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Dear Search Committee Chair,

I am writing to apply for the NBER Productivity, Innovation and Entrepreneurship Program's postdoctoral fellowship in Innovation Policy for the 2015-2016 academic year. I am currently a Ph.D. candidate in Public Policy at the Harvard Kennedy School (anticipating completion in May 2015) and Research Fellow at the Belfer Center for Science and International Affairs. My primary research interests are in innovation policy in the energy sector, which has inspired me to conduct research on several aspects of policies affecting innovation at the U.S. Department of Energy (DOE) and its National Laboratories. This letter details my proposal for a year-long research initiative on technology transfer arrangements at the National Labs that extends the work I conducted in preparation of my job market paper, "The Commercialization of Publicly Funded Science: How Licensing Federal Laboratory Inventions Affects Knowledge Spillovers."

The federal government allocates $13 billion (FY 2011) toward R&D activities at the seventeen DOE National Labs, constituting three-quarters of all R&D funding allocated to Federally Funded R&D Centers (FFRDCs). Since the 1980 Stevenson-Wydler Act, FFRDCs have been legislatively required to appropriate funds toward technology transfer and commercialization, resulting in over 1,000 newly issued patents per year and a stock of over 4,000 invention license agreements (National Science Board 2014). However, despite these totals and multiple policy reforms over the past three decades to enhance technology transfer at FFRDCs, there is limited evidence for the relationship between formal transactions over intellectual property and innovation spillovers from federally sponsored R&D[1].

Public funding for R&D is justified by inappropriable positive spillovers that arise when actors discover new ideas or technologies that have unanticipated applications (Nelson 1959; Arrow 1962), but realizing these spillovers requires complementary investment in downstream development and commercialization of follow-on innovation (Scotchmer 1991; Green and Scotchmer 1995). While transferring a publicly funded invention increases a licensee's incentive to invest in the invention's commercialization – potentially *increasing* the rate of innovation spillovers, transfer agreements also typically exclude other firms from utilizing a publicly funded technology – potentially *slowing* the rate of innovation spillovers. This theoretical ambiguity in whether technology transfer agreements increase or decrease the rate of innovation spillovers, makes this a policy-relevant area for empirical research.

In my job market paper, I focus on the most prominent and thoroughly utilized technology transfer mechanism at the National Labs, patent licensing agreements between a Lab and a private sector partner. These agreements transfer title for a patented National Lab invention from the Lab (or its operator) to a private sector partner under conditions that the licensee develop the technology along a

1 There are a small number of notable exceptions. Jaffe and Lerner (2001) study the effect of policy reforms and management practices on patenting and technology transfer activities at the DOE FFRDCs; however, the authors were limited by data availability and only examined aggregate patterns without specifically studying knowledge diffusion outcomes. In a more narrowly focused study, Adams et al. (2003) utilize two surveys on FFRDCs from the late 1990s to conclude that cooperative research and development agreements (CRADAs) between an FFRDC and an industrial lab induce greater patenting by the industrial lab. In an even more focused study, Mowery and Ziedonis (2001) study spin-off formation of companies from one National Lab. In contrast to FFFRDC technology transfer, technology transfer in the context of universities and colleges, enabled by the 1980 Bayh-Dole Act, has received significant attention in the innovation policy literature.

predefined commercialization schedule. In my paper, I provide the first quantitative evidence that patent licensing agreements between the National Labs and private sector licensees lead to greatly increased rates of innovation spillovers. Specifically, I find that the annual citation rate to licensed patents increases by 31 – 48% after licensing, relative to unlicensed Lab patents[2]. Additionally, I find that at least 75% of follow-on invention induced by licensing occurs outside of the licensing firm and that these follow-on innovations are unlikely to represent strategic patenting affects.

In my paper, I introduce a novel identification strategy broadly applicable to empirical innovation studies that rely on patent data with a sample of "treated patents" for which there is a relatively large pool of potential "control patents." In the literature, matching on USPTO classification remains a popular method to identify "control patents" despite several problematic issues utilizing USPTO classification to account for secular technology trends[3]. Motivated by the issues with using USPTO classifications and capitalizing on recent developments in automated content analysis in computer science, I match licensed patents to unlicensed patents based on a classification estimated from a machine learning algorithm applied to the text of the patent abstracts. I use the Latent Dirichlet Allocation (LDA) algorithm, which uses a Bayesian model of word co-occurrence, to classify documents into endogenously defined technology topic areas (Blei, Ng, and Jordan 2003; Blei and Lafferty 2007; Blei 2010).

The LDA model provides a quantitative description of each patent in terms of the proportion of words within the document that probabilistically are drawn from a distribution of frequently co-occurring words. In my job market paper I detail the usefulness of my matching approach by demonstrating:

- Incorporating the text of patent abstracts to identify "control" patents is feasible but – as with all matching designs – requires researcher judgment as to how observed covariates are utilized in identifying matches. Still, the causal estimates I present in my paper appear robust to many different matching design specifications.
- Unlike matching on USPTO classification, matching on patent abstracts can identify more similar matches in a way that scales with the size of the pool of potential control patents. Matching on USPTO classification requires exact matching of patents within categories, but matching on patent text can offer a continuous measure of technological similarity, which can be useful in other applications.
- Most importantly, matching based on the text of patent abstracts is less susceptible to omitted variable bias than matching based on the USPTO primary classification, quantified by Rosenbaum bounds estimated for a variety of matching designs.

Looking to my research agenda following the completion of my Ph.D., there are several expansions of my job market paper that I would like to make to prepare this work for publication in a leading economics journal. The NBER Productivity, Innovation and Entrepreneurship Program is an ideal place to continue the work on this project because of its data resources, its network of professors and fellows working on similar topics, its convening power with other researchers and policymakers, and its unique institutional structure that would allow me the freedom to pursue new research directions.

As a postdoctoral fellow, I would hit the ground running on several immediate extensions to my job market paper. First, I would like to expand the coverage of my dataset on FFRDC licensing agreements. In my job market paper, I was able to collect comprehensive licensing data from five

[2] Because of the central place of innovation spillovers in understanding the effectiveness of technology transfer efforts in fulfilling the original mandate of public R&D, the key dependent variable I utilize in my paper is the differential rate of forward citations received by licensed versus unlicensed patents.

[3] Examples of such issues include: PTO classification based on technical characteristics rather than potential application, inconsistent granularity of classes, revision of classes over time, noise induced by random assignment of patent examiners, the possibility for patents to belong to multiple classes is difficult to capture in a matching design, and patent classes are necessarily coarse and do not scale with sample size.

National Labs from 2000 – 2010, but a natural extension would be to leverage my current results to collect more data from other FFRDCs by demonstrating the policy relevance of my analysis. Second, I would like to explore the heterogeneity in the effect of licensing on spillover creation across technology areas. My analysis classifies patents based on the text of their abstracts, and a useful next step would be to explore whether certain technology areas are more likely to induce greater spillovers after licensing than others. Further, I would also like to examine heterogeneity in treatment effects stratified by the pre-licensing citations of a patent and by the length of patent grant delay. Third, I have conducted two sets of face-to-face interviews with technology transfer professionals at the National Labs. These interviews have been immensely helpful for understanding the dynamics of technology transfer agreements. In the next steps of my research, I would like to conduct more of these interviews to gain a deeper understanding of the mechanisms by which matches between National Lab inventors (and their technologies) and private sector licensees occur.

In addition to these immediate next steps that I would begin at the beginning of a postdoctoral fellowship, I would also use this opportunity to expand the impact of my job market paper research for both innovation researchers and policymakers. First, the methodology I develop to utilize the text of patent abstracts in an empirical matching design is broadly applicable to many other empirical studies of innovation. As an NBER Innovation Policy Postdoctoral Fellow, I would use the program's network to explore the possibilities to apply and improve this methodology in other contexts. Second, while I did some work to validate the advantages of matching based on the text of patent abstracts, I would like to provide more thorough evidence. If I could find the right example, I would like to compare several matching approaches against an experimental benchmark. Third, I would like to expand this research to cover FFRDC research in other government agencies as well as intramural R&D. In particular, I would be interested in collaborating with other NBER fellows working in this area to apply the ideas in my paper to the National Institutes of Health. Fourth, I am interested in other modes of FFRDC technology transfer. In my paper, I study patent licensing, but other mechanisms, such as cooperative research and development, spin-outs, and human capital exchanges are also important mechanisms for transferring technologies and are ripe for empirical evaluation. Finally, I am very interested and motivated to translate the research I have conducted for a policymaking audience. Policies shaping technology transfer at FFRDCs and the National Labs are currently very much in flux[4], increasing the potential impact of this research.

Taking the next step in my career as an NBER postdoctoral fellow would allow me to leverage the resources and personal connections available at the Bureau to make a number of important improvements to push my paper over the publication "goal line." More importantly, the unique resources at the NBER would simultaneously allow me to begin a number of new research initiatives that leverage the expertise in FFRDC technology transfer I have developed and the ongoing research at NBER to develop timely policy-relevant research. I would enjoy discussing my qualifications and fit for this position with you in the weeks to come. If you require any additional material or information, please do not hesitate to ask. Thank you very much for your consideration.

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[4] In July 2014, the U.S House of Representatives passed H.R. 5120, the Department of Energy Laboratory Modernization and Technology Transfer Act of 2014, which would reduce certain bureaucratic requirements for technology transfer while giving new authority for DOE FFRDCs to adopt best practice technology transfer activities of other federal agencies. As of October 2014, the bill is in committee in the Senate. In a parallel effort, the White House initiated a process in October 2011 under presidential memorandum to accelerate technology transfer at all FFRDCs by requiring federal agencies to develop five-year plans to improve technology transfer goals and metrics, streamline technology transfer processes, and develop regional commercialization partnerships. Finally, the President's Fiscal Year 2015 budget request included several relevant new initiatives, described in the President's Management Agenda as priorities for "accelerating and institutionalizing lab-to-market practices," which reflect "the Administration's commitment to accelerating and improving the transfer of the results of Federally-funded research to the commercial marketplace."

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