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Universities as Innovators: The Effect of Academic Incubators on Patent Quality

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Abstract

Despite a wealth of research on university incubators, science parks, and other attempts at commercialization, there is little consensus on the effectiveness of university-sponsored commercial innovation. We analyze the impact of incubators and other types of facilitators on the quality of innovations produced by US research-intensive academic institutions from 1969 to 2012. Using forward patent citations to measure the quality of innovation we show that establishing a university-affiliated incubator is followed by a reduction in innovation on campus, control-ling for patent-, university-, and time-specific characteristics. The results hold when we control for the endogeneity of the decision to establish an incubator using the presence of incubators at peer institutions as an instrument. The results suggest that university incubators compete for re-sources with technology transfer offices and other campus programs and activities, such that the useful and commercializable outputs they generate can be partially offset by reductions in innovation elsewhere on campus.

Jelcodes:O31,-

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30 May 2014

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JEL: C23, C26, L26, O31, O32

Keywords: Incubators, patents, innovation, forward citations

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1. Introduction

Universities are increasingly tasked with fostering entrepreneurship and innovation, encouraged to generate revenues from research produced on campus and contribute to (local) economic growth (Etzkowitz, 1998, 2002; Etzkowitz et al., 2000; Goldstein and Renault, 2004). This view of the entrepreneurial university reflects two recent trends. First, universities are increasingly patenting research with commercial potential and subsequently seeking to increase their licensing revenues (Bulut and Moschini, 2009; Henderson et al., 1998). At the same time, universities are creating incubator facilities to assist faculty members, university graduates, community members, or other parties to start new firms that not only contribute to local economic growth, but also generate income for the university which often holds equity positions in the incubator's tenant firms.

Establishing university incubators and increasing university patenting have similar underlying motivations: both are mainly motivated by reductions in public funding for academia and increasing pressures for public accountability. Moreover, the resources and capabilities used to support start-ups and to generate patented inventions are largely shared: maintaining these two activities simultaneously involves leveraging the same academic knowledge and talent, devoting dedicated personnel for patent-issuing procedures and auxiliary services to start-ups, as well as directing significant investments for research equipment that can be used not only by university faculty and staff but also by incubator tenants. By extension, the overlap of goals and resources between university patenting and incubators suggests that decisions to increase university revenue and contribute to innovation and local economic growth through the twin channels of patenting and incubator activities are made jointly. This observation calls for reflection upon the basic, yet unexplored, question of how each channel affects the other. In this paper we begin addressing that question by examining empirically whether the quality of university patents is influenced by the creation of incubator facilities across research-intensive US universities across time.

Theoretically, the creation of incubation facilities can improve the quality of university patents by facilitating knowledge flows between academic inventors and market participants, knowledge that can not only help university patents articulate the commercial value of their inventions but also help generate ideas to university inventors that lead to valuable patents. Moreover, assuming that industry–academia collaboration often yields superior outcomes, incubators can lead to higher-quality patents if incubator tenants collaborate with university inventors. On the other hand, the presence of an incubator can reduce the quality of university patents if auxiliary incubator services and patenting activities compete for the same scarce university resources such as funds and dedicated personnel. Similarly, the average quality of university patents may fall once an incubator is in place if the university's overall focus and associated investments and resources shifts towards, say, start-ups over high-quality patenting. Our research aims to see which effect outweighs the other.

We must keep in mind, however, that the decision to establish an incubator can be endogenous; if incubators are followed by increases in patent quality, this could indicate that universities with good projects in the pipeline, and the prospect of high-quality patents down the road, choose to establish an incubator, even though there is no direct effect of incubators on patent quality. Likewise, a decline in patent quality following the establishment of an incubator could indicate that the university expects patent quality to decrease, and establishes an incubator as an alternative mechanisms for generating revenue and fulfilling its entrepreneurial mission.

Theorizing about the connection between incubators and patent quality and empirically testing that connection have not, as far as we are aware, been addressed in previous work. We also add to the literature on the quality of university patenting which, in addition to insightful, mainly descriptive historical accounts (Henderson et al., 1998), has focused primarily on the effects of regulatory interventions such as the Bayh-Dole Act and the impact of university experience and other university-specific features (e.g. Mowery et al., 2002; Mowery and Ziedonis, 2002; Owen-Smith and Powell, 2003; Sampat et al., 2003).

Our empirical work follows convention in approximating patent value with the number of times a given patent is cited by subsequent patents (forward citations) (e.g. Harhoff et al., 1999; Lerner, 1994). We run a series of regressions that compare patent quality before and after an incubator is established, controlling for patent-, university-, and time-specific characteristics that may affect patent quality. To mitigate endogeneity, we also run instrumental-variables regressions; our identification strategy builds on the insight that universities compete with each other and tend to imitate their peer institutions, particularly those that are geographically close (Rey, 2001). Hence we use the presence of incubators at similar, nearby (and potentially competitor) universities as an instrument for the focal university's decision to establish an incubator.

To build our dataset, we collect information on all 55,919 patents granted from 1969 to 2012 to US-based universities that were members of the Association of American Universities as of the end of 2012. These universities are research-intensive, they patent extensively, and those that have established incubators have done so in different years, which allows enough time variation in our sample.

Our results suggest that, in terms of generating useful innovation, the value-added of university incubators may have been overstated: we find a strong negative association between the establishment of an incubator and the quality of patents produced subsequently by that university. This relationship holds across a variety of empirical specifications, using different control variables, adding indicators for university and year, and controlling for endogeneity using the instrument described above. The results support the idea that incubators and university patenting rely on similar resources, so that resource scarcity may be driving the negative relationship between incubators and subsequent patent quality.

This finding has important policy implications. University administrators, technology transfer office officials, and other stakeholders generally show a keen interest on the effects of incubators and university patenting (Carlson, 2000; Guy, 2013). This interest is understandable because patenting and incubation are two prime means for universities to fulfil their new roles of generating economic growth and securing income. If these two means compete for similar scarce resources, then establishing an incubator may, on balance, reduce the quality of the innovative outputs produced by the university. Our work suggests that these innovation channels should be treated jointly, as alternative, and potentially competing, means of fostering innovation and economic growth. In sum, adopting a new lens via which incubation and patenting are analyzed jointly can help decision makers in determining the most effective means for academic institutions to meet the expectations that arise from their new roles.

We organize the rest of the paper as follows: In the next section we review the relevant literature and develop our theoretical expectations on the effects of incubators on patent quality. In Sections 3 and 4 we describe our econometric model and estimation procedures, and in Section 5 we review the data we use. In Section 6 we present the estimation results. Finally, we conclude in Section 7.

2. The relationship between university patenting and university incubators

Universities have long been central to the innovative process through generating, codifying, and communicating basic knowledge. Since the middle of the 20th century, universities have also played an increasingly important role in developing and using applied knowledge, particularly in the scientific and technical fields (Henderson et al., 1998; Mansfield, 1991, 1995). Universities often serve as "anchors" in the emergence of technology clusters (Stanford University, in the heart of Silicon Valley, being the best-known example) (Swann and Prevezer, 1996). Universities train scientists and engineers, partner with established and emerging technology firms, and develop their own in-house technologies. The desire to increase universities' applied research outputs and give them a stronger role in the innovative process has led US policymakers to describe local economic development as a "fourth mission" of the public research university (along with research, teaching, and service) (Etzkowitz et al., 2000; Youtie and Shapira, 2008).

Universities also attempt to foster innovation and economic development directly by establishing business incubators. Business incubators ("incubators" for short) are organizations that help aspiring entrepreneurs translate ideas into profitable ventures. Incubators typically provide office space, consulting services, assistance in finding suppliers and distributors, access to venture capitalists and business angels, and sometimes direct financial support (Aernoudt, 2004; Finer and Holberton, 2002; Rothaermel and Thursby, 2005a). Incubators are operated by a variety of private and public actors including government agencies and NGOs, but more than half of US incubators are affiliated with higher-education institutions (Powell, 2013). University incubators (also called university technology business incubators or UTBIs) provide additional services to their tenant firms such as access to university labs and computing facilities, student workers, and faculty consultants (Mian, 1996). Their on-campus or near-campus location and close relationships with university personnel also make it easier for university faculty and students to establish their own ventures and become incubator tenants.[1] By 2013 all but ten of the US members of the Association of American Universities (AAU) had established a campus incubator. Journal-

[1] In emerging economies, incubators provide even more foundational support, helping firms establish basic supplier and customer relationships, write and enforce contracts, and so on – helping to establish market institutions rather than developing specific business capabilities (Dutt et al., 2013).

ist Nicholas Thompson (2013) wrote of Stanford: “Students can still study Chaucer, and there are still lovely palm trees. But the center of gravity at the university appears to have shifted. The school now looks like a giant tech incubator with a football team.”

Another approach for encouraging university innovation is to assist faculty, staff, and students in patenting innovations developed within the university. The prospect of a patent provides an important financial incentive for university personnel to devote time and effort to potentially valuable commercial technologies (Lach and Schankerman, 2008; Owen-Smith and Powell, 2001; Thursby et al., 2001).[2] To facilitate patenting, many universities have established technology transfer offices to ease the administrative burden of the patent application process and to manage the use of patents that are successfully obtained. Most often the university itself will be the patent holder, sharing licensing income with individual scientists; in a few cases, faculty members retain patent rights. The Association of University Technology Managers (AUTM), which represents technology transfer offices, reports that universities earned $2.6 billion in license fees in 2012. Of course, not all innovations are patentable, and not all patentable ideas are innovative. Nonetheless, patents serve as a useful proxy for (quality of) innovation (Acs et al., 2002; Igami, 2013), so we can draw inferences about the strength of a university’s innovative programs by examining its portfolio of university-owned patents.

There is a large literature on the use of patents and patent citations as proxies for innovation. Importantly, “innovation,” as famously characterized by Schumpeter (1934), includes not only the introduction of new products and services, but refers also to the establishment of new production methods, new sources of supply, new consumer markets, and new methods of organization. Nonetheless the innovation literature has tended to focus more narrowly on technological innova-

[2] Others have reached opposite conclusions about the incentives of academics to commercialize their research (Colyvas et al., 2002; Markman et al., 2004).

tion and to rely on patents as reasonable indicators of innovation (Acs et al., 2002; Igami, 2013). We follow that convention here.

Like most of the recent literature on technological innovation, we focus on patent quality, not quantity. Citations of patents by future patent applications ("forward patent citations") are commonly used to measure quality (Harhoff et al., 1999; Igami, 2013). The intuition behind the forward-citations measure is that higher citation levels imply superior scientific significance or applicability. Indeed, studies have consistently shown that forward citations correlate strongly with realized market value for a particular patent (e.g. Harhoff et al., 1999; Lerner, 1994). [3] Nevertheless, more recent patents tend to receive fewer citations largely due to the effective time needed before they become visible. In the same vein, the secular increase in the annual number of patents over time implies that very early patents may also tend to have fewer citations than more recent patents, mostly because patents tend to receive the bulk of their citations in the first few years after issue. Other things equal, then, earlier patents should have fewer forward citations than later patents simply because there were fewer other patents available to cite it (Lanjouw and Schankerman, 2004). As we explain in section 3, we take these observations into account when specifying our empirical model.

How could the presence of a university incubator affect patent quality? Our analysis begins with the observation that universities, like other organizations, are bundles of resources, routines, and capabilities (Barney, 1991; Penrose, 1959). A university incubator does not operate in isolation, but is part of a university's overall portfolio of innovative activities. From a resource-based or capabilities perspective, the creation of an incubator should have a positive net effect on uni-

[3] For direct evidence that patent value is well approximated by forward citations, see recent work on patent auctions, a direct setting for measuring patent value. This work shows that forward citations are a strong predictor of the auction price paid to acquire a patent (Fischer and Leidinger, 2013; Sneed and Johnson, 2009).

versity innovation if it leverages resources and capabilities that are not fully exploited by the university's other innovative activities such as research facilities and personnel and the technology transfer office (Lockett et al., 2005). Some university resources, such as land and buildings, are not easily divisible, creating the potential for excess capacity. Establishing an incubator can be an effective way of leveraging underutilized resources.

The presence of a university incubator can also create value by encouraging knowledge flows between academic researchers, students, and commercial firms that become incubator tenants (Rothaermel and Thursby, 2005b), increasing the likelihood of university personnel developing valuable, patentable innovations. Moreover, the presence of an incubator reduces the marginal cost for university personnel to establish their own ventures and become incubator tenants, increasing the incentives to generate high-quality patents. Over time, these knowledge flows and learning effects suggest that innovative capabilities may increase. For all these reasons, the presence of a university incubator should lead to higher quality, patentable innovations, suggesting a positive relationship between the establishment of a campus incubator and the patent citations flowing to the focal university.

If universities are resource constrained, and the effects of competition for resources outweigh the benefits of encouraging knowledge flows and capability development, then the net effect of establishing an incubator could be to reduce the quality of innovation. Incubators require resources: buildings must be constructed or expanded and maintained, personnel and operating funds must be allocated, and so on. These resources could also be devoted to other campus organizations and activities that encourage innovation, such as research facilities and personnel, training, and the technology transfer office. If the opportunity cost of devoting these resources to an incubator outweighs the benefits from incubation, the net effect of the incubator on university-based innovation will be negative. In short, the presence of an incubator could drain resources from other campus activities that encourage innovation, leading to lower-quality patenting.

The theoretical literature on university innovation does not offer much guidance about which effect is more likely, so we turn to the data to examine the net effect of establishing a university incubator on patent quality. This leads to our main hypothesis:

> *H1: The presence of a university incubator increases the quality of university-owned patents, other things equal.*

The alternative hypothesis is that incubators and patent quality do not work in tandem, but work against each other, in which case we would find a negative relationship between the presence of an incubator and patent citations, other things equal.

3. Methods

The general form of the empirical model we specify in order to test the two competing hypotheses is:

$$y_{it} = X_{it}\beta + \sum_i a_i A_i + \sum_t \gamma_t \Gamma_t \qquad (1)$$

where y_{it} refers to the number of forward citations through the end of 2012 received by a given patent submitted by university i in year t, divided by the number of years since the date the patent was granted (FORWARD). X_{it} is a vector of explanatory variables described below. The summation symbols represent university-specific and year-specific dummy variables.

To test the impact of incubators on patent quality we include a dummy variable (INCUBATOR) that takes the value of 1 if the application date of the focal patent is after the opening date of the university incubator and 0 otherwise. For universities that never established incubator facilities, the variable at hand takes the value of 0 for all patents. A positive sign of the associated coefficient would provide support for the hypothesis that incubators increase the quality of innovation on campus, while a negative sign would indicate the opposite.

Prompted by previous findings that experience in patenting is instrumental for university patent quality (Mowery et al., 2002), we also include two variables to capture university experience. The first variable, EXPERIENCE, measures the number of successful patent applications submitted by the focal university in the 5 years preceding the application date of a given patent. We expect a positive sign for this variable. The second variable, FOREXPERIENCE, is designed to capture the university's experience in producing quality patents. It measures the average number of forward citations per year garnered by the applications, once they are granted patent rights, used to construct the EXPERIENCE variable. Given path dependencies (Teece et al., 1997), we expect a positive sign for this variable.

To account for the possibility that a change in the quality of patents at a given year is influenced by the volume of patent activity in the same year, we include as a right-hand side variable the number of successful patent applications submitted by the focal university in the application year of the focal patent (QUANTITY).

Following previous literature (e.g. Czarnitzki et al., 2011; Sapsalis et al., 2006) we include several control variables in the analysis. First, we add the number of inventors and assignees in a given patent (INVENTORS, ASSIGNEES). Collaborative efforts generally enhance patent value, so we expect positive signs on the coefficients of both variables. To test whether there are moderating effects between the two variables we add their interaction as an additional regressor. We also include five patent-specific variables. The first measures the number of non-patent references (academic literature, government reports, and so on) included in the focal patent (NON-PATENTREF). The second depicts the number of patents listed in the references list of a given patent (PATENTREF). Based on previous findings we expect non-patent references to be negatively associated with patent quality and the opposite for patent references (Sapsalis et al., 2006). Moreover, because patents that span a wide range of fields are often more valuable than more narrowly focused patents, we include the number of different four-digit International Patent Classification categories assigned to the focal patent (SCOPE) as an indicator of scope (e.g. Gans et al., 2008; Harhoff et al., 2003). We expect a positive sign on the coefficient for scope. Patents that incorporate more applied knowledge, or borrow from different scientific fields, may also accumulate more forward citations precisely because more inventors may build on them. To account for such observation we include two dummy variables that take the value of 1 if the patent is classified as biotechnology or information & communication technology-related respectively (BIOTECH and ICT), 0 otherwise. Both scientific fields in question have immediate commercial applications while building on different knowledge bases (see Pisano, 2006 for the case of biotechnology) which is why we expect them to have a positive relationship with the dependent variable.

Finally, we include a set of university-specific dummy variables to account for unobservable characteristics of particular universities that might influence the quality of their patents. These include the underlying quality of the university faculty, the organizational structure of the academic institution, the effectiveness of rewards that encourage patenting, and the general attitude among the faculty members towards the commercialization of research via patenting.[4] Along the same lines, to account for year-to-year fluctuations that can also influence patent quality we incorporate in the analysis a set of year-specific dummy variables that match the publication year of

[4] We considered including additional measures of university quality such as the number of faculty awards and the number of faculty who are members of the Academy of Science. We decided to use dummy variables because consistent, comprehensive data on university quality from such sources as the National Science Foundation, AUTM, and the *Chronicle of Higher Education* are available only for the later years of the analysis. Including such variables reduces our sample by more than half.

the focal patent.[5] Such fluctuations may reflect, for instance, the spinoff activity of the focal university which may influence patent quality as firm formation and patent quality draw upon the same depleting resources. Along the same lines, the year dummies also account for the aforementioned observation that the secular increase in the annual number of patents over time may translate to less citations for early patents because there are only few other patents available to cite it (given that most patents receive their citations within a short window after issue).

Before presenting our data and sources in detail we note two significant considerations that relate to our modeling choices and the overall study design. First, we include in our sample only incubators with a physical presence on campus (i.e., a stand-alone building or location in another university building) whose primary function is to assist faculty members with entrepreneurial projects and are formally tied to the particular university.[6] We exclude from the analysis "virtual" or "soft" incubators that typically assist recent graduates in starting businesses by providing small soft loans. We focus on physical, campus incubators based on a) the theoretical expectation that these types of incubators are more likely to be sharing university resources with activities that could also support patenting (leading to a negative relationship between incubators and patent quality) and b) the behavioral assumption that these types of incubators are more likely to generate knowledge flows towards university-based investors (leading to a positive relationship).

The second consideration refers to our definition of "university" we employ and the implications of that definition for our empirical strategy. For universities with one main campus, which comprise the majority of the academic institutions in our sample, the definition is straightforward. For universities that are part of a system (in particular, the University of California and State

[5] In our dataset 20 years account for almost 80 percent of the publication years. We limit the year dummies to these years.

[6] This is not to imply that such incubators only host faculty entrepreneurs but to emphasize that faculty entrepreneurs tend to be core in the cohort of incubators we study.

University of New York systems), the unit of analysis could be either the system or the individual campus, as long as the latter is a member of Association of American Universities (AAU). There are practical implications of adopting each definition. If there are significant knowledge flows across campuses within system universities, and if patenting or/and incubation activities are influenced heavily by the central administration, then treating campuses from the same system as one university seems appropriate. Defining universities by campus emphasizes local-decision making but assumes that knowledge flows and overall direction are confined within campuses. In our baseline estimates we consider each system campus as a separate academic institution. Even when we define a system as a university the results remain qualitatively similar.[7]

4. Identification Strategy

Our analysis explains patent quality in terms of the presence of incubators and university-specific dummy variables that attempt to capture the scientific talent of university faculty, which should also influence patent quality. However, faculty quality at a given university is typically not time-invariant, due to learning by existing faculty and the addition of new faculty. As such, university-specific dummy variables may not fully capture scientific talent over the sample period. This creates an endogeneity concern if scientific talent is related to the establishment of incubators (i.e. universities establish incubators only when they have promising faculty or projects in house or as an alternative mechanism for generating revenue and fulfilling their entrepreneurial mission when faced with lesser quality talent) and scientific talent is not adequately measured (with the unobserved part ending up in the error term). To account for such potential endogeneity,

[7] A drawback of treating each system as a university, and assigning patents to systems rather than individual campuses, is that systems include campuses that are not AAU members (the University of California system campuses at Merced, Riverside, San Francisco, and Santa Cruz, and the SUNY campuses at Albany and Binghamton).

we need an instrument that is correlated with the decision of a given university to establish an incubator and uncorrelated with the scientific talent of the focal university.

Following techniques and underlying principles used in the literatures on organizational restructuring (e.g. Campa and Kedia, 2002; Klein and Saidenberg, 2010) , we assume that a university's decision to establish an incubator is influenced by the behavior of its peers. We thus construct an instrumental variable for the establishment of each university's incubator at time *t* as the number of incubators established before time *t* at peer institutions. We define peer institutions as those sample universities in either the same state as the focal university or an adjacent state. The presence of incubators in nearby institutions may influence the decision to establish an incubator, reflecting a form of institutional isomorphism (Meyer and Rowan, 1977; Powell and DiMaggio, 1983; Stensaker and Norgård, 2001) , but should be unrelated to the scientific talent of the focal university. As we explain in section 6, our results lend support to our choice of the instrumental variable

5. Data

In our regressions the unit of analysis is the patent. To construct our sample we begin with the 62 members of the Association of American Universities as of 2012. We excluded the two Canadian members of AAU to have a set of universities more comparable in terms of the motives and means to support incubators and patenting. Of the remaining 60 universities, 6 are members of the University of California system and 2 of the New York state university system. We were unable to obtain information for the University of Oregon, which reduces the number of universities to 59. As we explain below, the University of California, Berkeley is also excluded from the sample because we could not identify which of the UC system patents belonged to that campus. As such, the final dataset reflects patents assigned to 58 AAU universities.

To source the patent data for each university in the sample we searched the patent database maintained by Thomson Innovation using the name of each sample university; we then retrieved information on patent application and grant dates, the number of forward citations, and the list of inventors and assignees to construct the variables described above. The resulting dataset includes information on all 55,919 patents granted by the United States Patent and Trademark Office (USPTO) from 1969 through 2012 to a) single campus US universities that are AAU members (except the University of Oregon) and b) to all universities, including non-AAU members, of the system universities of California and New York. To assign patents from the system universities to campuses we employ the patent Network Dataverse maintained by Harvard Business School which lists the location address of all inventors listed in patents granted by the USPTO. Based on this location information we measure the distance of each patent inventor to each of the system campuses, and assign the patent to the closest campus. In cases where the inventor(s) were located between multiple campuses we omit the patent from the analysis (see Table 1 for details). This procedure eliminates 6,621 patents from the analysis and reveals that 358 patents were assigned to campuses of system universities that were not AAU members. Omitting these patents results in our final sample of 48,940 patents. These patents were granted from January 28, 1969 to December 25, 2012 (the corresponding application dates are March 29, 1957 to May 29, 2012).

For each sample patent, forward citations are measured as of December 2012. We collected information on campus incubators, including founding dates, from university websites, Lexis-Nexis and other news databases, and direct contacts with universities and their technology transfer offices.

Figure 1 shows the numbers of patents granted and incubators established during each of our sample years.

---Figure 1 about here---

As seen in Figure 1, the last four decades have witnessed a secular increase in university patenting, and university incubators have been also been established with increasing frequency. The number of patents per year increases steadily until 1999, stays at high levels with small yearly deviations from 2000 to 2009, and picks up again in 2010. From 1969 to 1989 the sample universities were granted 282 patents per year, on average; the corresponding figure for the 1990–99 period is to 1,344. Since 2000 the AAU universities as a whole have patented 2,274 inventions per year. The establishment of incubators proceeds more unevenly but close to 80 percent (36 of the 47) started after 1999. Interestingly, this is also the period in which patenting is becoming a university priority.[8] Purdue established the first university incubator in 1961, followed by Georgia Tech nearly two decades later in 1980.

Descriptive statistics are provided in Tables 1, 2, and 3. Table 1 presents the number of patents per university across the study period. The most patent-intensive single campus is MIT, with its patents accounting for 8.4 percent of the sample patents. The University of Texas at Austin, Stanford, Cal Tech and the University of Wisconsin round out the top five, followed by a group of mostly land-grand universities with more than 1,000 each. Note, however, that the table underreports the patent activity of the University of California system of universities for two main reasons: the first is that because many campuses are located close to each other (e.g. UC Berkeley and UC San Francisco), a number of UC system patents were not included in the analysis because the inventor(s) were located in equal distances between them and as such we could

[8] Nine our sample universities did not have an incubator by the end of 2012: the University of Pennsylvania, the University of California – San Diego, Washington University in Saint Louis, University of Colorado, University of California – Santa Barbara, University of California – Irvine, Tulane University and Brandeis University.

not identify the home institution of those inventors.[9] The second reason is that as a system, and measuring the aforementioned patents in the count, UC is the most prolific institution in terms of patent activity with more than 8,000 patents in the sample period.

--- Table 1 about here---

Table 2 summarizes the variables we use in the analysis. The dependent variable, forward citations per year, is skewed, with a mode of zero: most university patents in our sample did not receive any forward citations. As indicated by the difference between the standard deviation (2.44) and the mean (1.36), there is significant variability in forward citations. Before getting the focal patent, our sample universities had, on average, submitted 242 patent applications (that were later granted patent rights) in the preceding 5 years with 3 inventors and 1 assignee. Most patents were listed under one 4-digit IPC code and had, on average, 15 and 22 patent and non-patent references, respectively. Note that the modal values of 0 both for PATENTREF and NONPATENTREF come mostly from early patents of the 1960s and the 1970s. More recent patents tend to have more extensive lists of backward references. Indeed, the differences in the backward references are strongly indicated by the large standard deviations of PATENTREF and NONPATENTREF compared to their mean values. Thirty percent of the patents were classified as biotech and forty percent as information and communication technology.[10] Finally, more than 26 percent of the sample patents (13,039 of the 49,840) were applied for after the host campus established its incubator.

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[9] Previous works have opted to drop system observations altogether (Wong and Singh, 2010).

[10] To assign patents to technology areas we matched the IPC codes of the sample patents withe the lists of Biotech and ICT related IPC codes provided by the OECD.

--- Table 2 about here---

As seen in Table 3, the correlation coefficients of the variables used in the analysis are relatively weak which should help us to estimate the net effect of each of the independent variables on the value of university patents. The only exception is the high correlation between the number of applications submitted the focal year and the number of applications submitted in the preceding 5 years, which likely reflects path dependency of innovation. When either of the two highly correlated variables is omitted from the analysis the results remain qualitatively similar.

--- Table 3 about here---

6. Results

6.1 Baseline estimates

We start with an OLS regression, reported as our baseline estimates in Table 4. For all the estimates we report heteroskedasticity-consistent standard errors clustered at the university level. The fit statistics at the bottom of Table 4 indicate that the OLS model has reasonable explanatory power, though it explains a rather limited portion of the observed variance. The multicollinearity index is somewhat inflated, above the threshold level of 30, yet well below the worrisome level of 100 (Belsley et al., 1980). Elevated condition indices could inflate the standard errors and subsequently impact inference. Nevertheless, the inferences in models we present in section 6, which have lower multicollinearity indices, and in the baseline models are almost identical, indicating that multicollinearity does not hamper our estimates materially.

To address endogeneity we use the Two-Stage Residual Inclusion (2SRI) method pioneered by Terza et al. (2008). In the first stage we regress the probability that university *i* establishes an academic incubator time *t* conditional on university-specific characteristics.[11] We present the first-stage regression in Appendix Table 1. As expected, the more peer institutions that have established an incubator previously, the higher the chance the focal university will establish an incubator. In the second stage we include the residuals from the first stage in our baseline regression explaining patent quality. Model 2 of Table 4 presents these estimates. Also in support of our choice of instrumental variable, the residuals of the first stage are statistically significant in the second stage. Following Terza et al. (2008) we employ bootstrapped standard errors to account for the presence of the first-stage residual in the model of the second stage.[12]

--- Table 4 about here---

The overall conclusions from the OLS and the 2SRI estimates agree. We find that the establishment of on campus incubators is followed by a reduction in patent quality. But, the 2SRI estimate on INCUBATOR is larger than the OLS estimate[13] which implies that the OLS estimate presents a lower bound on the (detrimental) effect of incubators on patent quality. In the remaining of the manuscript we refer only to the baseline estimates.

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[11] To populate the list of regressors for the first stage estimation we adopt the view that incubators and other auxiliary services towards commercialization are set in place chiefly as a means to expand the opportunity set of academics and others that have an inclination towards entrepreneurship (Fini et al., 2011; Mian, 1996). As such, we would expect universities to establish incubators when the on campus research has elevated commercial potential. Accordingly, because medical inventions tend to be more marketable than inventions from other disciplines (Powers, 2003), we include a dummy variable that takes the value of 1 if the university has a medical school and 0 otherwise. In the same vein, we include the EXPERIENCE variable to capture the intensity of innovation efforts on campus and a dummy variable that takes the value of 1 if the university is private and 0 otherwise as a means to account for the culture of universities and the overall attitude towards applied research (Friedman and Silberman, 2003).

[12]Applications of 2SRI method can be found in a number of areas including policy analysis (Beaudry and Allaoui, 2012) and strategic management (Berry, 2013). Cai et al. (2011) discuss in detail the (desired) asymptotic properties of the 2SRI method when, as in our case, the first stage is a probabilistic model.

[13] What may explain this difference is that universities may mistakenly think that incubators will lead to better patents. When they anticipate a future improvement in their innovative capabilities (e.g., they have just gotten some new grants or endowment funds, they have just hired some star professors, they have just built some new labs, etc.) - developments that, independently of an incubator, should give them better patents - they establish an incubator. Thus even though incubators have a detrimental effect, the fact that they are established under those circumstances makes this effect appear smaller.

The baseline coefficient of INCUBATOR suggests that patents applied for after the establishment of an incubator receive 0.146 fewer forward citations per year. Besides the statistical significance, the size of that coefficient is also meaningful. To illustrate, if we evaluate the 0.146 figure at the mean value of the dependent variable, 1.36, as reported in Table 2, it suggests that the number of forward citations per year of the average patent decreases to 1.21—an 11 percent reduction. If evaluated at the median value, the reduction of forward citations per year approaches 30 percent.

The results for the experience variables are particularly interesting. While the focal university's 5 year experience in patenting has an unexpected negative and statistically significant effect on patent quality, its economic magnitude is tiny, suggesting that university experience has a limited impact on patent value. What appears to matter more is the experience of universities in producing higher-quality patents. Patents coming from universities with previous high-quality patents received 0.162 more forward citations than patents of universities with less experience in high quality patents.

The volume of patent activity of the focal university in the application year of a given patent has a statistically significant positive but economically weak effect on patent quality and alleviates concerns that the intensification of patenting activities can come at the expense of patent quality. Contrary to expectations, biotech patents receive less forward citations per year but in line with theory the opposite holds for ICT patents. The variables that capture the effects of collaboration suggest that patents with more inventors and more assignees tend to be more valuable. However, the negative sign of the interaction term implies that the relationship between number of inventors and assignees is subject to diminishing returns. Finally, the remaining control variables we use in the analysis imply that a) patent scope has a significant impact on patent value, b) an increased number of patent references is associated with more forward citations, and c) the number of non-patent references does not impact patent value. Not shown in Table 4, most of the university- and year-specific coefficients are statistically significant and this suggests that year to year differences as well as a time-invariant university features also matter for university patent quality.

6.2 Robustness Checks

To test the robustness of our findings we perform a series of checks which are presented in Table 5.[14]

--- Table 5 about here---

In the first test we replace our continuous dependent variable with a binary variable and run a Tobit model. Our baseline estimates are obtained using OLS, which ignores the skewness and left truncation of our dependent variable, forward citations per year with a lower bound of 0. In fact, slightly more than 22 percent of our dependent variable observations take the value of 0. In model 1 in Table 5 we use a different specification with a dichotomous dependent variable taking a value of one if the patent has any forward citations and zero otherwise, running Tobit models to assess whether the OLS feature of ignoring the lower bound of our dependent variable is distorting the results. In model 1 we present both the Tobit estimates and the marginal effects which are estimated with the right-hand variables held at their mean values. The marginal effects of the

[14] Besides the robustness checks we present here, we have performed additional tests which are available upon request. These tests include: (a) omitting from the analysis the patents that are owned by more than one sample university, (b) replacing the dependent variable with the number of forward citations and including patent age as a right hand side variable, (c) performing stepwise regression where the INCUBATOR variable enters the analysis first followed by the remaining variables, (d) including separate dummy variables for patents from universities that are part of university systems, (e) replace the 5 year experience variables with variables reflecting experience since the first patent of each university, (f) drop the interaction term and subsequently the multicollinearity condition index of the model and (g) drop the QUANTITY and EXPERIENCE variables, which have the highest Variance Inflation Factor among all variables and are highly correlated to each other. In all these tests, the results are qualitatively equivalent to the baseline estimates and further reinforce our main conclusions.

Tobit estimates are generally within the range of the baseline estimates; the variable signs of all the models are identical and the statistical significances are very similar. This supports our basic conclusion that the presence of incubators is detrimental to university patent value.

The baseline estimates rely on the implicit assumption that the impact of incubators on patent quality takes place shortly after the establishment date of the incubator. Model 2 tests the sensitivity of our estimates to the possibility that the effective time needed before this impact materializes is not immediate. Specifically, we consider as "post-incubator" only patents that have been applied at least one year after the establishment date of the incubator. The estimates in model 2 are nearly identical to the estimates of the baseline model and reinforce our main conclusions.

By design the analysis includes all sample patents and as such it provides evidence with regards to the impact of incubators on the average patent quality. In model 3 we explore the effect of incubators on the average quality of the most valuable patents. We do so by including in the analysis only those patents whose forward citations per year belong to the top 20 percentile. We find that while incubators do not deteriorate the quality of those patents, they do not improve it either. In unreported results, which are available upon request, we find that the deteriorating effect we report in the baseline estimates is driven by a reduction of the average quality of patents that do not belong to the top 20 percentile.[15] Therefore, we conclude that while incubators do not improve the average quality of the most valuable patents, they do hamper the average value of the lesser patents.

In model 4 of Table 5 we exclude the forward citations from the focal university from the dependent variable and from the variables that measure patent experience. We do this to test wheth-

[15] We reach identical conclusions in a) models that define as top patents those with forward citations per year in the top 10 percentile and b) when we construct models studying the probability that a patent belongs to the top 20/10 percentile after the establishment of the incubator.

er the driver of our findings is a potential tendency of the sample universities to cite mostly on-campus work. The coefficient of the INCUBATOR variable is somewhat lower but still within range of the corresponding baseline coefficient (−0.146 and −0.116). Overall, the main conclusions remain intact.

In model 5 we omit patents held by the University of California and State University of New York systems, to see if the results are sensitive to our definition of universities described in section 3. We do this for two reasons. As we have already argued, from a theoretical perspective defining universities per campus adopts the assumption that the central planning from the system has a relatively minor role in the innovation direction of each of the campus universities. From a practical perspective, the spatial proximity between campuses prevents us from assigning all patents owned by system universities to separate campuses. Accordingly, the number of patents included in the analysis for those campuses is only a portion of the true patent activity of those institutions. By omitting from the analysis the observations from the UC and the NY system of universities we test whether the abovementioned theoretical and practical considerations have an impact on our estimates. Model 5 shows that they do not. All the variables have similar (or identical) magnitude, sign and statistical significance. In short, the conclusions remain unchanged regardless of the inclusion of system universities.

Finally, in models 6 and 7 we omit from the analysis the year and university dummies respectively. The exclusion of the university dummies brings only minimal changes in the remaining coefficients mostly in terms of magnitude. On the other hand, while the exclusion of the year dummies does not alter our main conclusions, it brings about a significant increase in the size of the magnitudes. For instance, the coefficient for the INCUBATOR variable in model 6 is -0.274, which is almost double the corresponding coefficient of the baseline estimates (-0.146). As well, the portion of the overall variance explained drops in model 6 when compared to the baseline estimates. These results suggest the year to year deviations we previously describe have a strong explanatory power in shaping the value of academic patents.

7. Conclusion

University incubators, like other technology business incubators, are generally seen as effective mechanisms for translating academic research into commercially useful innovations and value-adding start-up companies. Indeed, some incubators, like Georgia Tech's—the second-oldest among AAU universities—have an impressive record (Rothaermel and Thursby, 2005b) in spawning new ventures, contributing to innovation and local economic growth. But most of the existing literature on incubators looks at an incubator's outputs, not the change in the university's overall innovative performance before and after an incubator is established. Even if incubators generate useful and commercializable knowledge, they may also compete with other university programs that also attempt to foster innovation and generate revenue.

Our work complements previous literature that demonstrates the positive contributions of incubators on innovation (Colombo and Delmastro, 2002; Kolympiris and Kalaitzandonakes, 2013; Markman et al., 2004) by suggesting that such contributions may come at the expense of other, equally valuable academic innovative activities. Specifically, we find that the establishment of a university incubator is followed by a decline in the average quality of the university's patents, controlling for patent-, university-, and time-specific characteristics. The results hold while also controlling for the potential endogeneity of the decision to establish an incubator.[16]

[16] Unfortunately we cannot tell which of a university's patents are specifically associated with its incubator, to see if the incubator's patents are better than those the university was producing before the incubator was set up, even while the average quality of the university's patents falls once the incubator appears.

To be clear, our results do not imply that incubators destroy value, as university incubators serve many purposes, educational as well as commercial.[17] The presence of an incubator may attract particular kinds of faculty and students, enhance the prestige of the university, and benefit the community as a whole. Because we do not measure these other outcome variables, or capture positive spillovers more generally, we cannot quantify the net effects of university incubators on innovation as a whole. However, much of the public discussion around incubators focuses on their specific impact on patenting, which generates licensing and other revenues. The decision to establish an incubator should thus be informed by reliable estimates of these specific effects. Our results suggest that university incubators may not generate net benefits for campus innovation. These are important findings for university administrators, policy makers, and remaining stakeholders who seek to promote innovation via the commercialization of academic research.

Our work also has a number of implications for innovation research. The literatures on incubators and academic patenting have, for the most part, grown in parallel. Here, we show that there are grounds for integration. As such, new works can explore in depths the interactions between incubators and university patenting. Another promising avenue for future research would be to examine more closely the specific mechanisms by which incubators affect university-based innovation, along the lines of Rothaermel and Thursby (2005a, b). Similarly, qualitative work can shed new light on the effect of academic entrepreneurs on the relationship between incubators and patent quality.

[17] An OECD handbook on incubators urges universities not to emphasize the educational aspects of their incubators, however. "[When universities are closely involved in the set-up of the incubator, there can be a conflict of views on the role of the incubator as a training tool (i.e. the view of education policy) and as a generator of high-potential start-ups (i.e. the view of business support policy). These approaches need to be reconciled, bearing in mind that a business incubation program that has a purely educational function is questionable and likely to produce poor value for money, though training and mentoring do play an important role in this policy. . . . When incubators are established within campuses, there is a danger that a wrong message about the contents of the program is transmitted to potentially interested participants. The incubator management will have to make it clear that training and teaching for tenant firms is of practical rather than academic nature" (OECD, 2010 pp 5)

Our study has a number of limitations that can be addressed in future work. First, as noted above, we look only at patent quality as the main effect of a university's innovative activities, rather than a broader set of impacts. Second, the lack of comprehensive data in the early years of the analysis does not allow us to incorporate additional university-specific attributes in the analysis and subsequently reach more refined estimates. Third, we focus exclusively on research-intensive universities and this may limit the generalizability of our results to remaining institutions that also establish incubators but boost their innovative efforts not so much via encouraging in house research but more so via alternative routes such as the promotion of student entrepreneurship.

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Table 1. Patents used in the analysis per university from 1969 to 2012 [a]

University	Number of patents	Percentage of total patents	Incubator Establishment Year
Massachusetts Institute of Technology	4108	8.39	2012
University of Texas	2490	5.09	1989
Stanford University	2471	5.05	2011
California Institute of Technology	2284	4.67	2013
University of Wisconsin	2164	4.42	1984
Johns Hopkins University	1675	3.42	2011
Cornell University	1465	2.99	2002
University of Michigan	1409	2.88	2011
University of Florida	1295	2.65	2012
Columbia University	1124	2.30	1995
University of Minnesota	1121	2.29	2006
University of Pennsylvania	1087	2.22	no incubator
University of Illinois	1062	2.17	2001
University of California - San Diego	989	2.02	no incubator
University of Chicago	989	2.02	2004
Iowa State University	988	2.02	1987
Georgia Institute of Technology	966	1.97	1980
New York University	965	1.97	2009
University of Washington	911	1.86	2012
Harvard University	894	1.83	2010
Michigan State University	821	1.68	2012
Duke University	784	1.60	2009
University of Maryland	766	1.57	1983
Purdue University	755	1.54	1961
University of Southern California	747	1.53	1998
University of California - Los Angeles	737	1.51	2009
Northwestern University	689	1.41	2012
University of North Carolina	677	1.38	2013
Penn State	658	1.34	1993
University of Pittsburgh	638	1.30	2002
WUSTL	608	1.24	no incubator
Ohio State University	600	1.23	2005
Rutgers	596	1.22	2002
Texas A&M	567	1.16	2011
Yale University	556	1.14	2007
University of Iowa	550	1.12	1984
University of California - Davis	527	1.08	2010
Princeton University	509	1.04	2012
University of Colorado	466	0.95	no incubator
University of Rochester	446	0.91	2010
State University of NY - Stony Brook	431	0.88	1992
University of Missouri	421	0.86	2009
University of California - Santa Barbara	420	0.86	no incubator
Carnegie Mellon	416	0.85	2010
University of Virginia	414	0.85	2012
Vanderbilt	406	0.83	2002
Boston University	403	0.82	2005
Emory University	377	0.77	no incubator
University of California - Irvine	375	0.77	2010
Case Western	367	0.75	2010
State University of NY - Buffalo	323	0.66	1988
Indiana University	293	0.60	2004
Rice University	283	0.58	2000
Brown University	214	0.44	2009
University of Arizona	198	0.40	2003
University of Kansas	189	0.39	2010
Tulane University	142	0.29	no incubator
Brandeis University	114	0.23	no incubator

[a] The sample universities were also granted 6621 patents which we did not include in the analysis because they could not be assigned to separate campuses for the following reasons: The inventors of 3996 University of California System patents were located in between two or more campuses with the most common case being the University of California - Berkeley and the University of California - San Francisco. 502 University of California System patents had inventors in the Los Alamos Laboratory. 372 University of California System patents had inventors that were not residing in California (mostly foreign inventors). The inventor of 1 University of California System patent had a dual appointment with two University of California System universities. 1547 patents in the sample had more than 1 in-sample assignee. 203 patents assigned to the System of New York Universities had inventors not residing in the state of New York. Also note that 358 patents were assigned to system uiversities that were not AAU members. These patents are not icnluded in the baseline analysis.

Table 2. Descriptive Statistics

	Variable Description	Variable Code	Number of Observations	Mean	Std Dev	Minimum	Maximum	Median	Mode
Dependent variable	(Number of times the focal patent has been cited by other patents since its grant date) / (December 31 2012 - grant date)	Forwardyear	48940	1.36	2.44	0.00	49.57	0.50	0.00
Continuous variables	Number of successful patent applications submitted by the focal university in the 5 years proceeding the application date of the focal patent	Experience	49298	241.56	193.42	0.00	851.00	194.00	121.00
	Average number of forward citations per year gathered by patents used to construct the Experience variable	Forexperience	48432	1.64	0.76	0.00	11.86	1.55	1.34
	Number of successful patent applications submitted by the focal university the focal year	Quantity	48940	53.50	40.65	1.00	187.00	43.00	39.00
	Number of non-patent references included in the list of references in the focal patent	Nonpatentref	48940	22.14	44.51	0.00	1045.00	7.00	0.00
	Number of patent references included in the list of references in the focal patent	Patentref	48940	15.75	31.63	0.00	837.00	7.00	0.00
	Number of inventors of the focal patent	Inventors	48940	2.70	1.62	0.00	22.00	1.00	2.00
	Number of assignees of the focal patent	Assignees	48940	1.11	0.35	0.00	6.00	-	1.00
	Number of IPC categories the focal patent belongs to	Scope	48888	2.24	1.54	1.00	18.00	-	1.00
Binary variables[a]	Variable that takes the value of 1 if the focal patent has a biotechnology related IPC code and 0 otherwise	Biotech	14610						
	Variable that takes the value of 1 if the focal patent has an ICT related IPC code and 0 otherwise	ICT	19318						
	Variable that takes the value of 1 if the application date of the focal patent is after the opening date of the university incubator and 0 otherwise	Incubator	13039						

[a] For these variables the figure in the "Mean" column presents the number of observations that take the value of 1

Table 3. Correlation Coefficients between Variables Used in the Analysis (excluding year and university - specific dummies)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Forwardyear	1.000												
2. Incubator	-0.056	1.000											
3. Experience	0.033	0.068	1.000										
4. Forexperience	0.157	-0.106	0.403	1.000									
5. Quantity	0.080	0.035	0.919	0.440	1.000								
6. Biotech	-0.099	-0.004	-0.021	0.025	-0.005	1.000							
7. ICT	0.098	-0.026	0.095	0.100	0.089	-0.134	1.000						
8. Nonpatentref	0.012	0.056	0.079	0.051	0.044	0.250	-0.060	1.000					
9. Patentref	0.095	0.048	0.130	0.072	0.079	-0.040	0.001	0.481	1.000				
10. Inventors	0.058	0.022	0.129	0.124	0.105	0.054	0.000	0.127	0.114	1.000			
11. Assignees	-0.009	0.008	0.026	0.029	0.009	0.085	-0.047	0.113	0.074	0.311	1.000		
12. Inventors * Assignees	0.028	0.012	0.090	0.083	0.068	0.080	-0.026	0.134	0.103	0.826	0.711	1.000	
13. Scope	0.052	-0.008	0.022	0.108	0.042	0.368	0.063	0.184	0.080	0.131	0.077	0.123	1.000

Table 4. Baseline Estimates. The dependent variable is the number of forward citations per year

Variables / Model	1. OLS estimation		2. Two-stage residual inclusion estimation	
Intercept	**0.168**		**0.175**	
	(0.229)		(0.126)	
Incubator	**-0.146**	***	**-0.295**	***
	(0.053)		(0.047)	
Experience	**-0.002**	***	**-0.002**	***
	(0.000)		(0.000)	
Forexperience	**0.162**	***	**0.163**	***
	(0.036)		(0.029)	
Quantity	**0.006**	***	**0.006**	***
	(0.001)		(0.001)	
Biotech	**-0.659**	***	**-0.661**	***
	(0.062)		(0.024)	
ICT	**0.400**	***	**0.400**	***
	(0.051)		(0.026)	
Nonpatentref	**0.000**		**0.000**	
	(0.001)		(0.000)	
Patentref	**0.009**	***	**0.009**	***
	(0.001)		(0.001)	
Inventors	**0.147**	***	**0.148**	***
	(0.026)		(0.019)	
Assignees	**0.044**		**0.045**	
	(0.141)		(0.069)	
Inventors * Assignees	**-0.045**	**	**-0.045**	***
	(0.018)		(0.013)	
Scope	**0.085**	***	**0.084**	***
	(0.027)		(0.010)	
Residual of first stage [a]			**0.040**	***
			(0.008)	
Year Dummies Included	YES		YES	
University Dummies Included	YES		YES	
R^2	0.113		0.113	
Adjusted R^2	0.111		0.111	
F - test of overall model significance	48.270	***	48.220	***
Multicollinearity Condition Index	40.282		40.819	
Number of Observations	48380		48380	

*** .01 significance, ** .05 significance, * .10 significance

Note: For model 1 robust standard errors, adjusted for heteroskedasticity and clustered by university, are reported in parentheses. For model 2 the standard errors are calculated using the bootstrap method

[a] The estimates of the first stage are presented in Appendix Table 1

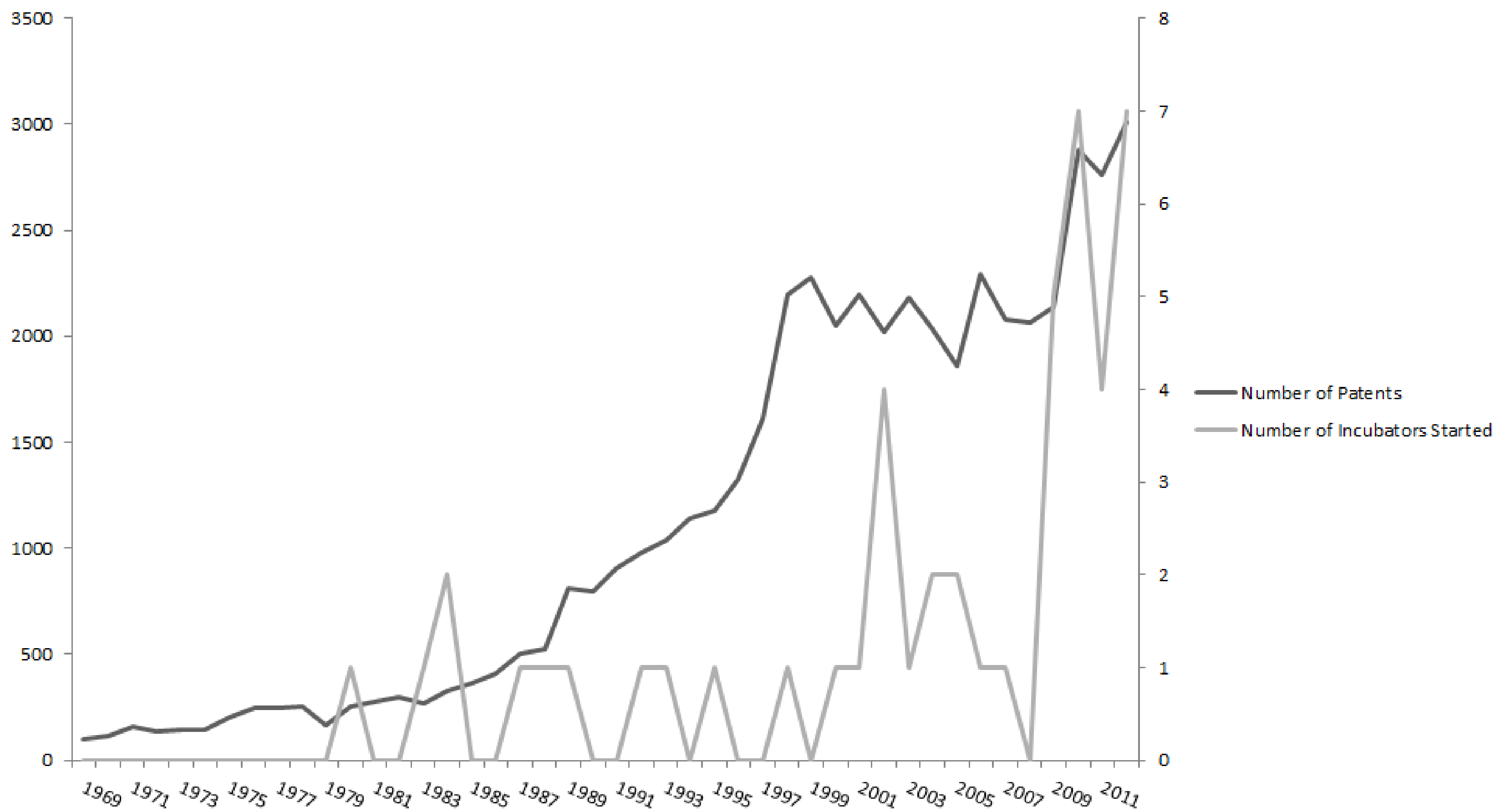
Table 5. Robustness Checks

Variables / Model	Model 1. Tobit Estimation		Model 2. Considering as post-incubator patents applied after 365 days from incubator's founding date	Model 3. Conduct the baseline analysis only for patents with forward citations per year in the top 20 percentile	Model 4. Exclude forward citations from the same university from the dependent variable and the experience variables	Model 5. Omit observations from University of California System and SUNY	Model 6. Omit year dummies from the analysis	Model 7. Omit university dummies from the analysis
	Estimate	Marginal Effect	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
Intercept	**0.639**	***	**0.163**	**3.498** ***	**0.240**	**0.097**	**0.317**	**0.021**
	(0.036)		(0.229)	(0.781)	(0.190)	(0.238)	(0.201)	(0.171)
Incubator	**-0.243**	-0.188 ***	**-0.130** **	**-0.306**	**-0.116** **	**-0.117** **	**-0.274** *	**-0.113** **
	(0.034)		(0.060)	(0.309)	(0.052)	(0.048)	(0.150)	(0.048)
Experience	**-0.002**	-0.002 ***	**-0.002** ***	**0.000** *	**-0.002** ***	**-0.002** ***	**-0.005** ***	**-0.002** ***
	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Forexperience	**0.036**	0.029 **	**0.164** ***	**-0.337**	**0.189** ***	**0.170** ***	**0.447** ***	**0.317** ***
	(0.017)		(0.036)	(0.252)	(0.031)	(0.037)	(0.053)	(0.035)
Quantity	**0.003**	0.002 ***	**0.006** ***	**0.004** *	**0.006** ***	**0.006** ***	**0.015** ***	**0.008** ***
	(0.000)		(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Biotech	**-0.142**	-0.113 ***	**-0.659** ***	**-0.469** **	**-0.635** ***	**-0.675** ***	**-0.599** ***	**-0.662** ***
	(0.011)		(0.062)	(0.187)	(0.064)	(0.063)	(0.059)	(0.067)
ICT	**0.040**	0.033 ***	**0.400** ***	**0.372** **	**0.414** ***	**0.390** ***	**0.339** ***	**0.423** ***
	(0.008)		(0.051)	(0.141)	(0.050)	(0.053)	(0.052)	(0.051)
Nonpatentref	**0.000**	0.000 *	**0.000**	**0.002**	**0.000**	**0.000**	**0.000**	**0.000**
	(0.000)		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Patentref	**0.001**	0.001 ***	**0.009** ***	**0.007** ***	**0.007** ***	**0.009** ***	**0.008** ***	**0.009** ***
	(0.000)		(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Inventors	**-0.002**	-0.001	**0.147** ***	**0.216** **	**0.131** ***	**0.153** ***	**0.148** ***	**0.139** ***
	(0.004)		(0.026)	(0.100)	(0.024)	(0.027)	(0.025)	(0.027)
Assignees	**-0.037**	-0.030 **	**0.043**	**0.143**	**0.031**	**0.064**	**0.090**	**0.033**
	(0.014)		(0.141)	(0.526)	(0.117)	(0.148)	(0.134)	(0.140)
Inventors * Assignees	**0.002**	0.002	**-0.045** **	**-0.073**	**-0.038** **	**-0.050** ***	**-0.050** ***	**-0.043** **
	(0.002)		(0.018)	(0.084)	(0.016)	(0.018)	(0.017)	(0.018)
Scope	**0.001**	0.001	**0.085** ***	**0.147** **	**0.068** **	**0.093** ***	**0.098** ***	**0.088** ***
	(0.002)		(0.027)	(0.057)	(0.026)	(0.028)	(0.027)	(0.027)
Year Dummies Included	YES		YES	YES	YES	YES	NO	YES
University Dummies Included	YES		YES	YES	YES	YES	YES	NO
R^2	0.187		0.113	0.073	0.110	0.116	0.076	0.105
Adjusted R^2	0.184		0.111	0.065	0.109	0.115	0.075	0.104
Test (LR of F-test depending on estimation technique) of overall model significance	132.43 ***		48.23 ***	7.87 ***	50.07 ***	49.61 ***	45.55 ***	114.58 ***
Multicollinearity Condition Index	40.282		40.251	44.375	40.264	39.446	38.421	32.491
Number of Observations	48379		48379	10014	48379	44625	48.379	48379

*** .01 significance, ** .05 significance, * .10 significance

Note: Robust standard errors, adjusted for heteroskedasticityand clustered by university, are reported in parentheses.

Figure 1.
Number of Patents Granted to sample AAU Universities and Number of Incubators Started Each Year



Appendix Table 1. First stage of two stage residual inclusion estimation. The dependent variable is the probability of a given university having established an incubator at a given time

Variables	Estimates		Marginal Effects
Intercept	**-0.662**		
	(0.616)		
Number of competing universities that had established an incubator previously	**0.627**	**	**0.070**
	(0.269)		
Experience	**0.000**		**0.000**
	(0.003)		
Variable that takes the value of 1 if the university is private, 0 otherwise	**-3.168**	**	**-0.384**
	(1.326)		
Variable that takes the value of 1 if the university has a medical school, 0 otherwise	**-0.867**		**-0.108**
	(0.939)		
Year Dummies Included	YES		
University Dummies Included	YES		
R^2	0.366		
Adjusted R^2	0.364		
Wald test of overall model significance	10814.710	***	
Multicollinearity Condition Index	8.471		
Number of Observations	48940		

*** .01 significance, ** .05 significance, * .10 significance

Note: Robust standard errors, adjusted for heteroskedasticity and clustered by university, are reported in parentheses