Evaluating Patent Licensing Agreements for Technology Diffusion at the U.S. National Labs

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Competing Views

"National labs do much more than research. Their reach can be seen in all sectors of the economy, and they help make America the most economically competitive country in the world."

Photo credit: Cindy Arnold

Congressman Randy Hultgren

(Republican, Illinois'14th District)

December 7, 2012

Competing Views

"The federal laboratories have received a mandate to transfer technology. This, however, is ***not the same as a mandate to help the private sector in the development and commercialization of technology*** for the marketplace … The laboratories were created to perform the R&D necessary to meet government needs, which typically are not consistent with the demands of the marketplace."

Congressional Research Service

December 3, 2012

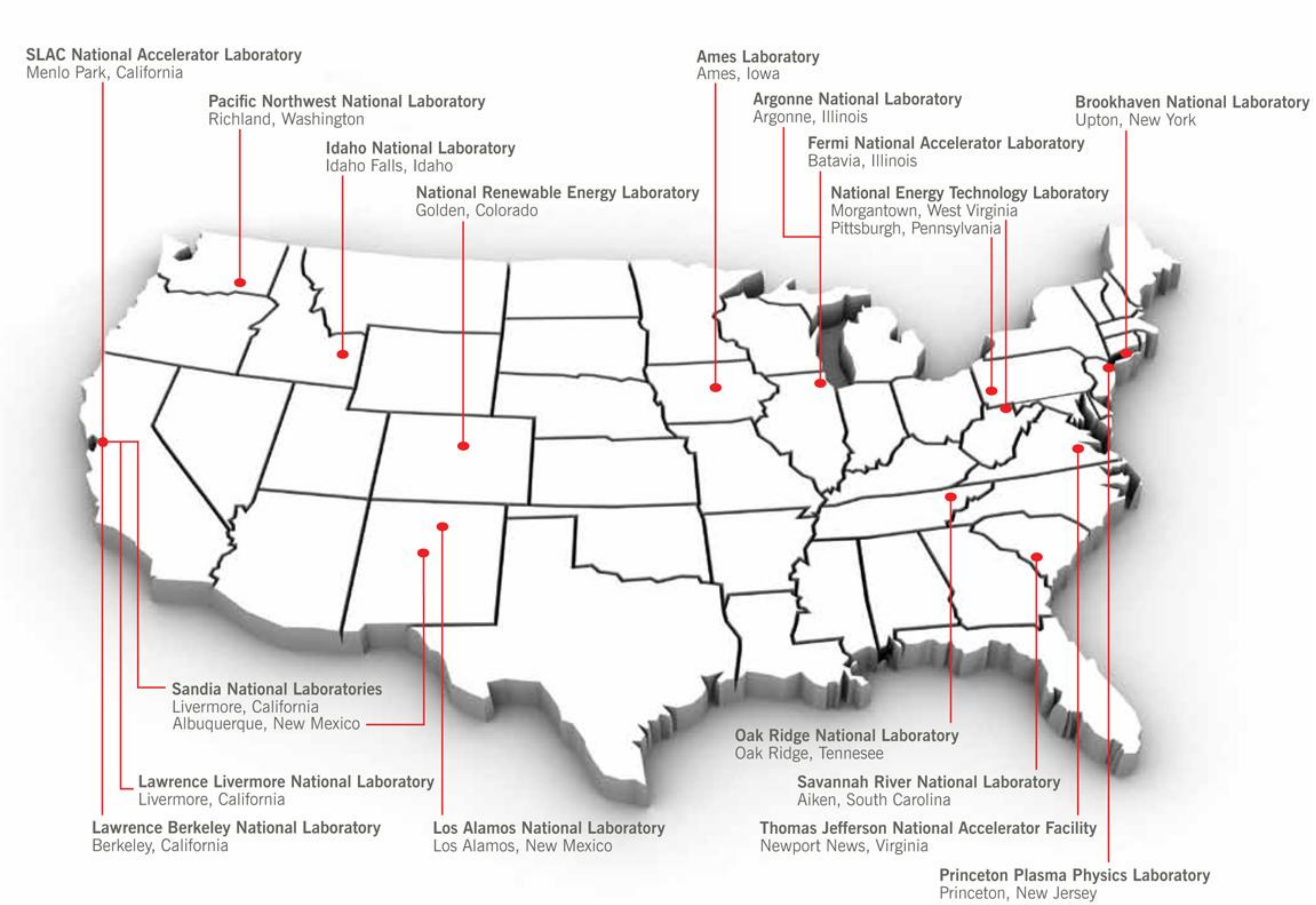
Institutional background

- The 17 National Labs are overseen by the U.S. Department of Energy and have a combined \$18 billion budget (FY11) (U.S. universities spent \$65 billion in R&D in 2011)

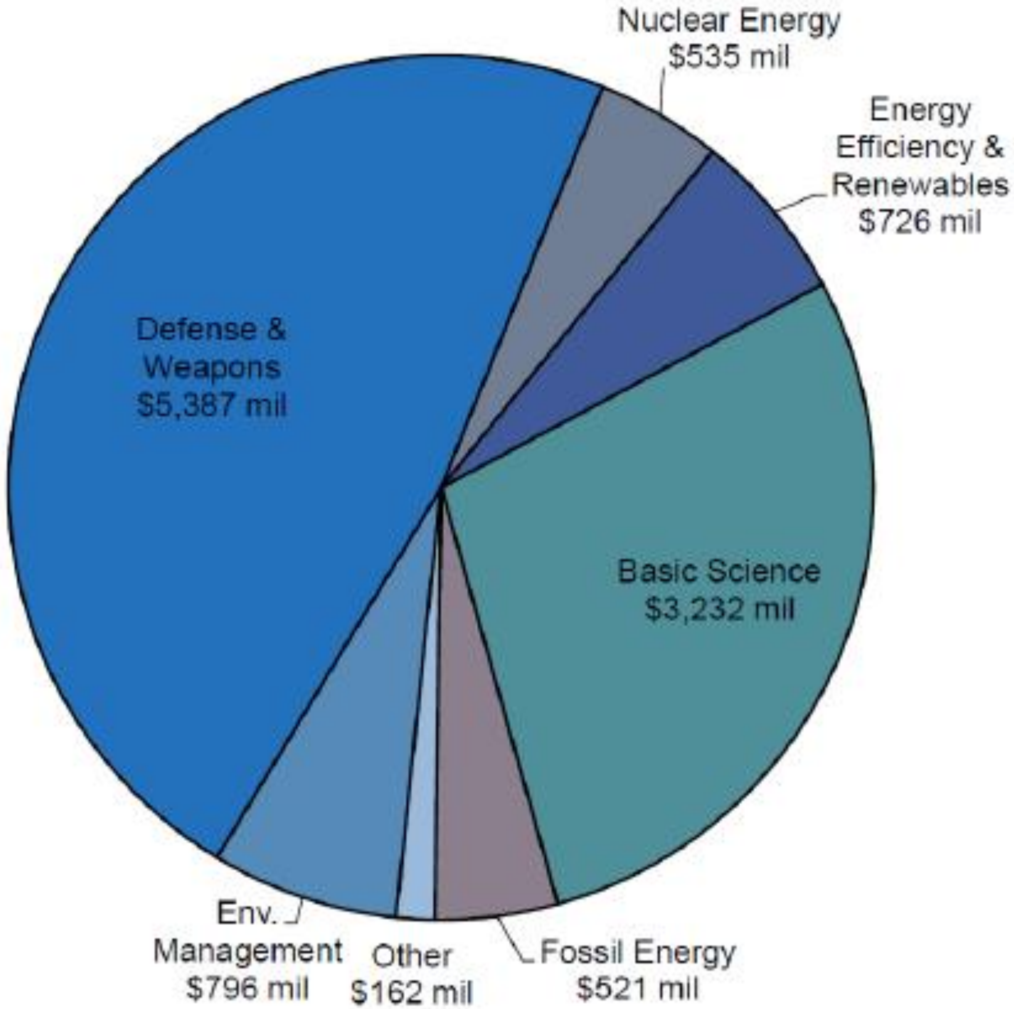
- Mission: "execute long-term government scientific and technological missions … by develop[-ing] …. scientific capabilities ***beyond the scope of academic and industrial institutions*** to benefit the Nation's researchers and ***national strategic priorities***."

- The labs provide >40% of total U.S. funding for physics, chemistry, and materials science but also conduct substantial applied R&D

Institutional background



Institutional background



1.2 Aggregate Fiscal Year 2011 Lab Budget by R&D Category

Technology transfer at the National Labs – major policies

- 1980 Stevenson-Wydler Technology Innovation Act
- 1980 Bayh-Dole Act
- 1986 Federal Technology Transfer Act
- 1989 National Competitiveness Technology Transfer Act
- 2000 Technology Transfer Commercialization Act

Technology transfer mechanisms

- Cooperative R&D agreements (CRADAs)
- Work for others (Lab employees temporarily work for a firm)
- User facilities (e.g. computing center, cyclotron, bio-refinery)
- Technical assistance (consulting)
- Spin-outs
- Personal exchanges
- Academic publishing
- **Licensing**

The Story of CCADS

- 1999: two NETL engineers invent a way to analyze electrical properties of a flame – using “two wires and a butane lighter”
- Their prototype used two electrodes on either side of a fuel injector nozzle to measure important combustion properties (e.g. fuel/air composition variations) that cause inefficiencies, higher emissions, or faster equipment degradation
- The intended application was in natural gas turbines

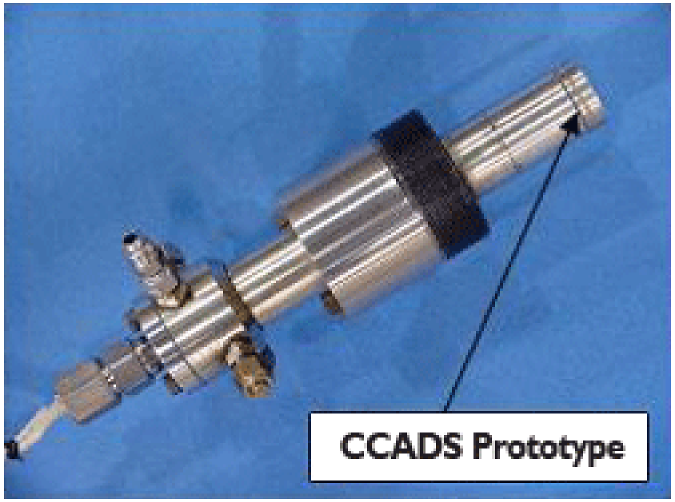


Photo Credit: NETL

The Story of CCADS

- June 2000: six NETL employees filed a patent application, “Flashback Detection Sensor for Lean Premix Fuel Nozzles,”
- September 2001: three of those six (along with a visiting professor and one other NETL employee) filed a separate “continuation-in-part” patent application “Real-time combustion controls and diagnostics sensors (CCADS)”
- The Federal government retained right to these patents.

(12) **United States Patent**
Thornton et al.

(10) **Patent No.: US 6,887,069 B1**
(45) **Date of Patent: May 3, 2005**

(54) **REAL-TIME COMBUSTION CONTROLS AND DIAGNOSTICS SENSORS (CCADS)**

(75) Inventors: **Jimmy D. Thornton**, Morgantown, WV (US); **George A. Richards**, Morgantown, WV (US); **Keith A. Dodrill**, Fairmont, WV (US); **Roy S. Nutter, Jr.**, Morgantown, WV (US); **Douglas Straub**, Morgantown, WV (US)

(73) Assignee: **The United States of America as represented by the United States Department of Energy**, Washington, DC (US)

4,965,048	A	*	10/1990	Ogasawara	422/54
5,073,753	A	*	12/1991	Collings et al.	324/468
5,588,825	A	*	12/1996	Kostiuk et al.	431/349
5,676,712	A	*	10/1997	Anderson	48/192

FOREIGN PATENT DOCUMENTS

DE	44 25 304 A1 *	2/1996		G01N/30/68
GB	2 037 066 A *	7/1980		G01N/30/68

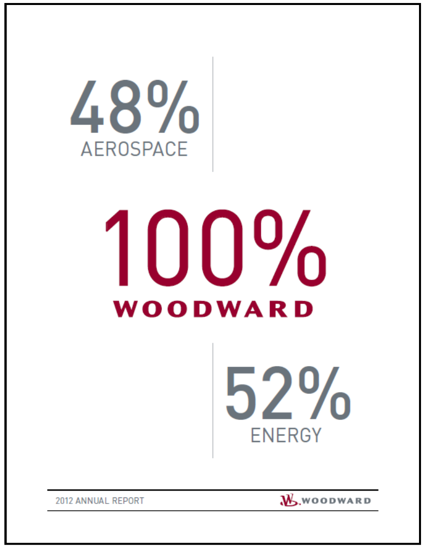
* cited by examiner

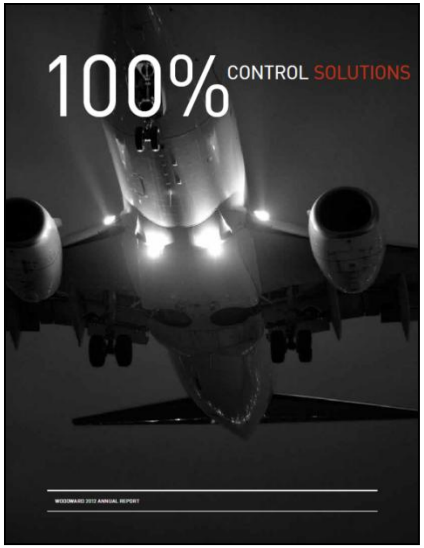
Primary Examiner—Josiah Cocks
(74) *Attorney, Agent, or Firm*—Mark F. LaMarre; Thomas G. Anderson; Paul A. Gottlieb

(57) **ABSTRACT**

The Story of CCADS

- On Dec. 28, 2001, NETL announced that it intended to grant an exclusive license on both of these patent-pending inventions to Woodward Industrial Controls of Fort Collins, CO
- Soon thereafter, Woodward entered into a cooperative R&D agreement (CRADA) with NETL and continued to jointly innovate on this technology.
  - NETL conducted “in-house … fundamental laboratory experiments and computational fluid dynamics models”
  - Woodward demonstrated the technology at commercial scale





Woodward 2012 Annual Report

The Story of CCADS

- 2005: 2nd Woodward-NETL CRADA initiated
- NETL continues to conduct R&D on CCADS ($200,000/yr)
- Woodward is marketing CCADS for commercial application
- Follow-on innovation led to lower cost and broader applicability of CCADS (notably for syngas turbines)
- NETL estimated full deployment would save $1 billion/year
- The Two NETL patents have been cited by 4 subsequent Woodward patents, 2 subsequent NETL patents, but also by companies like Boeing, ALSTOM, and Siemens

CCADS was installed in a NETL test rig.
Photo credit: NETL

The Story of CCADS: Key Takeaways

- The initial spark and the funding to develop a prototype originated internally at the Lab
- The Lab filed a patent application before licensing and before entering into a CRADA
- After licensing IP, the Lab stayed intimately involved (human and physical capital) with the technology
- NETL and Woodward cooperatively improved the technology for nearly a decade
- Knowledge developed by NETL and Woodward was utilized in subsequent internal and external inventions

The Story of CCADS: Key Takeaways

- Exclusive licensing means that other private actors continue to be denied access to CCADS, despite its origin in a public institution and formal IP held by the government. (The first 5 of 11 citations to the patents were by Woodward/NETL)
  - Therefore, we might think knowledge diffusion after licensing is **delayed**

- Without exclusive licensing, would any company have been willing to invest the necessary resources to develop CCADS? Further, commercialized products enable additional channels of diffusion and innovation (e.g. learning by using)
  - Therefore, we might think that knowledge diffusion after licensing is **accelerated**

- My project will attempt to estimate the effect of licensing a government patent on knowledge diffusion

Motivation

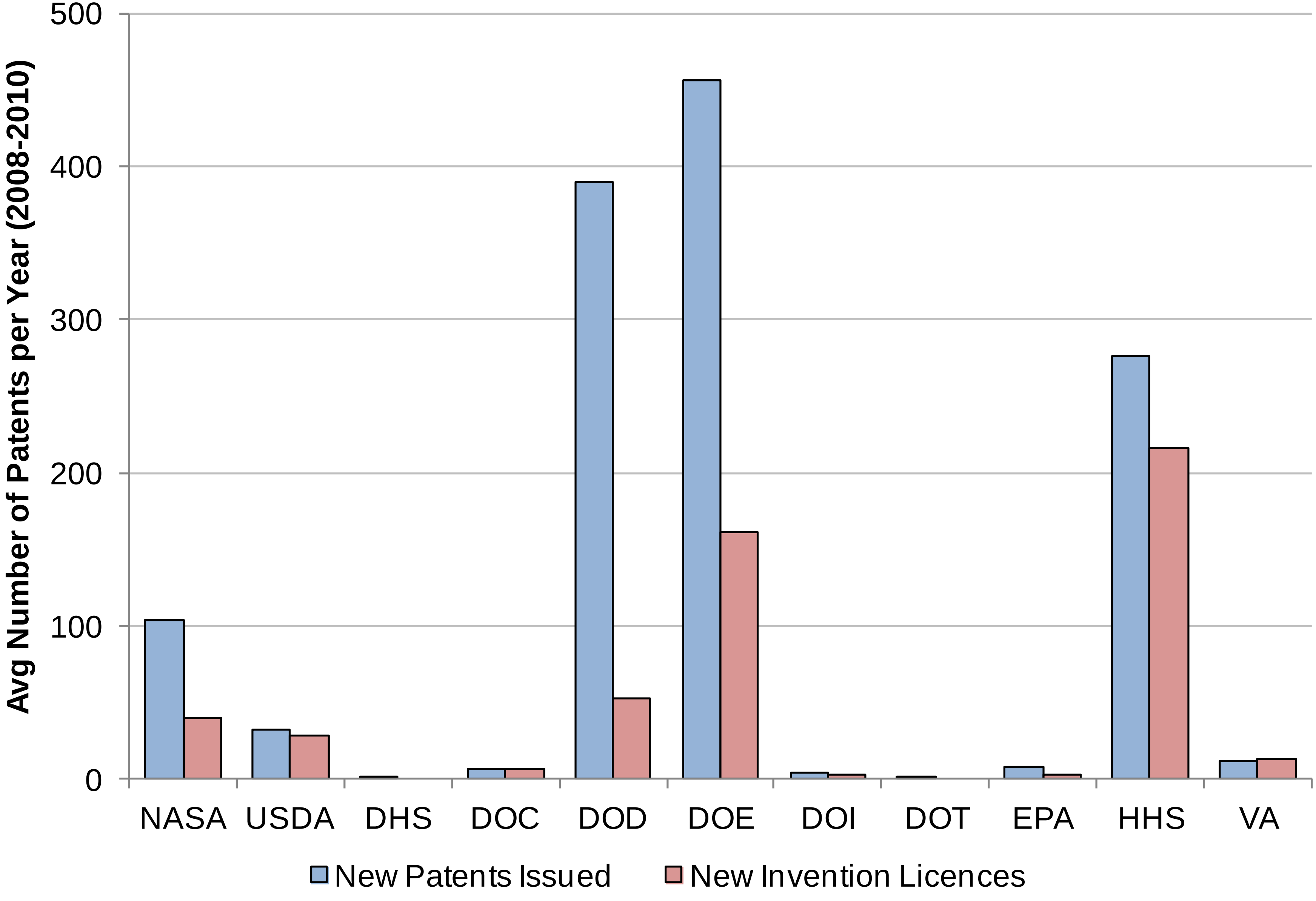
Key empirical question:

- How does the licensing of federally funded inventions affect the rate and direction of public knowledge diffusion (as measured by new forward citations to patents)?

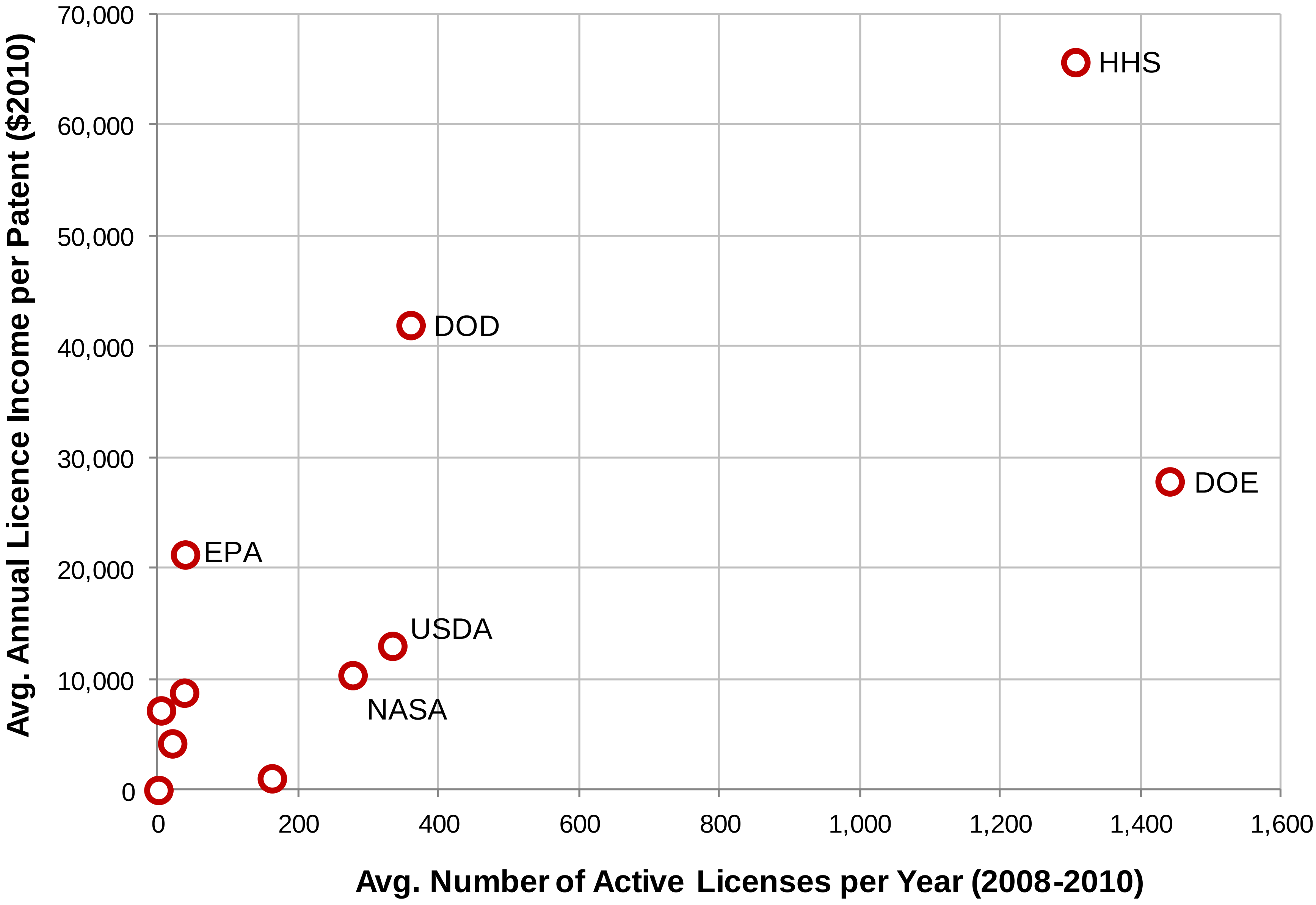
Motivation:

- Multiple policy reforms in the past 30 years have made licensing publically-funded inventions easier, but have these policy shifts helped or hindered the ability of federal labs to meet their technology transfer goals?
- Reviews consistently call for more data and metrics on the downstream impacts of Federal technology transfer efforts (ITIF/CAP/Heritage, 2013; NIST, 2012; DOE 2012; White House 2011, PCAST 2003)

Government Patenting and Licensing by Agency



Government Patenting and Licensing across Agencies



Why do the Labs patent and license patents?

- The Labs are legislatively-required and are appropriated funds to work towards transferring technology
- By making knowledge appropriable, patenting is a tool to facilitate technology transfer
  - In 2008 the Labs disclosed 1,460 new inventions, filed 904 patent applications, were granted 370 new patents, and executed 177 new patent licensing agreements (1,448 agreements were active)
  - Royalty payments are an individual and institutional incentive to license patents. The Labs generated $43.1 mil through their active royalty-bearing patent licenses, equivalent to 0.5% of their budget. $8.4 mil was distributed in royalties back to inventors
- Technology transfer is part of the organizational mission of DOE to “catalyze … material … transformation of the nation’s energy system”

Data

- Observations: 1,382 utility patents developed at 3 of the National Labs (PNNL, BNL, LBL) since 1990, housed in the U.S. Energy Innovation Portal (http://techportal.eere.energy.gov)
  - covariates: the Lab involved, assignee, application date, grant date, title, US and international classification, abstract, full text

- License agreements: 420 licensing agreements between one of the three Labs and a private sector partner
  - covariates from the Labs: effective dates of the license, basic agreement terms (exclusive vs. non-exclusive)

Method Sketch

1. Using the sample of 1,382 patents granted to the three Labs, construct a panel of patents by age

2. Estimate the causal effect of licensing on the rate of new citations:
   - Run a negative binomial difference-in-difference regression of annual forward citations on age dummies and their interaction with licensed dummies, lab fixed effects, and total past citations

3. Robustness checks:
   - Use citations only from patents assigned to unique assignees as the dependent variable
   - Use a matching approach to compare licensed patents only to patents with similar abstracts. Similarity metric calculated with a machine learning algorithm, matching based on time-dependent propensity score (this is a topic of another paper)
   - Restriction to only exclusively licensed patents

Results

	Exclusive and Non-Exclusive Licenses			
	(1)	(2)	(3)	(4)
Dependent Variable	Citations from All Assignees			
Cumulative Citations	-0.001			
	(0.002)			
Licensed -2 yrs	0.245			
	(0.271)			
Licensed 0 yrs	0.168			
	(0.242)			
Licensed 2 yrs	0.539 *			
	(0.220)			
Licensed 4 yrs	0.686 **			
	(0.223)			
Licensed 6 yrs	0.926 ***			
	(0.222)			
Licensed 8 yrs	1.004 ***			
	(0.236)			
Year FE?	Yes			
Patent FE?	Yes			
Matched Sample?	No			
N	478			
N * t	3,889			

Model: negative binomial; standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Results

(Estimates and 95% Confidence Interval)

Interpretation of Results

- Licensing increases the citations that a National Lab patent receives.
- Being licensed induces an increase in the forward citation rate to the patent of 1 – 1.5 citations per year beginning 2 years after the licensing agreement.

Robustness Checks: Matching, New Assignees

	Exclusive and Non-Exclusive Licenses			
	(1)	(2)	(3)	(4)
Dependent Variable	Citations from All Assignees		Citations from New Assignees	
Cumulative Citations	-0.001	-0.004	-0.087 ***	-0.071 ***
	(0.002)	(0.003)	(0.012)	(0.011)
Licensed -2 yrs	0.245	0.113	0.911	1.972
	(0.271)	(0.362)	(0.730)	(1.150)
Licensed 0 yrs	0.168	0.079	0.592	1.724
	(0.242)	(0.332)	(0.722)	(1.162)
Licensed 2 yrs	0.539 *	0.552	1.269	2.536 *
	(0.220)	(0.315)	(0.720)	(1.139)
Licensed 4 yrs	0.686 **	0.812 *	1.473 *	2.851 *
	(0.223)	(0.319)	(0.725)	(1.133)
Licensed 6 yrs	0.926 ***	1.162 ***	1.668 *	3.121 **
	(0.222)	(0.324)	(0.727)	(1.137)
Licensed 8 yrs	1.004 ***	1.321 ***	1.808 *	3.373 **
	(0.236)	(0.347)	(0.748)	(1.155)
Year FE?	Yes	Yes	Yes	Yes
Patent FE?	Yes	Yes	Yes	Yes
Matched Sample?	No	Yes	No	Yes
N	478	257	443	244
N * t	3,889	2,151	3,674	2,074

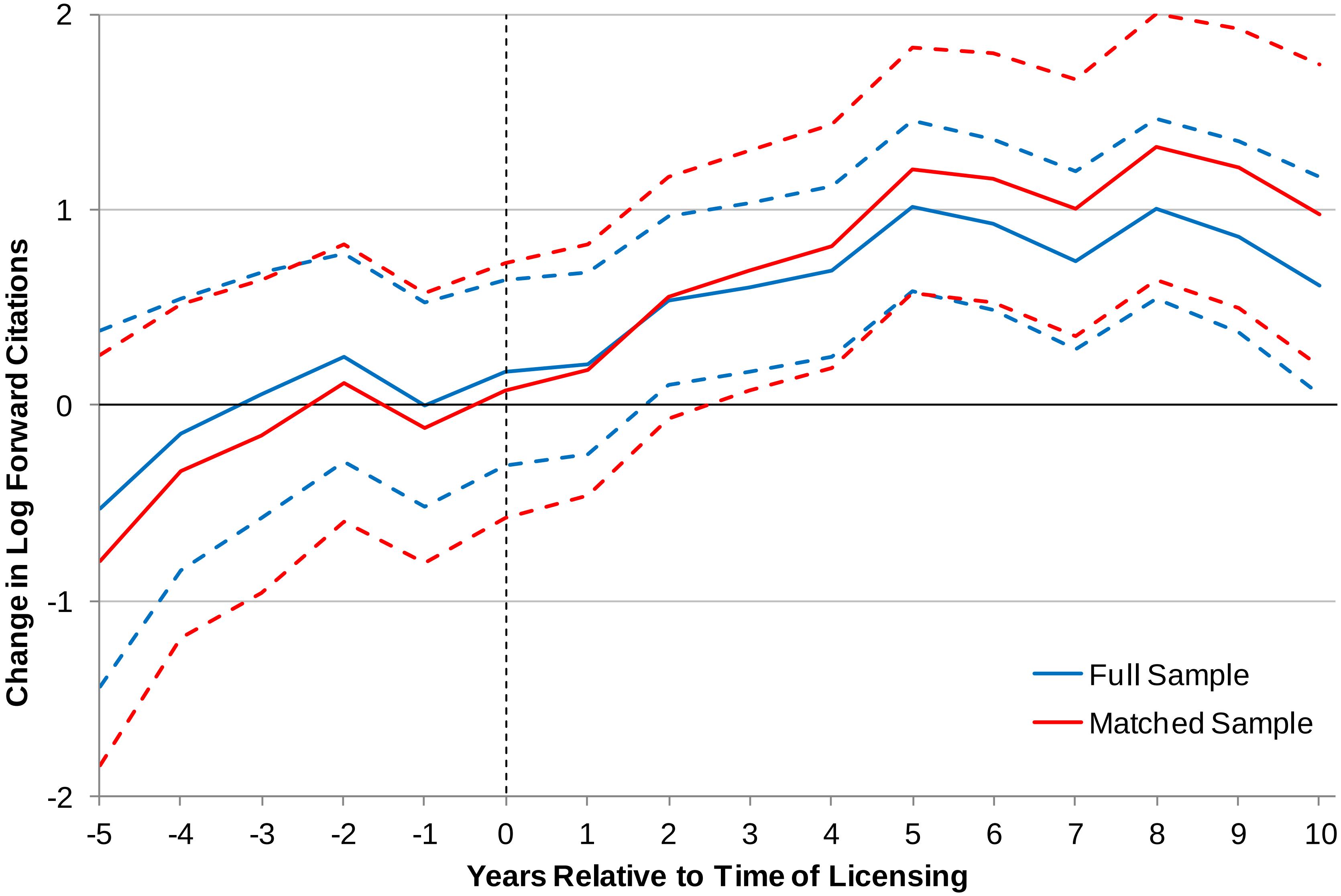
Model: negative binomial; standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Robustness Checks: Results for Exclusive Licenses

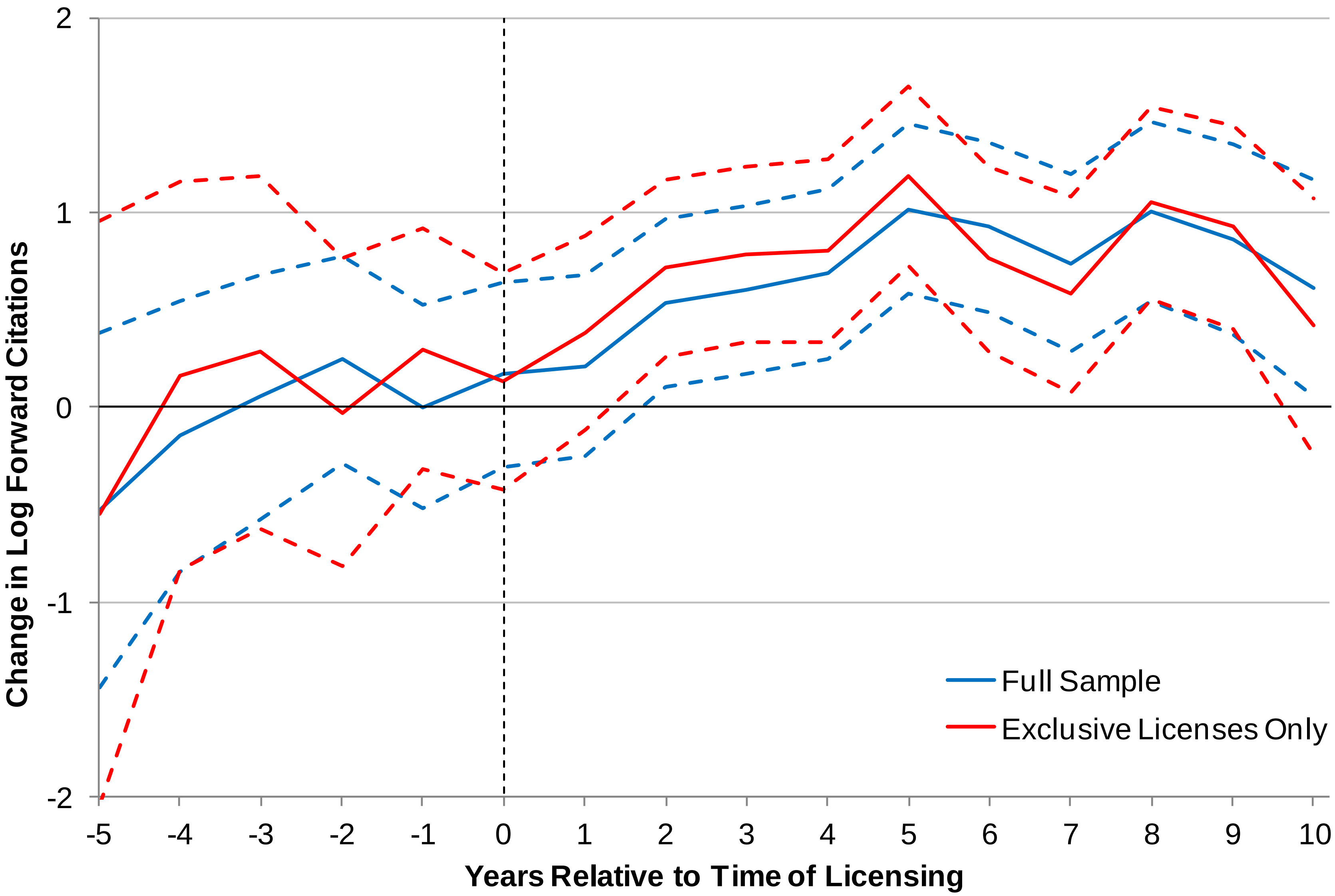
	Exclusive Licenses Only			
	(5)	(6)	(7)	(8)
Dependent Variable	Citations from All Assignees		Citations from New Assignees	
Cumulative Citations	0.002	0.001	-0.085 ***	-0.070 ***
	(0.002)	(0.003)	(0.013)	(0.014)
Licensed -2 yrs	-0.025	-0.261	1.130	0.972
	(0.403)	(0.465)	(0.871)	(1.287)
Licensed 0 yrs	0.135	-0.027	0.471	0.439
	(0.283)	(0.360)	(0.833)	(1.262)
Licensed 2 yrs	0.717 **	0.665 *	1.620 *	1.680
	(0.233)	(0.319)	(0.820)	(1.253)
Licensed 4 yrs	0.802 **	0.880 **	1.795 *	1.935
	(0.239)	(0.327)	(0.833)	(1.265)
Licensed 6 yrs	0.763 **	0.965 **	1.793 *	2.011
	(0.243)	(0.342)	(0.842)	(1.277)
Licensed 8 yrs	1.053 ***	1.356 ***	1.952 *	2.293
	(0.252)	(0.364)	(0.879)	(1.311)
Year FE?	Yes	Yes	Yes	Yes
Patent FE?	Yes	Yes	Yes	Yes
Matched Sample?	No	Yes	No	Yes
N	392	171	362	163
N * t	3,168	1,430	2,985	1,385

Model: negative binomial; standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

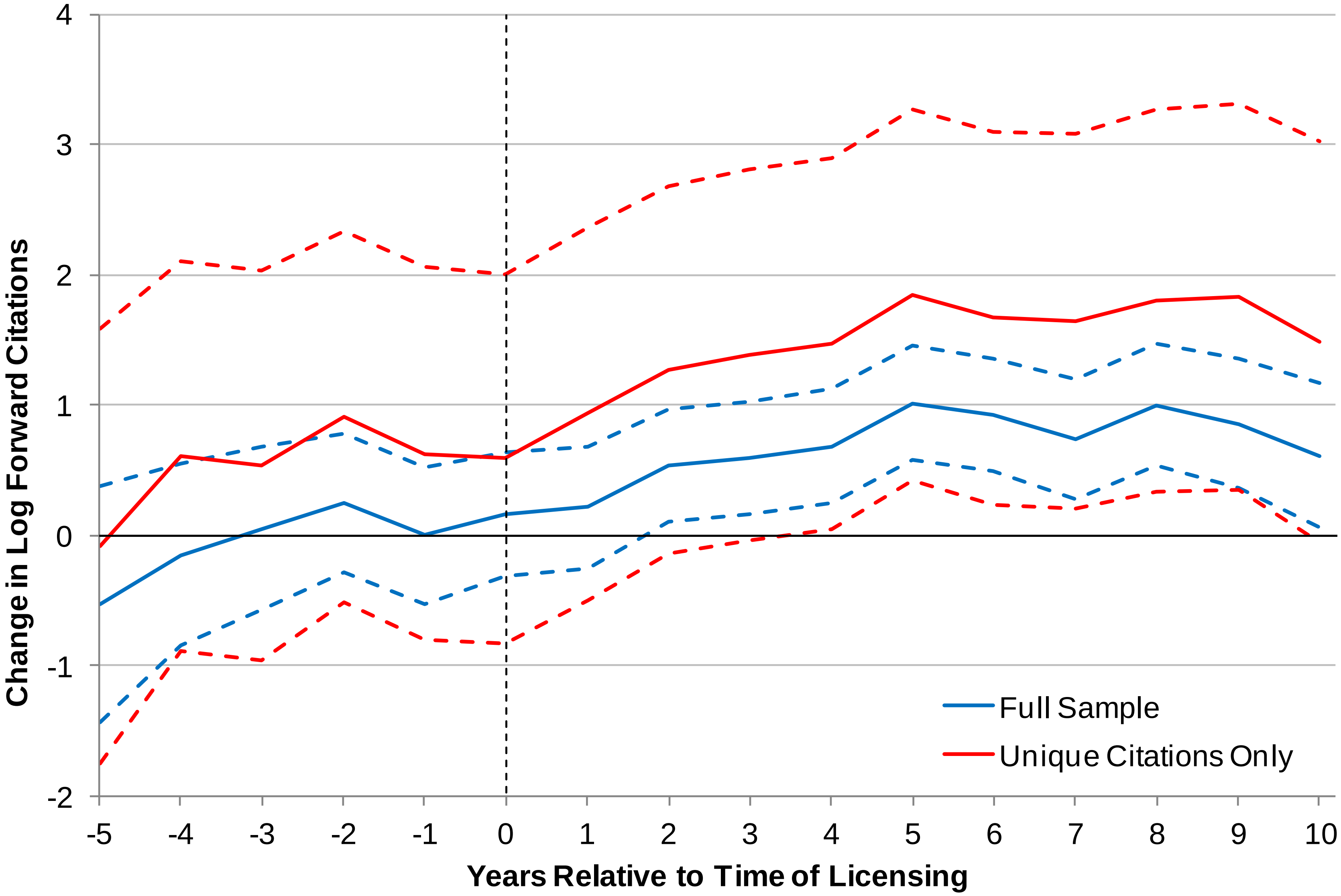
Robustness Checks: Matching to Control for Scope



Robustness Checks: Exclusive Licenses



Robustness Checks: Citations from Unique Inventors



Policy Conclusions

1. Licensing is consistent with the DOE's goals of fostering "scientific capabilities beyond the scope of academic and industrial institutions to benefit the Nation's researchers"

2. Policy reform in the past decades to lower the cost of licensing from the National Labs would seem to be well-justified

3. Anecdotally, several Lab technology transfer offices cite low funding as an impediment to broader technology transfer efforts. At the margin, my research argues that increasing technology transfer effort would accelerate the diffusion of the innovations developed at the Labs.

Limitations and Next Steps

- Only examining patented inventions and a subset of technology transfer activities
- Relying on a subset of outcome metrics that capture only a narrow view of technology transfer success – data on royalties and products are confidential
- I hope to add explanatory power with data from more of the National Labs
- Comparative work with University technology transfer could help identify best practices, ideas for reform

Thank You!

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Backup

Stylized facts on patents for public R&D

- The rationale for the public provision of R&D is rooted in the **public goods nature of knowledge**
- For private R&D, **the monopoly a patent confers slows diffusion**, all else equal. This is seen as a “necessary evil” to incentivize R&D investment.
- Public labs don’t respond to economic incentives; innovation effort isn’t affected by the lure of surplus profits, so patents for publicly funded inventions seem unfair and inefficient.
- However, the public R&D system relies on patents as a mechanism to **facilitate the transfer of knowledge from innovators to commercializers**.
- For many public inventions, the (public) returns to the public investment can only be realized through new product development.

Conclusions

1. For patents of similar substantive content, the effect of licensing on diffusion is even greater than when technology areas are not controlled for. This could indicate crowding out or cumulativeness in the Lab patent portfolio.

2. Exclusive licenses have approximately the same (positive) effect on technology diffusion as non-exclusive licenses.

3. Counterintuitively, licensing increases the rate of forward citations from new licensees faster than citations from incumbents. This could indicate greater concentration in the citations to unlicensed patents rather than greater diversity in licensed patents.

Results for Exclusive Licenses Only

	Exclusive Licenses Only			
	(5)	(6)	(7)	(8)
Dependent Variable	Citations from All Assignees		Citations from New Assignees	
Cumulative Citations	0.002	0.001	-0.085 ***	-0.070 ***
	(0.002)	(0.003)	(0.013)	(0.014)
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N * t	3,168	1,430	2,985	1,385

Model: negative binomial; standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Method Sketch

1. On the sample of 1,382 patents granted to the three Labs, classify each based on its patent abstract using a Bayesian model of document-level latent topic structure. (Blei, 2010)

2. Use the estimated document classification as patent-level covariates in a hazard regression using the lag between when a patent was filed and when a licensing agreement was announced as the outcome variable. (Cox, 1972)

3. Use the predicted hazard to calculate a time-dependent propensity score for a patent being licensed. Match licensed patents using a nearest neighbor algorithm. (Lu, 2005)

4. Construct a panel of patents by age and run a negative binomial difference in difference regression of annual forward citations on a limited set of covariates.

Topic Modeling

- Patent classification is based on the *physical phenomenon* a technology harnesses, not necessarily informative for what *"useful" application* a technology has.
- Automated classification can capture all aspects of a technology, as an inventor describes it.

Topic modeling approach (inspired by Blei, 2010)

1. Preprocess the text (remove punctuation, remove stop words, stem)

2. Construct a document-term matrix

3. Specify weakly informative priors and a Bayesian model structure

4. Fit the model with Monte Carlo methods

Topic modeling: The LDA model (Blei, 2010)

$$p(\boldsymbol{\beta}, \boldsymbol{\theta}, \mathbf{z}, \mathbf{w}) = \prod_{k=1}^{K} p(\beta_k) \prod_{d=1}^{D} p(\boldsymbol{\theta}_{\mathbf{d}}) \left(\prod_{n=1}^{N} p(z_{d,n}|\boldsymbol{\theta}_{\mathbf{d}}) p(w_{d,n}|\boldsymbol{\beta}, z_{d,n}) \right)$$

- The data-generation process:
  1. generate topics for entire corpus (K distributions of word compositions)
  2. within each document, generate a distribution of its topic composition
  3. assign each word position within a document a topic by drawing from the document's topic composition distribution
  4. draw a word from the chosen topic's word composition
- Inference for the unobserved variables is made by conditioning on the observed words and using a Gibbs sampler to estimate the joint posterior distribution of the observed/unobserved variables.

Topic modeling example

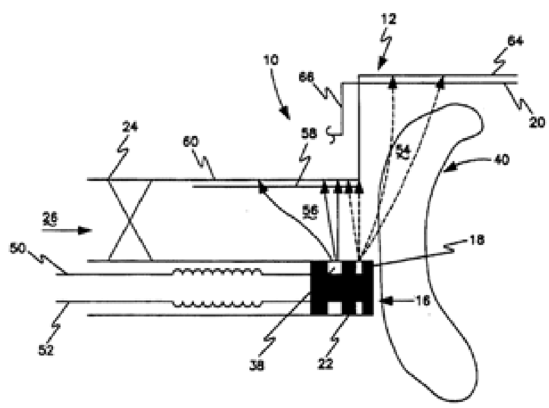
U.S. Patent 6,887,069 Real-time combustion controls and diagnostics sensors (CCADS)

The present invention is directed to an apparatus for the monitoring of the combustion process within a combustion system. The apparatus comprises; a combustion system, a means for supplying fuel and an oxidizer, a device for igniting the fuel and oxidizer in order to initiate combustion, and a sensor for determining the current conducted by the combustion process. The combustion system comprises a fuel nozzle and an outer shell attached to the combustion nozzle. The outer shell defines a combustion chamber. Preferably the nozzle is a lean premix fuel nozzle (LPN). Fuel and an oxidizer are provided to the fuel nozzle at separate rates. The fuel and oxidizer are ignited. A sensor positioned within the combustion system comprising at least two electrodes in spaced apart relationship from one another. At least a portion of the combustion process or flame is between the first and second electrodes. A voltage is applied between the first and second electrodes and the magnitude of resulting current between the first and second electrodes is determined.

Filed: Sept. 18, 2001. Granted: May 3, 2005. Patent application licensed exclusively to Woodward Industrial Controls on Dec. 28, 2001.

1	2	3	4	5	6	7	8	9	10	11	12	13
output	fluid	portion	tube	metal	apparatus	fuel	electrod	oxid	format	carbon	coal	contain
amplifi	separ	cut	section	composit	determin	chamber	measur	mix	earth	method	slurri	solut
capacitor	flow	mine	filter	pattern	surfac	cell	sensor	hydrogen	direct	provid	gasifi	mixtur
line	methan	energi	particul	titanium	method	generat	segment	compound	fractur	dioxid	gasif	form
remot	valv	receiv	interior	alloy	dust	engin	particl	pellet	inject	gase	direct	alkali
station	compris	bit	outlet	method	rock	nozzl	current	reactor	permeabl	invent	invent	compris
circuit	chamber	adjac	pass	base	sampl	oxid	detect	remov	plane	low	steam	agent
connect	mixtur	support	inlet	form	measur	turbin	sens	form	pressur	util	piston	step
provid	remov	time	clean	reduc	direct	feed	capacit	particular	provid	separ	produc	water
puls	process	mount	support	molten	mixtur	gaseous	temperatur	prepar	borehol	solid	pulver	acid

14	15	16	17	18	19	20	21	22	23	24	25
includ	combust	surfac	light	signal	assembl	materi	product	system	pressur	gas	bed
wall	air	electr	devic	use	seal	layer	liquid	includ	flow	stream	level
hous	zone	element	filter	time	mechan	form	temperatur	oper	control	sorbent	fluidiz
plate	heat	compris	signal	generat	provid	coat	process	control	improv	sulfur	select
shaft	system	conduct	sourc	control	solid	deposit	produc	miner	pump	contain	ash
relat	water	transmiss	fiber	provid	lower	organ	rang	modul	arrang	activ	provid
rotor	increas	compon	emiss	valu	posit	ceram	reaction	power	effici	stage	temperatu
inner	cool	connect	optic	voltag	drive	electrod	particl	condit	primari	regener	stirrer
outer	combustor	cabl	detect	phase	fire	electrolyt	catalyst	method	valv	remov	situ
coupl	hot	prefer	attach	convert	gate	contact	oil	ratio	compress	flue	fix



What is patent 6,887,069 “about”?

- LDA coding based on 25 topics and 283 NETL patents
  - 16%: fuel, chamber, cell, generat, engin,…
  - 15%: combust, air, zone, heat, system,…
  - 9%: electrod, measur, sensor, segment, particl,…
  - 6%: apparatus, determin, surfac, method, dust,…
- We learn *a little bit about a lot of patents*.
- But the PTO classification seems to do pretty well:
  - Class 431: … processes of combustion or combustion starting, and for apparatus peculiarly adapted to burn or ignite materials.
  - Subclass 12: Processes controlling the supply of fuel or air discharged into the combustion zone.

Another topic modeling example

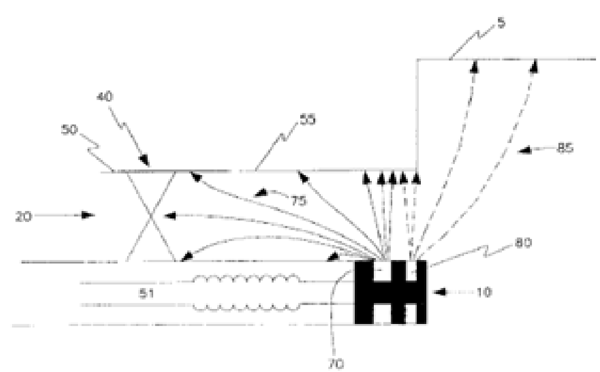
U.S. Patent 6,429,020 Flashback detection sensor for lean premix fuel nozzles

A sensor for detecting the flame occurring during a flashback condition in the fuel nozzle of a lean premix combustion system is presented. The sensor comprises an electrically isolated flashback detection electrode and a guard electrode, both of which generate electrical fields extending the walls of the combustion chamber and to the walls of the fuel nozzle. The sensor is positioned on the fuel nozzle center body at a location proximate the entrance to the combustion chamber of the gas turbine combustion system. The sensor provides 360.degree. detection of a flashback inside the fuel nozzle, by detecting the current conducted by the flame within a time frame that will prevent damage to the gas turbine combustion system caused by the flashback condition.

Filed: June 2, 2000. Granted: Aug. 6, 2002. Patent application licensed exclusively to Woodward Industrial Controls on Dec. 28, 2001.

1	2	3	4	5	6	7	8	9	10	11	12	13
output	fluid	portion	tube	metal	apparatus	fuel	electrod	oxid	format	carbon	coal	contain
amplifi	separ	cut	section	composit	determin	chamber	measur	mix	earth	method	slurri	solut
capacitor	flow	mine	filter	pattern	surfac	cell	sensor	hydrogen	direct	provid	gasifi	mixtur
line	methan	energi	particul	titanium	method	generat	segment	compound	fractur	dioxid	gasif	form
remot	valv	receiv	interior	alloy	dust	engin	particl	pellet	inject	gase	direct	alkali
station	compris	bit	outlet	method	rock	nozzl	current	reactor	permeabl	invent	invent	compris
circuit	chamber	adjac	pass	base	sampl	oxid	detect	remov	plane	low	steam	agent
connect	mixtur	support	inlet	form	measur	turbin	sens	form	pressur	util	piston	step
provid	remov	time	clean	reduc	direct	feed	capacit	particular	provid	separ	produc	water
puls	process	mount	support	molten	mixtur	gaseous	temperatur	prepar	borehol	solid	pulver	acid

14	15	16	17	18	19	20	21	22	23	24	25
includ	combust	surfac	light	signal	assembl	materi	product	system	pressur	gas	bed
wall	air	electr	devic	use	seal	layer	liquid	includ	flow	stream	level
hous	zone	element	filter	time	mechan	form	temperatur	oper	control	sorbent	fluidiz
plate	heat	compris	signal	generat	provid	coat	process	control	improv	sulfur	select
shaft	system	conduct	sourc	control	solid	deposit	produc	miner	pump	contain	ash
relat	water	transmiss	fiber	provid	lower	organ	rang	modul	arrang	activ	provid
rotor	increas	compon	emiss	valu	posit	ceram	reaction	power	effici	stage	temperatur
inner	cool	connect	optic	voltag	drive	electrod	particl	condit	primari	regener	stirrer
outer	combustor	cabl	detect	phase	fire	electrolyt	catalyst	method	valv	remov	situ
coupl	hot	prefer	attach	convert	gate	contact	oil	ratio	compress	flue	fix



What is patent 6,429,020 “about”?

- LDA coding based on 25 topics and 283 NETL patents
  - 16%: fuel, chamber, cell, generat, engin,…
  - 14%: electrod, measur, sensor, segment, particl,…
  - 10%: combust, air, zone, heat, system,…
  - 6%: surfac, electr, element, compris, conduct,…

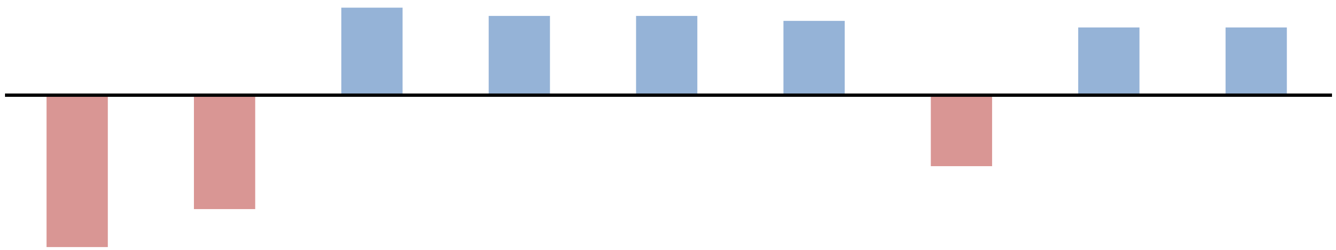
- This time the PTO classification doesn’t tell us much about what this invention could be used for – no mention of combustion at all:
  - Class 431: the generic class for … process which involve a chemical reaction for determining qualitatively or quantitatively the presence of a chemical element, compound or complex … [including] tests or measurements with methods of regulating a chemical reaction …
  - Subclass 153: Measurement of electrical or magnetic property or thermal conductivity … Subject matter wherein an electric or magnetic property of an ionized gas is measured as a step in analysis.(1) Note. The gas may be the result of heating a liquid sample.(2) Note. Wave or particle radiation as well as use of electric discharge to ionize the gas is included herein.

Cox proportional hazard model

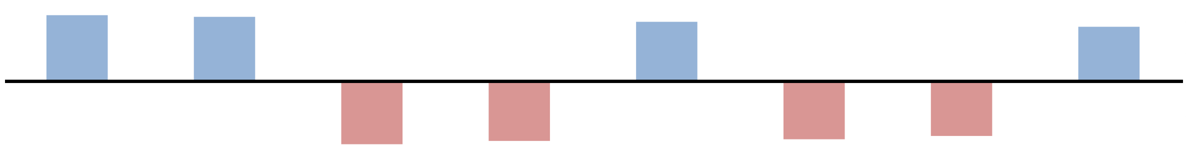
- Using the logit-transformed document-level topic proportions as covariates, I estimate a Cox proportional hazard model
- Years since a patent was filed is the “age” of the observations
- Whether or not a patent was licensed as of March 2013 is the indicator for censoring (i.e. “failure”).
- With 1,382 observations and 420 licenses, a topic model with 50 topics performs reasonably well at identifying technology areas that lead to more frequently licensed patents

The topics of patents more likely to be licensed

1	2	3	4	5	6	7	8	9
reactor	imag	ion	semiconductor	structur	inner	metal	form	particl
contain	system	plasma	capabl	devic	thin	temperatur	solut	method
vessel	plane	generat	nanocryst	provid	unit	coat	phase	densiti
pressur	object	sourc	radiat	form	outer	combin	method	size
water	refer	target	energi	porous	sheet	heat	precursor	describ
cool	diffract	chamber	link	techniqu	defin	alloy	polar	aerosol
dispos	optic	extract	portion	electrochem	lamin	resist	solvent	distribut
steam	pattern	produc	describ	electron	medium	thereof	fluid	vapor
tank	posit	antenna	compound	fire	plural	prefer	molecul	mean
pipe	test	neutron	electromagnet	low	perform	transit	dispers	reduc



10	11	12	13	14	15	16	17
layer	catalyst	field	dna	invent	support	protein	surfac
substrat	reaction	magnet	singl	relat	tube	acid	bond
film	acid	detect	crystallin	increas	includ	method	molecul
deposit	hydrogen	frequenc	produc	use	instrument	specif	wherein
form	contain	nmr	heterostructur	low	assembl	peptid	assembl
surfac	compound	signal	segment	reduc	portion	amino	silicon
thin	process	reson	nanostructur	addit	core	bind	function
materi	product	object	nanowir	particular	extend	provid	plural
onto	mixtur	puls	strand	effici	posit	pair	monolay
vacuum	carbon	imag	clone	accord	head	orthogon	improv

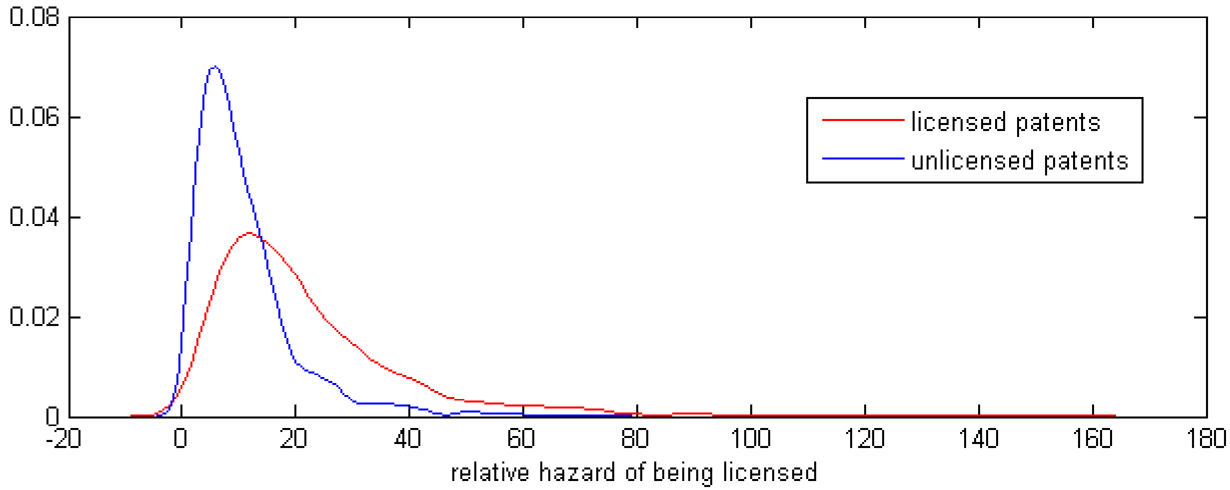


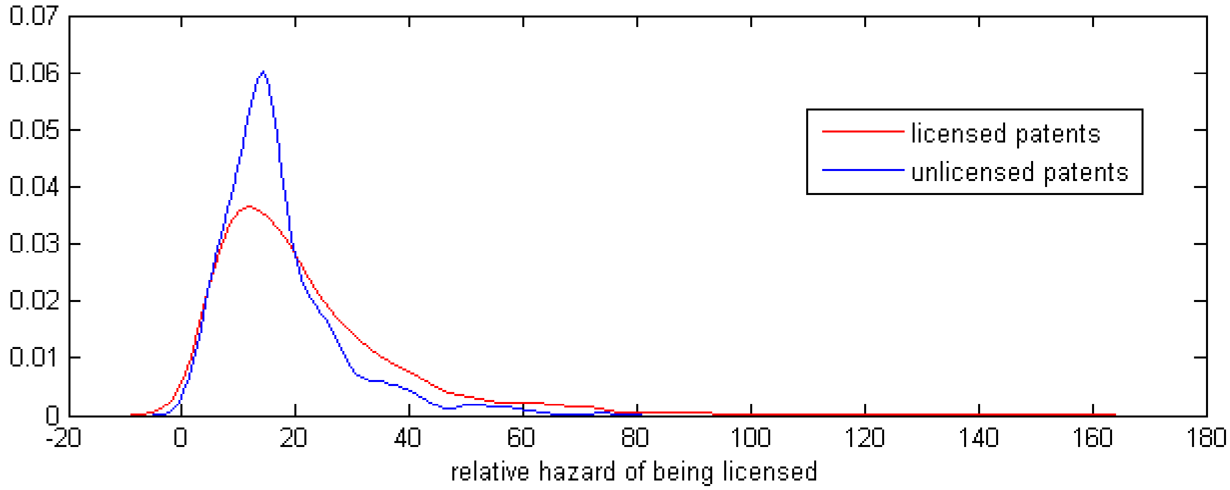
The topics of patents more likely to be licensed

- What is Topic 3?
  - Most frequently occurring words: “ion”, “plasma”, “generat”, “sourc”, “target”, “chamber”, “extract”, “produc”, “antenna”, “neutron”
- Which licensed patents consist of Topic 3 words?

Patent Number	Fraction Topic 3	Title	Patent Filed	Patent Licensed
6,907,097	54%	Cylindrical Neutron Generator	Mar 2002	June 2005
7,176,469	43%	Negative ion source with external RF antenna	Sept 2003	June 2005
7,342,988	39%	Neutron tubes	Feb 2003	June 2005
6,094,012	39%	Low energy spread ion source with a coaxial magnetic filter	Nov 1998	Mar 2000

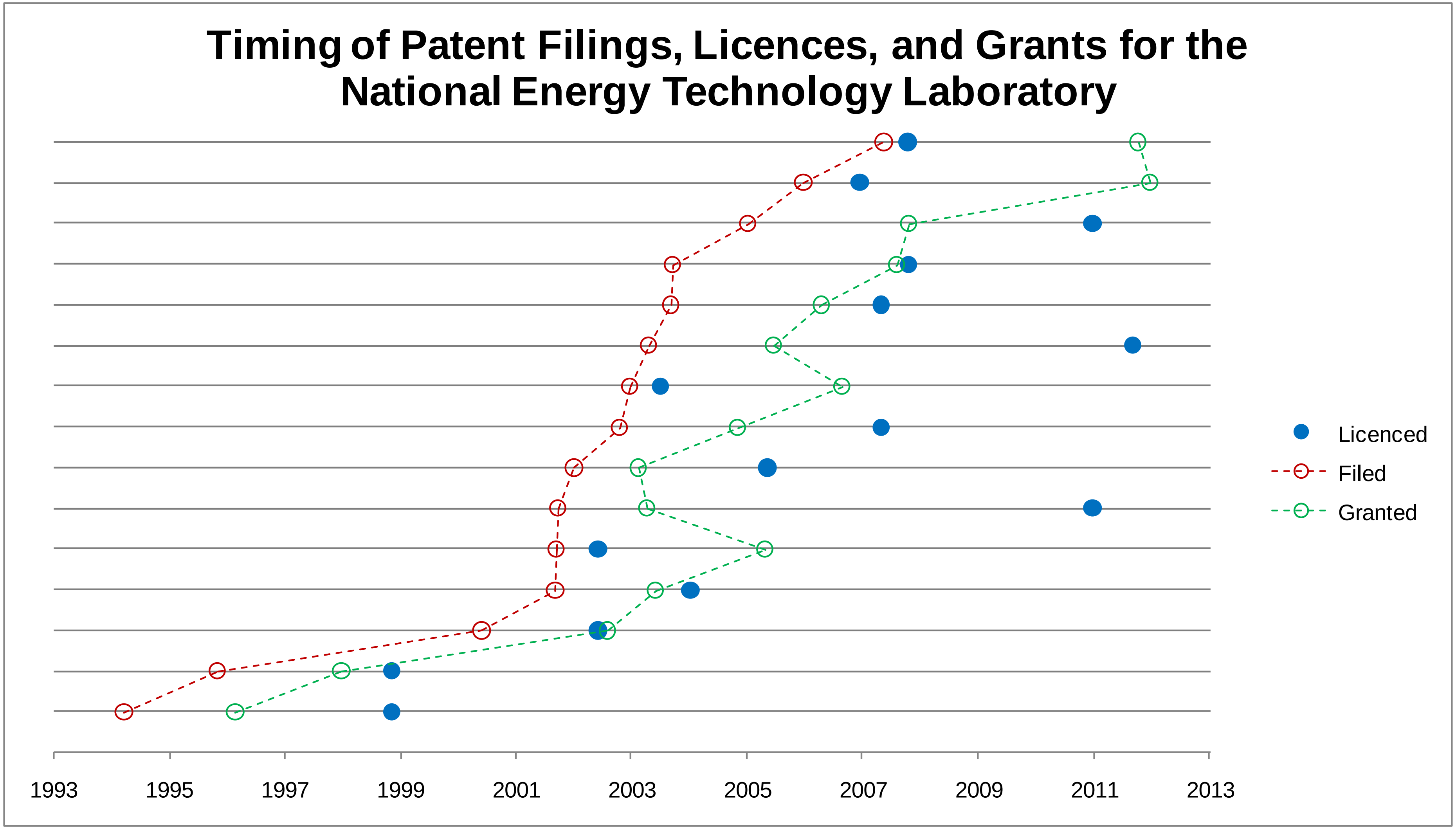
Matching on Relative Hazard





Matching on a time-dependent propensity score (Lu, 2005)

Formal IP



Timing of Patent Filings, Licences, and Grants for the National Energy Technology Laboratory
Licenced
Filed
Granted
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013

Introduction

- Innovation is stimulated by both supply-push and demand-pull, and there are public policies that affect one or both "forces"
- Relatively little research has been done to explicitly evaluate the effectiveness of public policy to directly stimulate supply-push drivers of innovation (with the exception of universities).
- In particular, there is a gap in the literature of studies of commercialization of technologies developed by the government, which I characterize as public institutions that specialize in supply-push operations, engaging with demand-pull forces
- I hope to fill this gap by quantitatively studying the commercialization of U.S. National Laboratory inventions