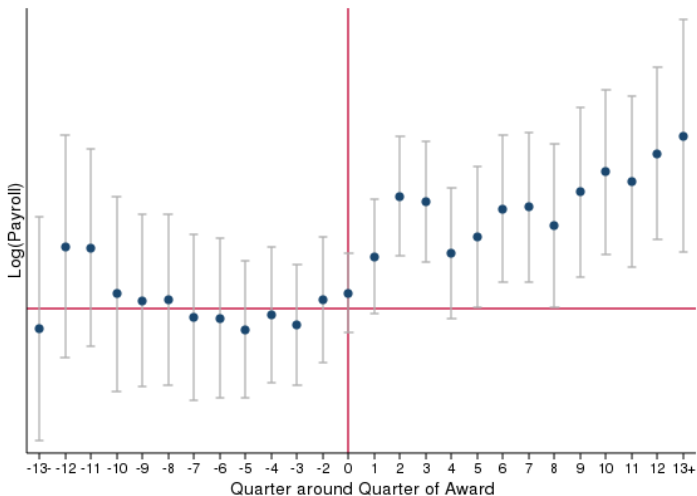
Effect of grant on employment by rank around award cutoff

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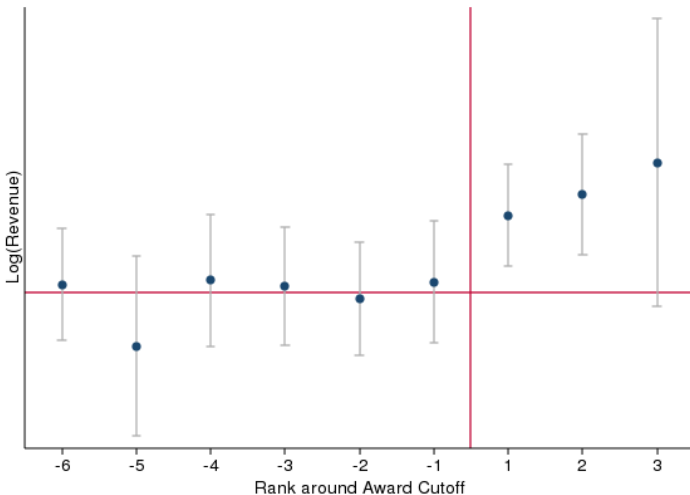## Effect of grant on employment by quarter around grant application

Effect of grant on average wage (2010$) by quarter around grant application

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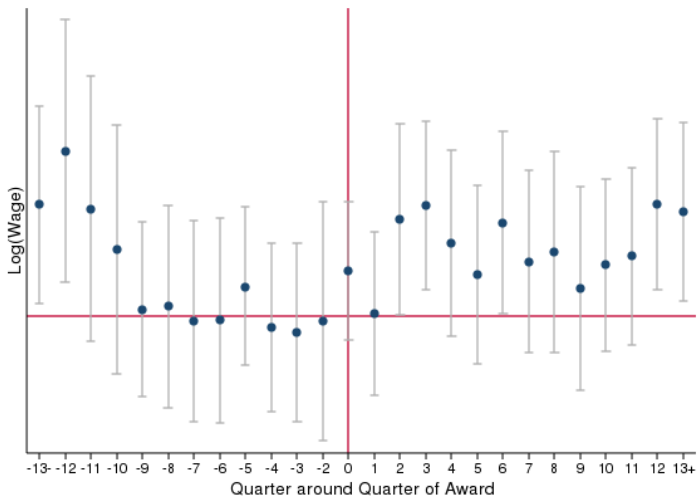
Effect of grant on revenue by rank around award cutoff

Ongoing work

- Effect of grant on total payroll and average wages among previous and new employees

- Effect of grant on within-firm inequality

- Heterogeneity in effect of grant by

    - Firm size

    - Firm industry

    - Founder gender, race/ethnicity, country of birth, and education

    - Firm share employees that are female, minorities

APPENDIX

Summary Statistics for Private Financing Matches (Number of Deals or Firms)

Applicant firms matched to ≥ 1 PF deal	838
Applicant firms matched to ≥ 1 VC deal	683
PF deals matched to applicant firms (Some companies have multiple funding events)	3,751
VC deals	2,638
Seed/Angel	178
Series A	1,313
Series B	561
Series C+	587
Acquisitions	221
IPOs	27
Debt deals	196
PE Buyout deals	59
Project Finance	61
Unique applicants with ≥ 1 PF deal & 0 grant wins	565
Unique applicants with ≥ 1 VC deal & 0 grant wins	451
Unique applicants with ≥ 1 PF deal & ≥ 1 grant wins	273
Unique applicants with ≥ 1 VC deal & ≥ 1 grant wins	232

Note: PF= all private finance; VC=venture capital (subset of PF). Sources: ThompsonOne VentureSource, Preqin, Cleantech Group's i3 Platform, CrunchBase, and CapitalIQ

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Patent Matching Summary Statistics

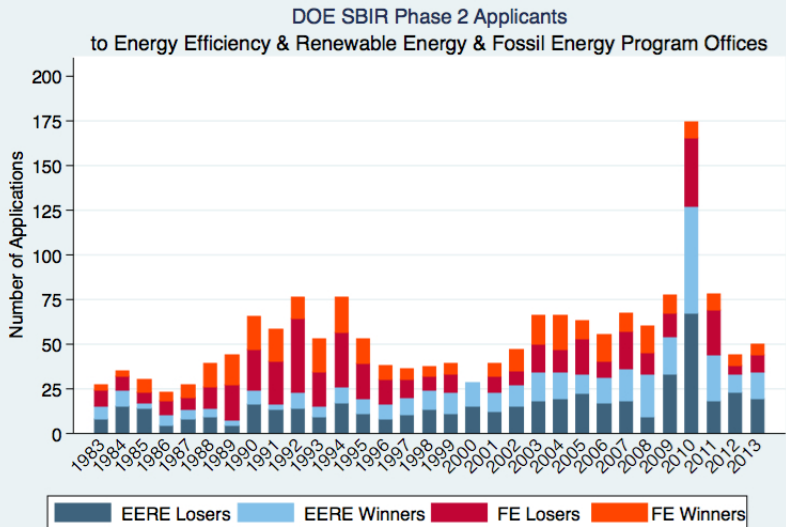|	
# Firms matched to ≥ 1 patent (1983-2013)	2,109
Average # Patents	2.06 (9.94)
Average # Patents for firms w/≥ 1 patent (1983-2013)	7.91 (18.25)
# Firms matched to ≥ 1 patent (1995-2013)	1,471
Average # Patents	2.44 (11.69)
Average # Patents for firms w/≥ 1 patent	8.82 (20.42)
Average per patent citations for a firm	9.9 (18)
Average per patent claims for a firm	21.2 (12)
Average total citations for a firm	75.9 (258)
Average total claims for a firm	171.8 (453)
Average total normalized 3-year citations for a firm	3.46 (24.72)
Average total normalized 3-year citations for a firm w/≥ 1 patent	11.80 (44.75)

Source: Berkeley Fung Institute Patent Database

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Summary Statistics of DOE EERE & FE SBIR Applicants

| 1983-2013	
# Phase 1 Applications	14,522
# Unique Phase 1 Applicant Firms	7,419
# Competitions	1,633
1995-2013	
# Phase 1 Applications	9,659
# Unique Phase 1 Applicant Firms	4,545
# Phase 1 Applications with ranking data used in RD	5,021
# Phase 1 Competitions used in RD (≥ 1 award)	428
Average # Phase 1 Applicants per Competition	11 (8.3)
Average # Phase 1 Awards per Competition	1.7 (1.1)
# Phase 2 Applications used in RD	919

Summary Statistics of DOE EERE & FE SBIR Applicants

	Type	Mean	Std Dev	Median	N
Pre-award venture capital (VC) investment	0-1	.083	.27	0	5,021
Pre-award venture capital deals	Count	.25	1.3	0	5,021
Pre-award cite-weighted patents	Count	21	122	0	5,021
Pre-award patents	Count	1.9	7.5	0	5,021
Pre-award acquisition or IPO	0-1	.033	.18	0	5,021
Post-award VC (VC_i^{post})	0-1	.11	.31	0	5,021
Post-award VC (mill 2012$) (VC Amt_i^{post})	Cont.	2.7	26	0	4,964
Post-award VC deals (VC Deals$_i^{post}$)	Count	.32	1.4	0	5,021
Post-award cite-weighted patents $(Cites_i^{post})$	Count	12	117	0	5,021
Post-award patents	Count	2	11	0	5,021
Post-award Acquisition or IPO $(Exit_i^{post})$	0-1	0.034	0.18	0	5,021
Revenue as of 2016 in $ millions $(Revenue_i)$	Cont.	2.0	6.6	0.20	3,583
Survival as of 2016 $(In\ Bus_i^{post})$	0-1	0.67	0.47	1	3,880
Probability in major metro area (top 6)	0-1	0.30	0.46	0	5,021
Age (years)	Count	9.5	11	6	3,427
Probability tech is hardware $(Hardware_i)$	0-1	0.43	0.49	1	2,571
Prob. new sub-sector $(Emerging\ Sector_i)$	0-1	0.58	0.49	1	2,571
Probability minority owned	0-1	0.077	0.27	0	1,722
Probability woman owned	0-1	0.084	0.28	0	1,722
All-gov't SBIR wins $(SBIR_i)$	Count	10	36	0	5,021
Future patents in modal class	Count	9,758	11,809	5,453	1,583
MSA VC investment 2011 ($ mill)	Cont.	851	1,570	0	4,950
MSA median per cap. income 2011 ($ thou)	Cont.	56	14	56	4,603

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DOE SBIR Phase 2 Applicants
to Energy Efficiency & Renewable Energy & Fossil Energy Program Offices

Note Phase 2 Grant size increased from $500,000 to $1,000,000 over life of program. Firms may appear more than once.

Number of Applicants by Award Status from Top 10 EERE/FE SBIR Applicant MSAs, 1995 & 2012
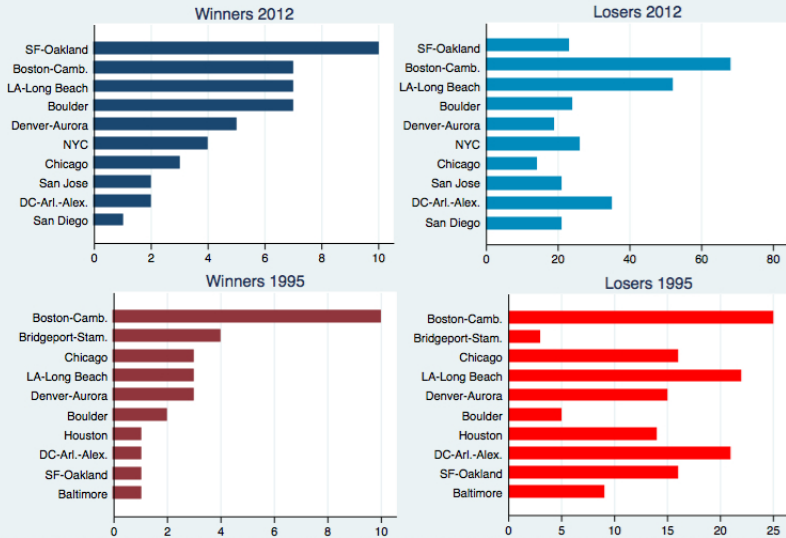
Note: In 2012, 80 (60%) winners and 459 (62.5%) losers came from MSAs outside the top 10. In 1995 these were 33 (59%) winners and 215 (57%) losers.

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Legend

Number of VC Funding Events for Firm

- ● 0 - 1
- ● 2 - 9
- ● 10 - 33

Midwest

San Francisco

Chicago

West Coast

Los Angeles

East Coast

Boston

New York City