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

Gabe Chan
Harvard Kennedy School of Government
Harvard Energy Technology Innovation Policy Group

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“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.”

Congressman Randy Hultgren (Republican, Illinois’14th District) 
December 7, 2012
“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

1.2 Aggregate Fiscal Year 2011 Lab Budget by R&D Category
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
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
The Story of CCADS

- 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.
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.
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 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?
Government Patenting and Licensing by Agency

- **Avg Number of Patents per Year (2008-2010)**

- **New Patents Issued**
- **New Invention Licences**

- **Agencies**
  - NASA
  - USDA
  - DHS
  - DOC
  - DOD
  - DOE
  - DOI
  - DOT
  - EPA
  - HHS
  - VA

- **Legend**
  - New Patents Issued
  - New Invention Licences
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

<table>
<thead>
<tr>
<th>Exclusive and Non-Exclusive Licenses</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
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<tr>
<td>Dependent Variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Citations</td>
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<tr>
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<td>(0.271)</td>
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<td></td>
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<tr>
<td>Licensed 0 yrs</td>
<td>0.168</td>
<td>(0.242)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensed 2 yrs</td>
<td>0.539 *</td>
<td>(0.220)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensed 4 yrs</td>
<td>0.686 **</td>
<td>(0.223)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensed 6 yrs</td>
<td>0.926 ***</td>
<td>(0.222)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensed 8 yrs</td>
<td>1.004 ***</td>
<td>(0.236)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year FE?</td>
<td>Yes</td>
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<td>N</td>
<td>478</td>
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<td></td>
</tr>
<tr>
<td>N * t</td>
<td>3,889</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Change in Log Forward Citations

Years Relative to Time of Licensing

(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

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Citations from All Assignees</th>
<th>Citations from New Assignees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Citations</td>
<td>-0.001 (0.002)</td>
<td>-0.004 (0.003)</td>
</tr>
<tr>
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<td>0.245 (0.271)</td>
<td>0.113 (0.362)</td>
</tr>
<tr>
<td>Licensed 0 yrs</td>
<td>0.168 (0.242)</td>
<td>0.079 (0.332)</td>
</tr>
<tr>
<td>Licensed 2 yrs</td>
<td>0.539 * (0.220)</td>
<td>0.552 (0.315)</td>
</tr>
<tr>
<td>Licensed 4 yrs</td>
<td>0.686 ** (0.223)</td>
<td>0.812 * (0.319)</td>
</tr>
<tr>
<td>Licensed 6 yrs</td>
<td>0.926 *** (0.222)</td>
<td>1.162 *** (0.324)</td>
</tr>
<tr>
<td>Licensed 8 yrs</td>
<td>1.004 *** (0.236)</td>
<td>1.321 *** (0.347)</td>
</tr>
</tbody>
</table>

| 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

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Citations from All Assignees</th>
<th>Citations from New Assignees</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cumulative Citations</strong></td>
<td>0.002 (0.002)</td>
<td>-0.085 *** (0.013)</td>
</tr>
<tr>
<td>Licensed -2 yrs</td>
<td>-0.025 (0.403)</td>
<td>1.130 (0.871)</td>
</tr>
<tr>
<td>Licensed 0 yrs</td>
<td>0.135 (0.283)</td>
<td>0.471 (0.833)</td>
</tr>
<tr>
<td>Licensed 2 yrs</td>
<td>0.717 ** (0.233)</td>
<td>1.620 * (0.820)</td>
</tr>
<tr>
<td>Licensed 4 yrs</td>
<td>0.802 ** (0.239)</td>
<td>1.795 * (0.833)</td>
</tr>
<tr>
<td>Licensed 6 yrs</td>
<td>0.763 ** (0.243)</td>
<td>1.793 * (0.842)</td>
</tr>
<tr>
<td>Licensed 8 yrs</td>
<td>1.053 *** (0.252)</td>
<td>1.952 * (0.879)</td>
</tr>
<tr>
<td>Year FE?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Yes</td>
</tr>
<tr>
<td>Matched Sample?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>392</td>
<td>171</td>
</tr>
<tr>
<td>N * t</td>
<td>3,168</td>
<td>1,430</td>
</tr>
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</table>

Model: negative binomial; standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001
Robustness Checks: Matching to Control for Scope

Change in Log Forward Citations

Years Relative to Time of Licensing

-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10

Full Sample
Matched Sample

-2
-1
0
1
2

Change in Log Forward Citations

Full Sample
Matched Sample
Robustness Checks: Exclusive Licenses

Change in Log Forward Citations

Full Sample
Exclusive Licenses Only

Years Relative to Time of Licensing

Change in Log Forward Citations

Full Sample
Exclusive Licenses Only
Robustness Checks: Citations from Unique Inventors

Change in Log Forward Citations vs Years Relative to Time of Licensing

- Full Sample
- Unique Citations Only

Legend:
- Blue: Full Sample
- Red: Unique Citations Only
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!

gabe-chan@hksphd.harvard.edu
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.
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

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</tr>
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<td>0.880 ** (0.327)</td>
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<td></td>
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<td>2.293 (1.311)</td>
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<tr>
<td>Year FE?</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
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Model: negative binomial; standard errors in parentheses; * p < 0.05, ** p < 0.01, *** p < 0.001
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.
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.
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)

\[
p(\beta, \theta, z, w) = \prod_{k=1}^{K} p(\beta_k) \prod_{d=1}^{D} p(\theta_d) \left( \prod_{n=1}^{N} p(z_{d,n} | \theta_d) p(w_{d,n} | \beta, z_{d,n}) \right)
\]

- 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.
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.

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° 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.

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
The topics of patents more likely to be licensed

- What is Topic 3?

- Which licensed patents consist of Topic 3 words?

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Fraction Topic 3</th>
<th>Title</th>
<th>Patent Filed</th>
<th>Patent Licensed</th>
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</thead>
<tbody>
<tr>
<td>6,907,097</td>
<td>54%</td>
<td>Cylindrical Neutron Generator</td>
<td>Mar 2002</td>
<td>June 2005</td>
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<td>7,176,469</td>
<td>43%</td>
<td>Negative ion source with external RF antenna</td>
<td>Sept 2003</td>
<td>June 2005</td>
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<td>7,342,988</td>
<td>39%</td>
<td>Neutron tubes</td>
<td>Feb 2003</td>
<td>June 2005</td>
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<td>6,094,012</td>
<td>39%</td>
<td>Low energy spread ion source with a coaxial magnetic filter</td>
<td>Nov 1998</td>
<td>Mar 2000</td>
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</table>
Matching on Relative Hazard

Matching on a time-dependent propensity score (Lu, 2005)
Timing of Patent Filings, Licences, and Grants for the National Energy Technology Laboratory
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