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Mobility of Inventors and Manipulating the Innovation Production Function

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Abstract

The impact of labor market and mobility of R&D personnel on innovation is increasingly a central concern for understanding innovation. Prior research has largely examined this relationship by analyzing the implications of treating labor market as a conduit of knowledge. But labor market and mobility options also conditions the terms at which R&D personnel are ready to offer their services. Given that in addition to monetary rewards, R&D personnel are also motivated by the nature of research they do, the labor market should also influence the nature of innovation through altering the bargaining position of researchers. In this paper, we use this insight to examine the impact of an exogenenous shock that increased the mobility options of a subset of R&D personnel on the way innovations are produced within firms. Using a difference-in-differences methodology, we find that the R&D personnel whose mobility options increased had a greater increase in their likelihood of working independently or in larger more significant projects. Their propensity to work on organizationally relevant projects and using in-house technologies to do so also increased.

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1 Introduction

The impact of labor market and mobility of R&D professionals on industrial innovation is an increasingly important subject of inquiry by strategy scholars (Agarwal et al. 2009; Almeida and Kogut 1999; Song et al. 2003; Corredoira and Rosenkopf 2010; Rosenkopf and Almeida 2003). This research has identified significant influences of mobility, both positive and negative: mobility helps firms overcome myopia (Almeida and Kogut 1999; Corredoira and Rosenkopf 2010; Rosenkopf and Almeida 2003) but it also creates a threat of knowledge leakage prompting a number of defensive strategies such as aggressive IP protection (Agarwal et al. 2009) and reducing risk taking (Conti 2013). This literature largely treats firms as unitary actors and analyzes the different implications of viewing the labor market primarily as a conduit of knowledge, perspectives that have indeed yielded considerable insights.

Yet, apart from serving as a conduit of knowledge, the labor market also determines the terms at which R&D personnel agree to work for the firm (Thompson James 1967; March and Simon 1958). These terms should also include the nature of R&D tasks the personnel undertake if the task characteristics (for e.g. independence and significance) are important to them and can't be easily monetized (Katz 2008, 2005; Sauermann and Cohen 2010; Stern 2004). Consequently we should expect the labor market conditions to influence the way innovation is produced within the firm, an observation whose implications are little examined in the literature. We propose to build on and extend the literature connecting technology labor markets and innovation by viewing the production of innovation as an outcome of bargaining between R&D professionals and the firm. We argue that labor market, by influencing relative bargaining power, significantly influences a firm's innovation production function: what knowledge inputs are utilized to produce innovation and by whom (i.e. which R&D personnel) and in what kind of teams. In particular, we examine how an increase in job opportunities for a R&D professional impacts her propensity to work independently, to work on large significant projects and the firm-specificity of technologies that she employs.

As the external job opportunities for a particular R&D professional increase, the individual's dependence on the firm decreases and her ability to get on or start a project with her desired properties increases. The increased possibility of turnover also creates significant challenges for the firm, both a threat of knowledge leakage as well as a threat of disruption leading to significant time delays which imposes competitive costs in fast paced high-technology environment. Managing these challenges also involves reconfiguring the innovation production function (Zhao 2006; Carley 1992). For instance, by ensuring that inventors use in-house technologies in the project reduces the project's vulnerability to turnover since it makes it easier to find an internal replacement. The innovation production function is the output of balancing these two forces: the R&D professional's desire for certain kind of projects and the firm's challenges. In this paper, we examine the impact of these two forces on the innovation production function.

Analyzing how the innovation production function varies at the individual level with the individual's mobility is important for both theoretical and empirical reasons. It provides a novel insight to our theoretical understanding of how mobility relates to the flow of knowledge between firms. Much attention is focused on the frictions that exist in the supply of knowledge to the destination firms (Agarwal et al. 2009; Ganco et al. 2014; Song et al. 2003; Tzabbar 2009). This literature implicitly assumes that increased mobility either does not affect or increases the demand for external knowledge albeit in varying degrees. Our study shows that this may not always be true since mobility can induce a preference for internal technologies within firms.

This individual-level analysis also points towards a paradoxical strategic challenge presented to firms by increased mobility of its knowledge workers which can't be easily seen in firm-level analyses. On the one hand, increased mobility increases the availability of foreign knowledge allowing the firms to experiment with a broader pool of technologies. On the other hand, increased mobility also increases the incentives to restrict the use of unfamiliar technologies. So how is the firm to manage this paradox? Our individual level analysis suggests that firms might distinguish between less and more mobile R&D personnel and use a different innovation production function for each in order to satisfy both the goals. This possibility can only be identified through an individual level analysis and not by examining the aggregate behavior at the firm level since at the aggregate level, one can only observe the average effect of these two contradictory forces.

This study also has important implications for firm strategy because they highlight hitherto unexplored constraints on how firms can utilize their human capital in producing their intellectual capital. We argue that firms are constrained in matching their human capital with research projects by the increased bargaining power of more mobile personnel as well as the two challenges of knowledge appropriation and disruption. The implications of these constraints on how innovation is produced within firms is not well understood but points toward why firms' response to reallocate human resources to avail opportunities in a growing product markets might be conditioned by labor market conditions that the growth might engender.

Examining how a firm's innovation production function varies with the changing likelihood of an individual engineer's turnover is an empirical challenge because mobility is tied to ability, and ability may influence innovation production function. We exploit a legal change in immigration law that exogenously increased the employment prospects of only a section of R&D work force - the H-1B immigrants - without influencing their quality of human capital. This allows us to employ a difference-in-differences methodology to investigate how this change in mobility prospects altered the kind of teams immigrants worked in compared to non-immigrants and the nature of knowledge inputs used as well as the kind of innovations produced by immigrants compared to non-immigrants. We find that this increase in employment prospects increased the proclivity of immigrant R&D professionals to get independent charge of projects, or work in larger projects with greater scope. We also find that the immigrants used more in-house technologies compared to external technologies and also produce innovations that are of less utility outside of the firm.

2 Theory & Hypotheses

Scholars of technology strategy have recognized that the labor market for R&D professionals (referred henceforth as labor market) considerably influences the production of innovation in industrial firms (Agarwal et al. 2009; Almeida and Kogut 1999; Marx et al. 2009; Song et al. 2003; Gittelman

2006; Corredoira and Rosenkopf 2010; Rosenkopf and Almeida 2003) by influencing the availability and distribution of the two crucial inputs into the innovation production function: knowledge (Agarwal et al. 2009; Almeida and Kogut 1999; Corredoira and Rosenkopf 2010; Conti 2013) and labor (Kerr and Lincoln 2010; Marx et al. 2009).

A lot of scholarly attention has been devoted to the impact of technology labor market on the availability and flow of knowledge and its strategic implications for innovation. The labor market serves as one of the major, if not the most important, conduit of knowledge (Almeida and Kogut 1999; Agarwal et al. 2009; Conti 2013). Much of the knowledge used in innovation is tacit which requires face-to-face interactions and experiential teaching to flow (Vincenti 1990; de Vries and de Vries 2003; Senker 1995). Such knowledge remains with individuals as unarticulated heuristics, guidelines, technological experiments that did not work, and technology-specific findings, many a times without well understood underlying theoretical principles (Vincenti 1990; Senker 1995). Hence, the flow of this knowledge considerably depends on the mobility of R&D personnel. This creates considerable challenge for firms to prevent the leakage of knowledge through mobility and firms adopt a number of defensive strategies such as aggressive litigation to protect intellectual property (Agarwal et al. 2009) and reducing risk taking (Conti 2013).

This research however treats firms as unitary actors and consequently does not examine the impact of individual professionals' preferences on how the innovation production processes within firms change when labor market conditions change. The innovation production function involves allocation of tasks - who is to work in which projects and with what teams and using what technologies, and because the R&D function is a specialized activity that affords considerable say to the professional (Sauermann and Cohen 2010; Cohen and Sauermann 2007; Bailyn 1985), the bargaining power of inventors and their motivations should also play a role in shaping how a firm changes its innovation process when labor market conditions change (Thompson James 1967). This role has not been examined in depth, a task we take up further.

It is almost trivial to note that the nature of labor market influences innovation by impacting the availability of R&D personnel who are ultimately responsible for innovation. This is however significant when we recognize the unique nature of innovative process and the inventors' crucial role in it. The inventive process is cumulative, uncertain and requires specialized knowledge and skills (Freeman and Soete 1997; Nelson 1962; Vincenti 1990; Cohen and Sauermann 2007; Katz 2008). The uncertainty makes monitoring and evaluating performance extremely difficult (Schainblatt 1982), this combined with the specialized nature of skills required gives a lot of say to inventors in the innovation production process (Cohen and Sauermann 2007; Bailyn 1985). The cumulative nature of innovation within firms implies that the knowledge of historic precedence is important (Nelson and Winter 1982; Dosi 1988). This knowledge (what problems have been attempted with the current technologies, with what degree of success, what technology specific parameters work, need to be employed and avoided and for what historical reasons etc.) is typically acquired by experiential hit and trial learning which is not amenable to codification and thus owned by the individual (Vincenti 1990; Senker 1995). This makes the innovation projects prone to disruption and failure in face of turnover, a vulnerability that becomes especially salient when labor market conditions become favorable to inventors (Carley 1992).

Through regulating the supply of R&D labor and providing alternate employment opportunities to the R&D workforce, the labor market influences the bargaining power of the R&D workforce relative to the firm (Pfeffer and Salancik 1978; Lazear 2009; Thompson James 1967). The greater are the external job opportunities of the R&D employees, the greater is the bargaining power of the employees and vice-versa (March and Simon 1958). Much of the research has examined the direct influence of these relative bargaining positions on the sharing of returns and the distribution of benefits and wages in the firm (Ethiraj and Garg 2012; Bidwell et al. 2013; Phillips and Srensen 2003). We have however less understanding on how this bargaining power impacts the innovation production function - how does the nature of innovative tasks change across inventors based on their relative bargaining power, an impact that is likely in face of evidence that R&D professionals value the nature of their R&D tasks enough to be ready to sacrifice monetary rewards for the same Stern (2004). The impact of bargaining power is likely to be significant not only because the non-pecuniary motivations of R&D professionals prevent the firm from monetizing the professionals' preferences but also due to the political nature of R&D task allocation (Taylor 2010).

Research has shown that the task allocation and definition in the R&D function depends not only on technical merits but is also political in nature (Taylor 2010; Nerkar and Paruchuri 2005; Paruchuri et al. 2006). R&D professionals value their influence within the firm (Paruchuri et al. 2006; Paruchuri 2010; Kehoe and Tzabbar 2014) and even take political action to influence the nature of R&D to preserve their positions (Taylor 2010). The nature of R&D activity thus is a part of negotiated agreement that cannot be completely monetized especially when intrinsic motivations and the characteristics of the research project one is working on are important intrinsic motivators of R&D personnel (Katz 2008; Hackman and Oldham 1976).

It is now well recognized that R&D professionals are not only motivated by extrinsic factors such as wages and bonuses but also intrinsically by the nature of the R&D projects they are asked to do - how significant is the project for instance (Katz 2008; Sauermann and Cohen 2010). Despite this recognition, it is by no means a forgone conclusion that all R&D professionals are provided projects with desirable properties or to the same degree. Not all projects in the firms satisfy these criteria to the same degree (Katz 2008). For instance, some projects may be designed more towards maintaining existing products with limited opportunities for growth and exciting work.

Which R&D professional gets to undertake which project then becomes a point of negotiation. The labor market opportunities significantly influence the terms of this negotiation (Thompson James 1967). However the way tasks are structured and allocated also influences a firm's ability to manage the two challenges of turnover: knowledge leakage and disruption (Conti 2013; Carley 1992; Zhao 2006). For instance, assigning more mobile personnel to projects that are more useful internally rather than externally could be a protection from leakage (Zhao 2006) but the firm would have to increase the desirability of the project in some other dimension to encourage the more mobile personnel to accept the task. The properties of the research project desired by the individual on one hand and the firm's concerns of knowledge appropriation and project disruption on the other thus together affect the innovation production function. We examine these two forces and their implications in greater detail below.

2.1 Independence and Task Significance

The literature on what motivates innovators (Katz 2005, 2008; Sauermann and Cohen 2010) generally agrees that a R&D professional derives considerable motivation from the nature of job that she does (Oldham and Hackman 2010; Oldham and Cummings 1996). Indeed in most surveys, the R&D professionals indicate that certain characteristics of their work in itself were their main motivators. In particular, scholars have consistently highlighted task significance and task independence to be among the most important characteristics that R&D professionals look forward to in a R&D project (Sauermann and Cohen 2010; Katz 2008). Consequently, we argue that R&D professionals are likely to lobby for projects that give them more independent responsibility and/or projects that are quite significant and have a large scope.

Having more independent responsibility is important to the R&D professionals because it gives a psychological sense of ownership of the project (Damanpour 1996, 1991; Amabile et al. 1996) on one hand and a number of varied learning opportunities enabling her to grow in her job on the other. In this discussion however, it is useful to distinguish between "strategic" and "operational" autonomy. Strategic autonomy refers to freedom to choose goals whereas operational autonomy refers to freedom to choose what path to take to reach the goals (Bailyn 1985; Katz 2008). Scholars have shown that what the R&D professionals are looking for is operational rather than strategic autonomy. Indeed, Bailyn (1985) found that R&D professionals do not like open-ended mandate to "be innovative" because this might lead them to a trajectory that the firm is not interested in. They likened it to a "long rope to hang oneself with". What they really disliked was micromanagement in their operational decisions; clear strategic goals with freedom in operational decisions was what they found most motivating and enabling.

Independent charge of the research project motivates a R&D professional to take personal responsibility for the project and influence the direction of the project based on her own judgment and knowledge; the project becomes her own creation and gives her a sense of achievement (Oldham and Hackman 2010; Katz 2008). Given the uncertainty involved in the R&D process, decision making in R&D is quite judgmental and as a result, two similarly trained professionals can honestly disagree on the best technical path forward. In such a scenario, having independent charge of the project allows the R&D professional to exercise his or her judgment, as well as afford her freedom to experiment and learn from the pitfalls encountered. This freedom to explore thus allows the professional to develop her capabilities and grow as a professional as well.

An independent charge of a project also allows a professional to develop entrepreneurial skills. Research in firms is not performed in isolation. Successful completion of a project requires gathering resources and knowledge inputs from rest of the organization as well. Since independent charge of a project involves personal responsibility (Bailyn 1985), the professional is personally in charge of gathering resources and knowledge necessary for the project. However independent charge also implies that the credit (or discredit) of the project is also largely attributed solely to the particular individual. Thus, gathering resources and knowledge from others in the firm requires her to liaise with and convince others who do not share the "spoils" of the project to that a degree. This makes the research project quite similar to an entrepreneurial activity of defining the problem and gathering resources and thus provides valuable opportunity to develop such capabilities.

Given these reasons, one would expect professionals to lobby for projects with independent charge. As a person's mobility option increases, his or her leverage with the firm also increases and the threat of quitting becomes more credible. Thus the chances of such a person getting independent charge also increases.

Giving more independent charge to a person whose mobility options have increased is consistent from the firm's perspective as well as long as the person is working on projects that are firm specific, i.e. are more useful within the firm than outside. This is because giving independent charge for firm specific projects decreases the potential disruption due to turnover on one hand while the firm-specificity reduces the threat of knowledge leakage on the other. Team production is an interdependent activity. As a result, when one member of the team leaves, it can disrupt other members' activities. One way a firm's production of innovation can be made resilient to turnover is by decomposing the activities into separate independent sets so that when a personnel responsible for one module leaves, the damage is limited to a confined set of activities (Carley 1992). Even if the disrupted project was a part of a larger plan, the act of assigning independent charge would necessitate clarifying the boundaries and interfaces between projects. The decomposition implies that turnover would not create an immediate widespread disruption and allow other related projects to go on while the replacement is being sought. Thus, we should expect:

Hypothesis 1 *An increase in external job opportunities for R&D professionals increases the probability of those professionals to work independently compared to other R&D professionals.*

Another important dimension that R&D professionals look for in their tasks is the degree to which the tasks that they perform are significant. Indeed, Katz (2008) while discussing what motivates R&D professional states: "The most critical dimension by far for elevating motivation is task significance. Professionals become more excited and energized when they feel they are working on something important - something that clearly makes a difference within the business unit."

Working on a large significant project which is important to the firm makes the work meaningful to the R&D professionals and gives them a sense of accomplishment (Hackman and Oldham 1976). Entrepreneurship literature has demonstrated that one of the major reasons why R&D employees leave the firm to start new businesses is frustration with the firm for not commercializing their inventions and taking their research forward (Klepper and Thompson 2005). This is a strong indication that R&D professionals enjoy working on projects that see "light of the day", projects that the firm invests resources in and is likely to push forward (Katz 2008). This is more probable if the research project that the R&D professional is working on is large and involves a lot of resource commitment from the firm.

Apart from the sense of achievement, working on prominent large projects within the firm is also likely to afford R&D professionals opportunities to gain visibility as well as build social networks within the firm (Nerkar and Paruchuri 2005). Large prominent projects within the firm involve large teams and working with such a team provides the R&D professional opportunities to interact with a number of different professionals - technical or otherwise - within the firm. Indeed R&D

professionals who work for teams that are more isolated from rest of the firm are less likely to gain promotion and other career opportunities within the firm (Katz et al. 1995). A large prominent project is also likely to be visible outside the firm and thus being a part of large projects is likely to be beneficial from a broader career progression point of view as well.

Thus we would expect R&D professionals to lobby for being a part large prominent projects within the firm. Of course, this desire to be on a large prominent project somewhat contradicts the desire to be given an independent charge. Large projects normally involve large teams with a lot of resources but it might involve less autonomy due to interdependencies and greater planning in large projects. However, not all R&D professionals are the same. Indeed, career anchor theory (Schein 1996; Katz 2008) has shown tremendous variety in R&D professionals in what they seek from their jobs. So more entrepreneurially oriented R&D professionals could value independent charge more than being part of a large prominent team while R&D professionals with more managerial ambition who are more organizationally focused might prefer the latter. Furthermore, it is difficult to devise projects that satisfy all the desirable properties in one assignment. Indeed the general advice given to R&D managers is to discover the individual specific career anchor and create or approve heterogeneous projects that suit individual motivations (Katz 2008). Thus to the extent that these characteristics contradict, the firms may offer projects with one or the other to their R&D professionals if it is also in its interest.

As we discussed above, team production involves interdependence between team members which subjects the firm's innovation production to disruption. The firm has two structural mechanisms to deal with this challenge: first is task decomposition as discussed above. The second is to create redundancies between team members to increase knowledge overlap so that the firm can still "fill in" for the personnel who has quit (Carley 1992). Putting more mobile personnel in larger teams is consistent with this second mechanism.

The threat of disruption is more likely in small teams rather than big teams because big teams are likely to be more structured and hierarchical to ensure co-ordination. It is known that hierarchies are more resilient to turnover and memory loss because hierarchy ensures redundancy; the manager or supervisor knows at least part of what the subordinate is working on (Carley 1992). Further, large teams are more likely to have slack which allows the creation of redundancies. Thus in large teams other existing team members can step in and continue where the professional who quit left off. In small lean teams however, the interdependencies are likely to be tighter, the structure is likely to be flatter, redundancies are smaller and therefore disruptions greater.

Thus we predict,

Hypothesis 2 *An increase in external job opportunities for R&D professionals increases the team size of these professionals when they work in a team, in comparison to other R&D professionals.*

2.2 Firm-Specificity of tasks

A R&D professional's increased mobility in the labor market creates dual challenges for the firm, that of knowledge leakage through this professional's turnover as well as threat of disruption of the projects on which the professional is working. From a firm's perspective, providing independence and assigning the professional to a large prominent project reduces the chances of turnover since these characteristics make the job inherently motivating for the professional. However, in return of providing these desirable projects to the now more mobile professional, the firm is also likely to demand protection from the above two threats in return. One mechanism to do so is to demand that the more mobile professionals work on more organizationally relevant technologies (Zhao 2006). Firms are likely to ensure that such professionals work on technologies that are more relevant inside rather than outside the firm. This prevents the flow of knowledge and counters the threat of appropriation.

Furthermore firms can negotiate that the R&D professionals use technologies that are more well known within the firm and reduce the use of unfamiliar technologies such as those developed outside the firm. The usage of in-house technologies reduces the threat of disruption. If the more mobile professional uses less of external technologies in her work and more of in-house technologies, it is easier to find a replacement who is familiar with the technology should the turnover materialize.

This reduces the firm's dependency on the professional and reduces the threat of disruption.

From the R&D professional's perspective, it is not clear which way the preferences go. On the one hand, the professional is likely to want to work on less firm-specific technologies to increase her chances in the labor market. But on the other hand, working on firm-specific technologies also increases her chances to make valuable contributions to the firm's bottom-line which increases her chances of promotion and more responsible roles within the firm. These promotions, in turn, also increase her external mobility options because of added visibility that these roles imply. While we do not derive clear predictions regarding these motivations, we can speculate that R&D professionals of prominent firms or of firms that are working on cutting-edge prominent technologies are more likely to be willing to work on firm-specific technologies because of this latter effect. We leave this for future analysis.

The above discussion leads us to predict:

Hypothesis 3a *An increase in external job opportunities for R&D professionals leads to decrease in use of external technologies and greater use of in-house technologies by these professionals in their innovative activities in comparison to other R&D professionals.*

Hypothesis 3b *An increase in external job opportunities for R&D professionals leads these professionals to work on research projects that have greater utility for the firms employing them rather than for external firms.*

3 H-1B Law and Mobility of R&D Professionals.

We use the American Competitiveness in the Twenty-first Century Act of 2000 as an exogenous change in the mobility options for the H-1B visa holders, our treatment group. A number of studies demonstrate the importance of immigrant R&D professionals in technological innovation and entrepreneurship in the US economy (e.g., Kerr 2008; Kerr and Lincoln 2010) and the employment of many of these immigrant R&D professionals is governed by the H-1B visa, an employer sponsored visa that allows highly skilled immigrants to work for the sponsoring US firms.

An H-1B holder "is an alien admitted to the United States to perform services in [...] 'specialty occupations'." (USCIS 2006, p.3) These "specialty occupations" are mainly characterized by being sufficiently demanding that a bachelor's or higher degree is a generally accepted requirement for performing them and is specifically required by the employer. An H-1B visa is approved for at most three years and maybe renewed for another three years. A new six-year period can start after at least one year's absence from the USA and many H-1B holders also transition to permanent residency and eventually citizenship during their stay. The Congress has enacted an annual cap in the number of new H-1B visas issued, varying from 65,000 originally in the early 1990s to approximately 200,000 in the early 2000s. A new petition is required for extensions of the visa and changes of job, but these do not count against the quota (USCIS 2006)[1].

In line with the requirements, the H-1B visa holders tend to be highly educated with approximately 50% holding bachelor's degrees or equivalents and the remainder holding higher degrees. A sizeable proportion, varying from 25% to 50% from year to year, work in computer-related occupations, with engineering, education, and administration the next most common occupations at roughly 10-15% each. The largest country of origin is India with a 30-50% share followed by China at about 10% share. The Anglo-Saxon countries (Canada, UK, Australia) jointly account for roughly 10% of the visa holders. Around 45-65% of the initial employment petitions were for persons who were already in the USA on another visa (USCIS 2006). Many are hired after completing a bachelor's or a higher degree in a US institution, as indicated by the VP-HR of Sun:

> "...of all the H-1B workers that Sun has hired, only a very small handful are actually recruited outside the United States and then brought into the country. The majority of H-1Bs that Sun hires are already in the U.S. having graduated from United States schools frequently at the top of their class." (Kenneth Alvares, VP-HR, Sun Microsys-

[1] The USCIS report for fiscal year 2004 published in 2006 is the earliest publicly available.

tems, Senate committee hearing, 1998 as reported in Senate Report 106-260)

For an H-1B holder to change jobs, the new employer has to file an H-1B transfer petition. Prior to 17 October 2000, an H-1B holder could start working for the new employer only after the USCIS (then called the INS) had approved the petition. This approval process took around 4-6 months and therefore severely restricted the mobility of immigrant high skill workers. With the enactment of American Competitiveness in the Twenty-first century act of 2000 on 17 October 2000 however, the law was changed to allow the H-1B holder to start working for a new employer right after the new employer filed a transfer petition, which happened within a matter of days from signing the contract.

This change in law, commonly known as the "H-1B portability provisions"[2], made the process of switching jobs much easier for H-1B holding R&D professionals and thereby increased their employment prospects. Before the change in law, these professionals could start working for new employers only after a period of 4-5 months. This required the new employer to be able to predict the need for the professionals about six months in advance. This long period most likely also imposed significant costs on the employee who would have to either ensure that her attempt to move to another employer is kept secret in the current firm or else risk reduced career prospects within the firm or even risk losing her job. After the law change however, it became easier for firms to hire H-1B holders as well as for employees to start working in a new firm. As a result, the set of available employment opportunities increased for the H-1B holding employees. This change in law however did not impact the permanent residents and citizens.

4 Data & Methods

Our data comes from the "Disambiguation and Co-authorship Networks of the U.S. Patent Inventor Database (1975 - 2010)" project (Lai et al. 2011) and covers the careers of inventors who filed patent applications in the USA. The project has specifically focused on identifying individual inventors and

[2] http://www.visapro.com/S/Article-Print-Preview.asp?articleid=1327, accessed February 19,2014

their employers in the patent data and is thus very suitable for our purpose. Summary statistics are presented in Table 1 and correlations in Table 2.

We establish the likelihood of an innovator being an H-1B holder by matching his or her name to an ethnicity using an established algorithm (Kerr 2008; Kerr and Lincoln 2010). We assume that innovators with Indian or Chinese names are more likely to be H-1B holders than innovators with Anglo-Saxon names. That is, we assume that a greater proportion of innovators with Chinese and Indian names is H-1B holders than among innovators with Anglo-Saxon names. This is naturally a noisy measure, but the noise will make the measure less sharp and hence bias the regressions against finding a result. That is, the extent to which there are H-1B holders among those with Anglo-Saxon names on one hand and citizens or green card holders among those with Chinese and Indian names will move the estimates towards zero, away from finding a result. This assumption is thus quite conservative but regardless we use several robustness checks to increase our confidence in it.

We are interested in changes that occurred due to the H-1B law change of 17 October 2000. We assume that a project on the average takes six months from initiation to patent application and that the characteristics of the team and innovation target are set at the initiation of the project. We thus look at differences in patents applied before and after 17 April 2001, six months after the law change, as our assumption indicates that patents applied after this were started after 17 October 2000 and hence should reflect the reality after the law change.

Since an H-1B visa can only be held for six years (or in rare cases nine years if working for the military), we limit our sample to innovators whose first patent is at most two years prior to the law change and look at patents applied within a window of plus or minus two years from the 17 April 2001 date. We include only innovators who had at least one patent before and one after the law change. We also limit the data to innovators whose address during this period was always in the USA and who were never self-employed (i.e., did not have patents without an assignee) as H-1B holders must maintain employment. While there were changes in the quota of H-1B visas granted each year, they have no effect on our estimates as H-1B holders changing employment do not count towards the quota.

We use Chinese and Indian innovators, the likely H-1B holders, as the treatment group and Anglo-Saxon innovators as the control group. We use a differences-in-differences methodology and thus identify the effect of the law change through the difference in the outcomes between the likely H-1B holders and the control group after the law change relative to that difference prior to the law change. In practice, this means that we include a dummy variable *H-1B* for the likely H-1B holders to control for stable differences between the groups and dummy variables for each year to control for changes over time that affect both groups and finally we interact a dummy *Law Change* for the period after the law change with the dummy for the likely H-1B holders — the coefficient for this variable *H-1B* $\times$ *Law Change* then captures the impact of the law change on the H-1B holders. The "main effect" of the law change is subsumed in the year dummies.

The identification assumption — the assumption that the coefficient of the *H-1B* $\times$ *Law Change* corresponds to the effect of the law change on the H-1B holders — then is that the only relative change between the H-1B and control groups is due to the law change, conditional on the control variables. First, as controls we include the above-mentioned dummy for H-1B holders and the year dummies which together control for stable differences between the H-1B holders and the control group as well as for general changes over time. Second, we control with a full set of dummies for the state of residency to remove any effect caused by the H-1B holders living on the average in different parts of the country as compared to the control group. Third, we control with a full set of dummies for the technology subclasses of the patents the innovators are involved with to remove any bias that may have been caused by the H-1B holders and the control group working in different technological areas. Fourth, we control with a full set of dummies for the assignee firm of each patent, the likely employer, to remove any bias that may have crept in if the H-1B holders and the control group on average work for different employers. Fifth, we control for the productivity of the innovator in case the H-1B holders and the control group may have a different level of productivity (which also proxies for ability) which could potentially bias the results. Sixth, we control for the size and age of the assignee firm to remove any effect caused by the H-1B holders and the control group working at the same firm at different times.

Not content with the controls alone, we also conducted two placebo tests. First, there is a concern that maybe the career trajectories of H-1B holders and the control group are different even after controlling for the variables listed above. To alleviate this concern, we arbitrarily chose another law change date three years earlier than the actual and repeated our regressions with this artificial date. The results disappear, suggesting that they were more likely to be due to the law change than due to career track differences. Second, one may worry about our identification of H-1B holders and be concerned that there is something else that creates the differences between the ethnic groups at the time of the law change. To alleviate this concern, we ran the same regression but chose a placebo treatment group: those who have been in the USA for at least ten years prior to the law change as they cannot be H-1B holders. The results again disappear, increasing our confidence that the results are really driven by the law change affecting the H-1B holders.

We use OLS in our estimations even when the dependent variable is dichotomous (i.e., a linear probability model) as logit regression in Stata would not allow adding the same number of fixed effects. The results are consistent if we use logit with fewer fixed effects, but we choose to report the most rigorous specification. We use robust standard errors clustered by the person to eliminate bias in the standard errors due to repeated sampling of the same persons.

We will now describe the variables we construct.

Lone Inv: To test Hypothesis 1, we identify an innovator working independently if he or she is the sole innovator listed on a patent.

Team Size: To test Hypothesis 2, we measure the team size that the focal innovator is part of by the number of innovators listed on a patent where the focal innovator is also listed.

Use of Internal versus External Technologies: To test Hypothesis 3a and to consider the technologies used by the team in inventing the focal patent, we look at the citations that the focal patent makes to other patents and whether those patents belong to the same firm (internal technologies) or other firms (external technologies). In line with existing literature, we consider patent citations as the best, though admittedly not perfect, measure of what existing ideas and technologies a patent builds on. Hence, we consider Hypothesis 3a supported if the patents with H-1B innovators increasingly cite other patents by the same firm relative to patents with non-H-1B innovators. It should be noted that the key word here is "increasingly". Given the difference-in-differences regression framework explained above, we are not interested in the level of citations going to patents of the same assignee firm versus other firms, but rather seeing whether patents that likely H-1B holders are associated with increase in the number of citations that they give to patents in the same firm versus other firms relative to changes pertaining to

Utility for Assignee Firm versus Others: To test Hypothesis 3b, we consider the citations that later patents make to the focal patent within a five-year window. Hence, if citations to the focal patent come increasingly from other patents that also belong to the same firm rather than other firms, we consider the patent to be increasingly useful for that firm relative to other firms. Likewise, we are looking at changes in citations rather than levels in the difference-in-differences regressions. The variable *SelfFor5* counts the number of times the focal patent is cited by other patents from the same assignee firm within a five year window. The variable *OthFor5* similarly counts the number of times the focal patent is cited by other patents from other firms within a five year window. We log both variables and add one to avoid zeros.

Control Variables: We control for the size of the employer, measured as the log of the number of patents applied in the prior five years, the age of the employer, measured as the log of the years since first patent[3], and productivity of the innovator, measured as the log of the number of patent applications (including the current one). We add fixed effects for the year, state of residence, technology subclass of the patent, and the assignee firm as well as a dummy for the H-1B group.

We thus identify the impact of the law change by using differences-in-differences regressions and

[3]We add 1 to both before taking logs to avoid zeros.

comparing the Anglo-Saxon innovators with the Chinese & Indian innovators before and after 17 April 2001. The identifying assumption is then that in the sample described above, conditional on the year, state, technology, employer, productivity of the innovator, size of the employer, and age of the employer, the differences between the trends of the treatment and control groups is because of the law. The variable of the interest is the interaction of the indicator for the period after the law change with the H-1B indicator, *H-1B* × *Law Change*. The "main effect" of the law change is subsumed in the year fixed effects.

5 Results

Table 3 reports the basic regressions. Model 1 considers if the innovators are likely to work independently and the dependent variable is a dummy indicating if the innovator is the only one listed on the patent[4]. To test Hypothesis 1, we need to look at the coefficient of *H-1B* × *Law Change* and we expect the coefficient to be positive. The result shows that there is an increased propensity for H-1B holders relative to the control group after the law change to work alone and thus the result is consistent with Hypothesis 1.

Model 2 considers if those innovators who are not working alone work in larger teams and the dependent variable is the log of the number of innovators listed on the patent.[5] To test Hypothesis 2, we need to consider the coefficient of *H-1B* × *Law Change* and we expect the coefficient to be positive. The result shows that there is an increase in the team size for H-1B holders relative to others after the law change and thus the result is consistent with Hypothesis 2.

Models 4 and 5 consider the technologies used in the innovation and the dependent variables are the logs of the number of patents cited that belong to the same assignee firm vs. others, respectively. The results show that there's a decrease in the H-1B holders use of outside technologies relative to non H-1B holders after the law change and no statistically-significant change in the use of in-house

[4]We use OLS in these regressions (i.e., a linear probability model) as logit regression in Stata would not allow adding the same number of fixed effects. The results are consistent if we use logit with fewer fixed effects, but we choose to report the most rigorous specification.

[5]The sample here excludes the lone inventors and hence is smaller than in the other regressions.

technologies. This is consistent with Hypothesis 3a.

Models 6 and 7 consider the usage of the technology in the focal patent. In Model 6, the dependent variable is the log of the number of citations that the focal patent gets from other patents belonging the same firm within a five-year window. Model 7 considers those patents that belong to other assignee firms. The results show an increased tendency for H-1B holders relative to others after the law change to work on technologies that are more useful to the firm and less useful to other firms. This is consistent with Hypothesis 3b.

While the results are quite strong, there are still possible alternative explanations that they do not rule out. We consider those next in the additional tables.

First, in addition to private firms, H-1B holders can work for government, military, and universities. These may not face similar pressures as private firms and hence there is a worry that maybe the results are biased by innovators working in for the public and non-profit sectors. Table 4 excludes patents assigned to government, military, and universities from the regressions. The results remain robust.

Second, use of the patent data relies on matching the individual to ethnicity, the individual across time, and the assignee firm across time. There is a concern that maybe these matches have biased the results. In Tables 5, 6, and 7 we present alternative ways to identify the ethnicity, the person, and the assignee firm in the data, respectively. In Table 5, we identify ethnicity more loosely than in the main results in Table 3, which also increases the sample size. In Table 6, we use the alternative person identification provided by Lai et al. (2011). In Table 7, we supplement the assignee codes given by Lai et al. (2011) with those from the NBER patent data project. The results are robust in each case.

Third, our identification assumption in the differences-in-differences regression is that the trajectories (not necessarily the levels) of H-1B holders are similar to others conditional on the year, state, technology, employer, productivity of the innovator, size of the employer, and age of the employer. If this is not the case, we should see results at other arbitrarily chosen dates too. Table 8 presents the same regressions as earlier but with a placebo law change on 17 October 1997, three years earlier than the actual change, and shows no results. Hence, it is likely that the results are driven by the law change and not a difference in career trajectories.

Fourth, the results could also be driven by a difference between Anglo-Saxons on one hand and Chinese & Indians on the other, not with H-1B holders per se. In Table 9, we present a placebo regression where we look at innovators who had their first patent at least 10 years before the law change and hence could not have been H-1B holders at the time. We find no results. Hence, it seems that the effect is driven by the H-1B holders in particular and not the ethnicities in general.

6 Discussion

Given the presence of autonomy in R&D and the importance of human capital for technology management, it is important to take the characteristics that the professionals desire in their tasks as an important determinant of how R&D tasks are designed. The salience of professionals' desires is likely to be impacted by their bargaining position, which in turn is a function of their job opportunities. In this paper, we have focused on getting a handle on how increasing labor market opportunities for R&D professionals affect the innovation production function within firms.

Identifying the impact of labor market opportunities on the innovation production function is an empirical challenge because a R&D professional's job prospects are inherently tied with her ability and ability obviously influences the kind of projects she is entrusted with. We exploit an exogenous law change that increased the job prospects but not the ability of only a section of R&D labor force, the H-1B immigrants, leaving the prospects of other R&D personnel unchanged. This allows us to use a differences-in-differences approach to compare the change in the nature of R&D conducted by the R&D personnel whose job prospects increase with the change in R&D conducted by other personnel. The evidence suggests that firms distinguish between their less and more mobile R&D workforce and either give more independent charge to their more mobile workforce or allow them to work in more significant projects. In return they ensure that the more mobile workforce works on more organizationally relevant projects and use more in-house technologies to do so.

This study makes significant contributions to technology management literature by identifying important constraints imposed by technology labor market on how R&D managers can utilize their valuable human capital, constraints that are difficult to examine from conventional firm-level analysis. Strategy scholars have conventionally focused on two influences of technology labor markets on innovation. By providing knowledgeable workforce, the labor market changes the repository of knowledge available for innovation (Almeida and Kogut 1999; Song et al. 2003; Tzabbar 2009). By facilitating knowledge leakage, it promotes aggressive IP protection strategies (Agarwal et al. 2009) and alters firms' risk-appetites since risks of R&D are private while leakage can make the gains public (Arrow 1962; Conti 2013). In this top-down perspective, the direction of R&D may change due to labor market conditions but firms are not constrained in how they allocate their R&D workforce across projects. Since the firm is viewed as a monolith, the motives of R&D personnel are not accounted for and consequently this research does not answer why the R&D personnel with greater bargaining power in improved labor markets merely follow what firms want them to do especially when some important dimensions of tasks cannot be completely monetized (Stern 2004; Sauermann and Cohen 2010)?

This study shifts attention to R&D professionals' motivations and desires for certain kinds of projects. By doing so it shows that labor market conditions considerably restricts the firms' ability to allocate R&D projects to professionals by altering the bargaining power of individual researchers.

Focusing on individuals' preferences and their bargaining power also contributes to our understanding of how jobs are designed. The dominant explanation of how jobs are designed and allocated takes the efficiency and effectiveness perspectives and focuses on attributes such as what competencies are needed and how the job is interdependent with other jobs in the firm (Thompson James 1967; Puranam et al. 2012). In this view therefore efficiency concerns drive whether a job is divided into small chunks with independent charge or given to a large team. However this study shows that at least in innovation tasks, how a job is designed and allocated is also determined by a contentious process where bargaining power of individual professionals also play a role, an insight that arises when we view the characteristics of a job also as intrinsic motivators that can't be easily monetized.

One limitation of this study is that it uses a measure of immigration status of individual R&D professionals by inferring the status from their ethnicity. This method is a well established technique that has yielded valuable insights in the past (Kerr 2008; Kerr and Lincoln 2010) but it does add considerable noise in the data. This noise however makes it more difficult for us to find results. Regardless, we conduct a number of robustness tests to show that the results we observe are due to immigration law and not ethnicity. We conduct placebo tests by including only those inventors who were in the country for at least 10 years and conduct the same tests. Since none of the inventors in this new sample are affected by the new law, we should expect to find no results in this new sample if what we observe is due to immigration law change; on the other hand if what we observe is due to ethnicity, we should find same results. The placebo tests show no results adding confidence in our results. Using alternate specifications for ethnicity also yields similar results further bolstering our confidence in our findings.

Our study also points toward two potentially fruitful directions for future research. First, it might be fruitful to examine more closely the R&D professional's motives to work on firm-specific projects, i.e. when does working on firm-specific projects help her mobility options and how do labor market conditions affect these motivations. Second, are the labor market opportunities that are externally driven (say by law changes or by technological changes) qualitatively different from those that arise due to factors internal to the firm such as working for prominent firms. These two sources might be different because in the latter case, the labor market opportunities are derived from the firm and might not increase the bargaining power of the individual in the same way. For instance working for a prominent firm might increase job opportunities outside but may not increase the bargaining power of the individual. Does the latter form of increased labor market opportunities lead to more frustration because an individual might experience more job opportunities but is still powerless to capitalize on it within the firm?

This study introduces a new aspect to study how R&D projects are designed and managed within firms. It shows that job design is influenced not only by the technical merits of the design -

what does the job need but also by what organization or design is desired by the R&D professionals and how much bargaining power do they have in the firm. This study shows that these intrinsic motivations attached to job characteristics are also a significant force influencing R&D job designs which leads us to think of a different mechanism through which the labor market influences innovation: not only through provision of knowledge but also by empowering (or reducing the power of) individual professionals to influence the structure of innovative activities.

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Table 1: Summary Statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Lone Inv	0.098	0.298	0	1	56374
Team Size	3.94	2.746	1	76	56374
SelfBack	1.62	4.309	0	157	56374
OthBack	18.938	33.432	0	764	56374
SelfFor5	1.352	4.629	0	127	56374
OthFor5	5.224	10.091	0	275	56374
Assignee Size	1690.272	3499.289	0	17533	56374
Assignee Age	14.643	9.567	0	27	56374
Productivity	4.531	7.083	1	156	56374
H-1B	0.251	0.433	0	1	56374

Table 2: Correlation Table

	Variables	1	2	3	4	5	6	7	8	9	10
1	Lone Inv	1.000									
2	Team Size	-0.353	1.000								
3	SelfBack	-0.035	0.089	1.000							
4	OthBack	-0.046	0.114	0.325	1.000						
5	SelfFor5	-0.034	0.058	0.146	0.078	1.000					
6	OthFor5	-0.025	0.041	-0.012	0.090	0.169	1.000				
7	Assignee Size	-0.008	-0.020	0.095	-0.100	-0.003	-0.013	1.000			
8	Assignee Age	-0.012	-0.003	0.158	-0.138	0.029	-0.092	0.437	1.000		
9	Productivity	-0.033	0.036	0.038	0.007	-0.006	-0.061	0.053	0.024	1.000	
10	H-1B	-0.011	0.009	-0.010	-0.044	0.010	0.013	0.071	0.056	0.029	1.000

Table 3: Effects of Law Change on Patenting by H-1B Holders

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Lone Inv	Team size	SelfBack	OthBack	SelfFor5	OthFor5
Assignee Size (ln)	0.00188	-0.00483	0.0500***	-0.0353**	-0.0646***	-0.0122
	(0.42)	(-0.64)	(4.81)	(-2.20)	(-5.67)	(-0.81)
Assignee Age (ln)	-0.00344	0.0316**	0.0912***	0.0181	-0.0272	-0.128***
	(-0.33)	(1.97)	(4.29)	(0.51)	(-1.05)	(-3.55)
Productivity (ln)	-0.0114***	-0.00161	0.0619***	0.0481***	0.0290***	-0.00359
	(-3.58)	(-0.28)	(6.75)	(4.23)	(3.96)	(-0.35)
H-1B	-0.00903	-0.0160	0.00836	0.0270	-0.00476	0.0598***
	(-1.43)	(-1.45)	(0.48)	(1.25)	(-0.31)	(2.83)
H-1B x Law Change	0.0146**	0.0265**	-0.0266	-0.0703***	0.0316*	-0.0480**
	(2.24)	(2.41)	(-1.48)	(-3.26)	(1.94)	(-2.16)
R^2	0.279	0.394	0.387	0.473	0.333	0.379
Clusters	13204	12747	13204	13204	13204	13204
N	56374	50835	56374	56374	56374	56374

t statistics in parentheses, standard errors clustered by person, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects for the year, state of residence, technology subclass, and the assignee firm included but not reported.

Table 4: Robustness Check: Excluding Government, Military, and Universities

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Lone Inv	Team size	SelfBack	OthBack	SelfFor5	OthFor5
Assignee Size (ln)	0.00183	-0.00381	0.0511***	-0.0321*	-0.0586***	-0.0102
	(0.40)	(-0.50)	(4.79)	(-1.96)	(-5.05)	(-0.67)
Assignee Age (ln)	-0.00244	0.0316*	0.0924***	0.0170	-0.0294	-0.129***
	(-0.23)	(1.94)	(4.28)	(0.47)	(-1.12)	(-3.53)
Productivity (ln)	-0.0116***	-0.00321	0.0601***	0.0380***	0.0262***	-0.00922
	(-3.54)	(-0.54)	(6.40)	(3.33)	(3.53)	(-0.87)
H-1B	-0.00744	-0.0141	0.0110	0.0330	-0.00127	0.0609***
	(-1.10)	(-1.20)	(0.59)	(1.47)	(-0.08)	(2.74)
H-1B x Law Change	0.0148**	0.0272**	-0.0282	-0.0839***	0.0308*	-0.0438*
	(2.11)	(2.32)	(-1.48)	(-3.74)	(1.78)	(-1.87)
R^2	0.281	0.402	0.388	0.480	0.336	0.380
Log-likelihood	-2850.4	-22077.3	-48800.6	-60605.1	-46966.5	-63949.1
Clusters	12387	11944	12387	12387	12387	12387
N	52970	47627	52970	52970	52970	52970

t statistics in parentheses, standard errors clustered by person, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects for the year, state of residence, technology subclass, and the assignee firm included but not reported.

Table 5: Robustness Check: Alternative Ethnicity Identification

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Lone Inv	Team size	SelfBack	OthBack	SelfFor5	OthFor5
Assignee Size (ln)	0.00118	-0.00616	0.0467***	-0.0341**	-0.0614***	-0.00964
	(0.28)	(-0.87)	(4.88)	(-2.25)	(-5.80)	(-0.67)
Assignee Age (ln)	-0.00203	0.0336**	0.0898***	0.0144	-0.0274	-0.144***
	(-0.21)	(2.24)	(4.56)	(0.43)	(-1.14)	(-4.26)
Productivity (ln)	-0.0123***	-0.000378	0.0607***	0.0505***	0.0298***	-0.00327
	(-4.10)	(-0.07)	(6.96)	(4.59)	(4.32)	(-0.34)
H-1B	-0.00719	-0.0181*	0.0177	0.0334	-0.00420	0.0550***
	(-1.20)	(-1.74)	(1.08)	(1.62)	(-0.29)	(2.73)
H-1B x Law Change	0.0122*	0.0255**	-0.0280	-0.0708***	0.0378**	-0.0389*
	(1.95)	(2.40)	(-1.63)	(-3.39)	(2.43)	(-1.82)
R^2	0.277	0.390	0.380	0.467	0.328	0.377
Clusters	14882	14356	14882	14882	14882	14882
N	63089	56877	63089	63089	63089	63089

t statistics in parentheses, standard errors clustered by person, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects for the year, state of residence, technology subclass, and the assignee firm included but not reported.

Table 6: Robustness Check: Alternative Person Identification

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Lone Inv	Team size	SelfBack	OthBack	SelfFor5	OthFor5
Assignee Size (ln)	0.000698	-0.00547	0.0501***	-0.0352**	-0.0653***	-0.0133
	(0.16)	(-0.72)	(4.78)	(-2.18)	(-5.71)	(-0.88)
Assignee Age (ln)	-0.00175	0.0302*	0.0931***	0.0203	-0.0267	-0.128***
	(-0.17)	(1.88)	(4.36)	(0.57)	(-1.02)	(-3.54)
invpatcnt_u_ln	-0.0105***	-0.00132	0.0625***	0.0475***	0.0266***	-0.00729
	(-3.31)	(-0.23)	(6.81)	(4.11)	(3.58)	(-0.70)
H-1B	-0.00982	-0.0152	0.00761	0.0272	-0.00521	0.0595***
	(-1.55)	(-1.38)	(0.44)	(1.25)	(-0.34)	(2.81)
H-1B x Law Change	0.0147**	0.0263**	-0.0258	-0.0708***	0.0324**	-0.0464**
	(2.24)	(2.38)	(-1.43)	(-3.28)	(1.98)	(-2.08)
R^2	0.277	0.395	0.387	0.473	0.333	0.378
Clusters	13056	12611	13056	13056	13056	13056
N	56044	50566	56044	56044	56044	56044

t statistics in parentheses, standard errors clustered by person, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects for the year, state of residence, technology subclass, and the assignee firm included but not reported.

Table 7: Robustness Check: Alternative Assignee Firm Identification

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Lone Inv	Team size	SelfBack	OthBack	SelfFor5	OthFor5
patcnt65_ni_ln	-0.000685	-0.00568	0.0309***	-0.0329**	-0.0271***	0.0131
	(-0.15)	(-0.82)	(3.57)	(-2.56)	(-2.99)	(1.00)
asgage6_ni_ln	-0.00154	0.0109	0.111***	0.00495	-0.0549**	-0.147***
	(-0.15)	(0.73)	(5.83)	(0.16)	(-2.34)	(-4.39)
Productivity (ln)	-0.0112***	-0.000403	0.0604***	0.0472***	0.0197***	0.000860
	(-3.54)	(-0.07)	(6.63)	(4.15)	(2.87)	(0.08)
H-1B	-0.00856	-0.0173	0.00779	0.0247	-0.0135	0.0555***
	(-1.36)	(-1.57)	(0.45)	(1.14)	(-0.96)	(2.64)
H-1B x Law Change	0.0145**	0.0237**	-0.0298*	-0.0681***	0.0409***	-0.0506**
	(2.20)	(2.15)	(-1.70)	(-3.15)	(2.64)	(-2.28)
R^2	0.281	0.395	0.403	0.477	0.322	0.399
Clusters	13264	12805	13264	13264	13264	13264
N	56687	51116	56687	56687	56687	56687

t statistics in parentheses, standard errors clustered by person, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects for the year, state of residence, technology subclass, and the assignee firm included but not reported.

Table 8: Robustness Check: Placebo Law Change on 17 Oct 1997

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Lone Inv	Team size	SelfBack	OthBack	SelfFor5	OthFor5
Assignee Size (ln)	0.00104	-0.00573	0.0295***	-0.0352**	-0.0313**	0.00363
	(0.20)	(-0.63)	(2.59)	(-2.15)	(-2.42)	(0.22)
Assignee Age (ln)	0.000321	0.00546	0.179***	0.0000556	-0.139***	-0.115***
	(0.03)	(0.32)	(9.13)	(0.00)	(-5.35)	(-3.10)
Productivity (ln)	-0.00148	0.0000591	0.0831***	0.0586***	0.0242**	0.000885
	(-0.39)	(0.01)	(7.84)	(4.84)	(2.55)	(0.07)
H-1B	0.0114	-0.0216*	-0.00407	-0.0693***	0.00119	0.0493**
	(1.44)	(-1.72)	(-0.23)	(-3.22)	(0.07)	(2.07)
H-1B x Law Change	-0.0145*	-0.0116	0.00317	0.0383	-0.00572	-0.00733
	(-1.80)	(-0.85)	(0.15)	(1.44)	(-0.29)	(-0.28)
R^2	0.305	0.351	0.371	0.447	0.342	0.416
Clusters	11764	11273	11764	11764	11764	11764
N	47756	42249	47756	47756	47756	47756

t statistics in parentheses, standard errors clustered by person, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects for the year, state of residence, technology subclass, and the assignee firm included but not reported.

Table 9: Robustness Check: Placebo Using Innovators with at Least 10 Years since First Patent

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Lone Inv	Team size	SelfBack	OthBack	SelfFor5	OthFor5
Assignee Size (ln)	-0.00159	-0.00566	0.0940***	-0.0175	-0.0409***	0.0137
	(-0.32)	(-0.73)	(8.18)	(-1.20)	(-3.61)	(0.98)
Assignee Age (ln)	0.00447	0.0156	0.0964***	-0.0400	-0.110***	-0.202***
	(0.31)	(0.72)	(3.25)	(-0.95)	(-3.51)	(-4.57)
Productivity (ln)	0.00745**	-0.00298	0.0822***	0.0323***	0.0132**	0.0153**
	(2.55)	(-0.66)	(9.58)	(3.62)	(2.28)	(2.02)
(Chinese & Indian)	-0.0106	-0.00782	0.0195	-0.00807	0.0216	0.0308
	(-1.33)	(-0.57)	(0.92)	(-0.36)	(1.20)	(1.33)
(Chinese & Indian)	0.00198	0.000814	-0.0155	0.00377	0.0210	-0.0240
x Law Change	(0.25)	(0.06)	(-0.63)	(0.14)	(1.09)	(-0.96)
R^2	0.260	0.325	0.387	0.418	0.294	0.330
Clusters	15885	14984	15885	15885	15885	15885
N	67418	59530	67418	67418	67418	67418

t statistics in parentheses, standard errors clustered by person, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects for the year, state of residence, technology subclass, and the assignee firm included but not reported.