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University Start-Ups:
Critical for Improving Technology Transfer

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EXECUTIVE SUMMARY

Universities are under increasing political pressure to assert, measure, and improve their impact on national wellbeing, with attention primarily to economic growth, job creation, and competitiveness. Universities receive significant public resources for research and policymakers wish to hold them accountable for those investments. Policymakers also want universities to be more responsive to market forces, more entrepreneurial, and more attuned to the needs of industry. Consequently, the government accountability crunch on university is focusing on technology transfer, the complex work done at the interface of research and productive organizations.

Universities revamped their technology transfer capabilities over the last three decades in order to seize the opportunities of reforms to the patent system that included: Supreme Court decisions that expanded patentable matter; stronger patent protection; and the legal right, given to universities, to take title to inventions made from federal research grants (Bayh-Dole Act of 1980). The emphasis has been largely on licensing patents but only a few universities have been able to generate significant revenues from this activity. In fact, most university technology transfer offices do not generate income to even cover their operating expenses. This is explained in part by the asymmetry in the distribution of resources across the university system, particularly research funds allocated on a competitive basis. It is no coincidence that blockbuster patents and high licensing revenues benefit only a few select universities. This financial pressure doubled the political pressure on universities to improve

technology transfer. The universities' response has been the organic emergence of what I call here the "nurturing start-ups model."

This new model of technology transfer involves creating the incentives and organizational capacity within universities to support the entrepreneurial efforts of their faculty. By devoting resources to support campus entrepreneurs, by introducing career incentives, and by partnering with local business incubators and capital investors, universities are creating a nurturing environment for these nascent enterprises.

I conclude with a set of recommendations for institutional support of these entrepreneurial initiatives of the university. First, the government should expand funding for the Small Business Technology Transfer (STTR) program designating funds specifically for university start-ups. A bill introduced in the House last August is moving in precisely this direction (H.R. 2981) but does not go far enough expanding STTR funding, only reapportions funds for early stage start-ups. Second, Congress should authorize a patent use exemption for non-profit research organizations for the purpose of exclusive experimental use. In addition the executive branch should empower federal agencies to use the march-in rights provision under Bayh-Dole to extend non-exclusive licenses for research tool patents that have been subjected to pricing excesses. Third, the government should create an equity rule for the distribution of funds among universities. This rule has the aim to bring sufficient support to technology transfer at each university in order to promote enterprises that are competitive in state and regional markets but that may not qualify for grants in national competitions.

"The greatest invention of the nineteenth century was the invention of the method of invention... One element in the new method is just the discovery of how to set about bridging the gap between the scientific ideas, and the ultimate product. It is a process of disciplined attack upon one difficulty after another."

- Alfred North Whitehead, Lowell Lectures 1925 (1967, p. 96-97)

1. He who pays the piper will ask questions about the tune

Over the last few years the scientific establishment and particularly the university system have come under political pressure to assert, measure, and improve their impact on national wellbeing, with attention primarily to economic growth, job creation, and competitiveness, but also to public health and security. This pressure is exemplified by two high-profile requests from Congress to the National Academies that led to the famous reports, *Rising Above the Gathering Storm*[1] and *Research Universities and the Future of America*.[2,3]

Congress and the National Academies both recognize innovation as the main driver of economic growth and prosperity and the well-received reports offered several policy recommendations. I will turn my attention to two of them: *Gathering Storm* advocated increasing research funding (in STEM fields), while *Research Universities* stressed the importance of fostering a closer partnerships between university and industry.

More recently, echoing the plead of *Gathering Storm*, 165 university presidents sent an open letter to President Obama and the members of Congress to ask for decisive action in closing, what they called, the *innovation deficit*, defined as the inadequacy of public investments in research and higher education to keep the U.S. economy competitive.[4] When university presidents ask for a firm commitment from government to increase research funding, they are also inviting policymakers to hold them ever more accountable for the public money they receive. In fact, the government is likely to increase the accountability pressure on universities in direct proportion to the tax dollars devoted to close the innovation deficit. But what part or function of the university will bear the brunt of this pressure? Given that policymakers are primarily concerned with how much intellectual value is converted into economic value, the focus will be precisely on that conversion process and how the university interfaces with industry.

Let me digress for a moment to discuss a facet of this political pressure that reveals its source and hints at some of its effects: University and industry are both large recipients of public funds for research and development, however, accountability is unevenly demanded from the university system. Federal R&D is in the order of $124 billion.[5,6] From that total, the federal government performed $46 billion in research contracts through its own laboratories and federally funded research centers, industry performed $40 billion, and the university system did $32 billion.[7] Industry is indeed a very large recipient of public funds; yet, curiously, it hardly comes under the same pressure as universities to demonstrate the economic impact of their R&D contracts. Three likely reasons explain this. The first is that universities focus on research, not development projects—97.6% of the total public contracts they obtain are for basic or applied research. In the R&D world, the merits of research projects are more difficult to explain to non-experts than the merits of development projects, not only their internal logic—although development projects could be quite complex—but also the uncertainty of their outcomes. Policymakers are bound to be more skeptical of the beneficial impact of research.

The second reason is the general presumption among policymakers that when research is conducted by the business sector, it will automatically be put to practical use. Industry receives 56% of the total value of federal contracts for development projects, and these projects usually entail delivery of ready-to-use technologies. In turn, the university performs only a negligible amount (less than 2%).

The third reason why the government is able to demand more from universities than from industry is because academic research is far more dependent on federal funds than industrial research, even though the latter receives more money in R&D contracts. Universities receive $32 billion in public research funds which account for 58% of their total R&D budget, whereas industry receives $40 billion which account for only 14% of their budget. The White House and Capitol Hill understand this dependence only too well.

That the government applies more pressure on the university and less on industry to show the returns of public R&D reveals a particular type of influence exerted over the university. The message is that the university should be a bit more like industry, not in the sense of rebalancing its R&D portfolio in favor of development contracts, but in the sense of being more responsive to market forces, more entrepreneurial, and to make its research and teaching more attuned to the needs of industry. The public emphasis on fostering innovation translates at the university level into an emphasis on linking more effectively research to commercial applications; thus, the focal point of the accountability crunch is technology transfer. In this paper, I discuss the response to this pressure and other economic factors that have led to the organic emergence of a new model of university technology transfer.

Technology transfer is an old term of art. Its meaning has morphed and accommodated to changing times and understandings of innovation. It generally describes the transactions between organizations dedicated primarily to research, such as universities and laboratories, and organizations dedicated to produce goods for sale in the marketplace. Technology transfer was prominent during the Kilgore-Bush debates about how to reorganize the scientific enterprise mobilized to fight World War II for civilian purposes.[8] At that time the dominant view of innovation was that of a linear process; that's why "transfer" suggests a unidirectional transaction, like a wire transfer. In time, the linear model of innovation has proven inadequate for description and misguiding for the governance of innovation. Instead of an assembly line moving an invention down a conveyor belt adding greater applicability and commercial value at each stage, we now speak of an innovation ecosystem to highlight the contingency and complexity of the system, the interdependence of environment and economic agents, the interconnectedness of its actors, and the recursive process (as opposed to a unidirectional process) by which ideas inspire commercial applications and these in turn inspire further ideas. Technology transfer is thus not a matter of patents alone; rather, it is the complex work that takes place at the interface of research and productive organizations. It is a function of innovation that permeates the entire ecosystem because all the major players intervene: universities, laboratories, big and small companies, high-tech and capital intensive industries, and also investment capital and regulatory bodies.

The Bayh-Dole Act of 1980 and its subsequent amendments govern university technology transfer by mandating a uniform rule across federal agencies to allow universities to take title to public patents—patents derived from federally funded research. Proponents of Bayh-Dole argue that if the government retained title to public patents, the private sector would not invest in the development and commercialization of those patents. This logic assumes that firms fear the kind of government intervention that would end their patent monopolies by granting non-exclusive licenses, implement price controls, or seek to recoup its investments. It is worth noting that the government has not always retained title to public patents. Before Bayh-Dole, federal agencies had discretion to specify the terms under which their grantees were allowed to take title to patents and at one point there were as many as 26 different policies across the federal government. Bayh-Dole created a uniform rule of patent ownership thus making its transfer administratively efficient. To implement this policy, the universities created a small bureaucracy, in their own campuses, to manage the university's intellectual property.

These technology transfer offices (TTOs) are costly to the university. What is more, the financial challenges that universities confront, coupled with the political pressure for more accountability, are shaping the way universities manage technology transfer and reconsider their own role in the innovation system.

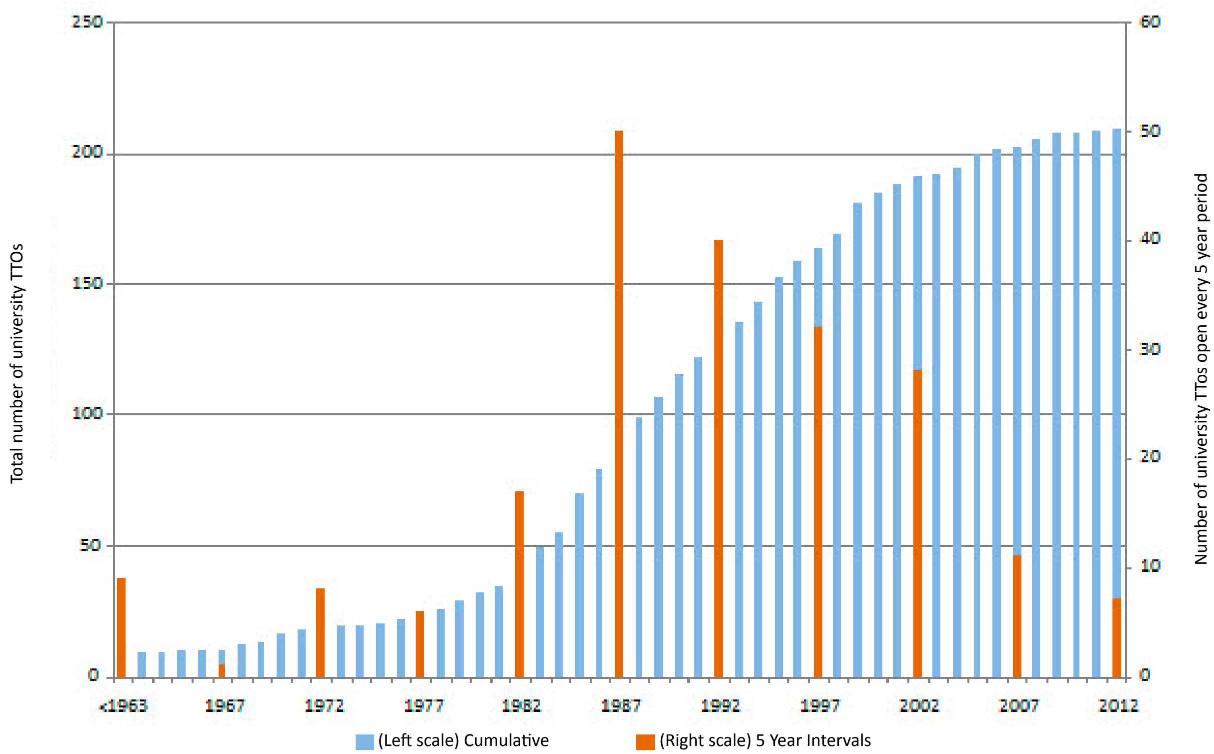
2. Patenting: A costly affair for universities

After Bayh-Dole was enacted universities created the organizational capacities for managing their intellectual property, opening and staffing technology transfer offices (TTOs) in a great hurry. The Association of University Technology Managers (AUTM) reports that by 1979, only 30 universities had a TTO but in two decades this number went up to 174 in 1999 (see Figure 1). The annual growth of TTO openings is exponential through the 1980s and 1990s, and now that most research universities are in business, the yearly increment is only marginal. As of 2012, 155 University TTOs reported to AUTM.[9] The 2010 Carnegie Classification of Higher Education counts 206 U.S. universities with very high or high research activity; all of them have TTOs, but not all report to AUTM.

While universities rushed to open TTOs, only a few raised significant income from licensing their patents under Bayh-Dole. Figure 2 shows the great asymmetry in the distribution of licensing gross income, an asymmetry that seems consistent for 2012 when compared to the average of the last three years and the average of the last decade. In all cases, an exponential trend is the best fit to that distribution. In 2012, a year very much in line with the ten-year trends in this sector, the top 5% of earners (8 universities) took 50% of the total licensing income of the university system; and the top 10% (16 universities) took nearly three-quarters of the system's income.

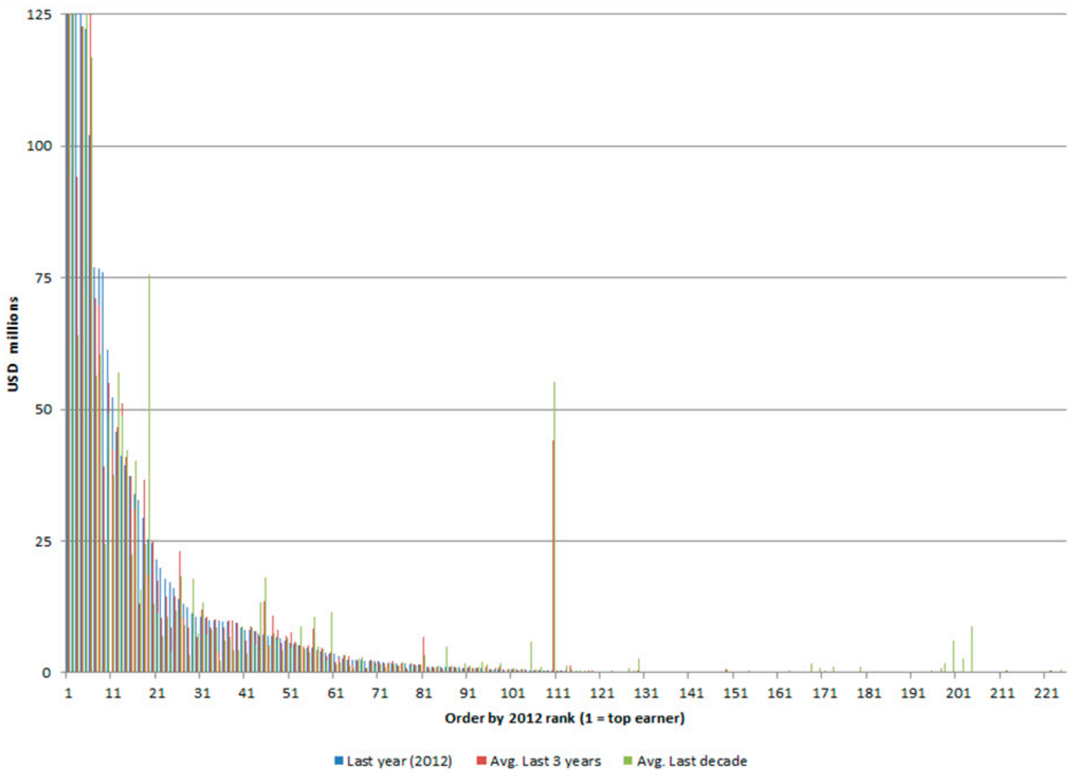
Not only licensing revenue is highly asymmetric but also the highest earners have become a select club with a stable membership. Only 37 universities have been able to reach the top 20 of licensing revenue any given year over the last decade. Table 1 shows the 2012 ranking of licensing income the number of times each university made it to the top 20 over the last 10 years, and two additional rankings adjusting licensing income by size of TTO (number of employees), and by size of the university (research expenditures).[10]

FIGURE 1: GROWTH OF UNIVERSITY TTOs



Source: AUTM (2013)

FIGURE 2: DISTRIBUTION OF LICENSING GROSS INCOME BY UNIVERSITY



Source: AUTM (2013)

TABLE 1: TOP EARNERS OF LICENSING GROSS INCOME 2003-2012

University	Rank 2012	Number of times on top 20 over the last decade	Rank adjusted by number of TTO employees	Rank adjusted by university research expenses
New York University	1	10	2	2
Columbia University	2	6	6	5
Massachusetts Institute of Technology	3	10	8	15
Princeton University	4	2	1	1
Northwestern University	5	7	4	6
Univ. of California System	6	10	38	46
University of Washington	7	10	23	17
Stanford University	8	9	15	13
Mount Sinai School of Medicine	9	7	5	4
University of Texas System	10	4	34	34
University of Massachusetts All Campuses	11	10	13	16
University of Minnesota-Twin Cities	12	9	21	24
University of Wisconsin-Madison	13	10	40	30
University of Rochester	14	10	11	10
University of Utah	15	8	26	11
University of Florida	16	10	25	23
University of Colorado System	17	5	19	28
California Institute of Technology	18	5	12	19
Emory University	19	6	20	25
Duke University	20	4	30	32
University of Illinois at Urbana-Champaign	21	1	37	38
University of Pennsylvania	23	1	41	43
University of Michigan-Ann Arbor	26	6	46	65
Harvard University	29	5	69	55
State University of New York System	31	3	56	64
Iowa State University	34	1	35	31
University of Nebraska - Lincoln	38	1	53	36
University of Georgia	44	4	33	40
University of Iowa	45	6	57	48
Washington University in St Louis	53	1	66	77
Michigan State University	60	3	85	81
University of South Florida	81	1	108	109
Florida State University	86	2	97	85
Wayne State University	105	2	110	118
Wake Forest University	110	9	124	120
Eastern Virginia Medical School	129	1	126	116
University of Texas Southwestern Med Center	150	1		

Source: AUTM (2013)

The distribution of licensing income among universities seems to reflect the wide disparities that are prevalent within the U.S. university system where resource distribution of endowments, public and private funding of research, tuition fees, etc., is heavily lopsided. For instance, of the 155 universities reporting licensing data in 2012, the top half in terms of research expenditures controls about nine of each ten dollars of research funds and of licensing revenue.[11]

In addition, universities generally split licensing revenue in three parts: a third for the faculty-inventors, a third for their department or lab, and a third as discretionary funds for the university. That is to say, universities collect only one third of the licensing revenues raised by the TTO but shoulder all of its operating costs. Not only do most universities fail to raise significant licensing income (whatever the amount) but they also keep a third of it to support technology transfer operations. It would be of little surprise to find out that the vast majority of university TTOs will function at an operational loss. Using information of TTO expenses, I calculated a rough estimate of net operating income (NOI)[12] and found that of the 155 universities reporting to the AUTM survey, 130 did not generate enough licensing income in 2012 to cover the wages of their technology transfer staff and the legal costs for the patents they file. What is more, with 84% universities operating technology transfer in the red, 2012 was a good year because over the last 20 years, on average, 87% did not break even. If TTOs were to be considered strictly business units, they would be forced to radically change the way they do business.

This financial picture of university technology transfer suggests that universities have strong incentives to come up with new models of technology transfer that better square the books and I return to this in the next section. This dire situation also puts in evidence the resolve of universities to maintain and keep open these expensive offices. In fact, universities realize that technology transfer is a crucial function of the university in terms of promoting innovation and that keeping TTOs open demonstrates their commitment to their public mission.

The losses incurred in managing their intellectual property are not the result of low-selectivity in the inventions universities decide to patent. That may have been true for universities that started to patent only after passage of Bayh-Dole—overly eager TTOs were at that time not sufficiently discriminating about what they were patenting; they simply incurred the costs. However, there is increasing evidence that entrants to the patenting business learned quickly to be as selective as long time incumbents.[13]

There has been at times a contradiction of aims between the university and its TTO. While universities must always keep in mind their service mission and thus are inclined to forgo some licensing revenue by granting non-exclusive licenses on research tools, and fee waivers to promote equity and humanitarian causes, their TTOs are primarily interested in generating revenues.[14] This concern is manifest by industry's regular complaint about universities being too aggressive negotiating patent licenses and it is also manifest by certain practices that form time to time have exposed TTO as profit maximizing entities—for instance, contracts with "creative" clauses such reach-through that ignited the OncoMouse controversy.

This occasional clash of aims between the university and its TTO is inherent to their charter, the former being a non-profit organization and the latter being fundamentally a business unit. Organizational culture is also part of the explanation, as TTOs are usually staffed with former intellectual property attorneys and professionals with venture capital experience, whose compensation can be partly tied to revenue (in the form of bonuses). In addition, these teams are tasked with managing technology transfer but that may be too broad for business oriented people; so they interpret the goal to mean, in practice, commercializing the university patent portfolio.

Furthermore, TTOs are well organized, meet regularly, and exchange information on best business practices. Informally, they too share bits and pieces of recent hot deals. They may not be in competition for clients but they certainly compete for prestige, and prestige is measured in terms of high-value contracts and licensing income. How could they not pay attention to stories of blockbuster patents that benefit society and are a boon to universities. Any list of historical blockbuster patents starts always with the emblematic gene splicing method of the Cohen-Boyer patents that yielded near $255 million for Stanford University and UCSF during the life of the patent; and the Axel patents for co-transformation, a method to insert DNA into eukaryotic cells, from which Columbia University collected $790 million in licensing fees.[15] Further examples include the cancer treatments Taxol (Florida State U.) and Cisplatin (Michigan State U.), the vaccine for Hepatitis-B (UCSF), the antiretroviral Zerit (Yale U.), and the treatments for glaucoma Xalatan (Columbia U.) and Trusopt (Michigan State U.). The lucky universities that owned these patents derived significant revenues for their universities, between $15 and $45 million per year—and the products yielded even greater returns for the firms that commercialized them, namely, Merck, Bristol-Myers Squibb, Pharmacia & Upjohn now GE Healthcare.[16]

Thus far, I have shown that the asymmetries of resources that pervade the university system are even more pronounced when looking at the asymmetries of licensing incomes. As a result, only few universities raise significant revenue from their patents and most universities lose money in their technology transfer operations. The standard model of technology transfer, licensing to the highest bidder, depends on the ability of the TTO to negotiate favorable licensing terms, which depends to some extent on its bargaining skills—although, it risks alienating industry if it is too aggressive—and depends for the most part on the quality of the patent to be licensed. This begs the question of what is the probability for a given university with a certain level of research resources to land a blockbuster patent? If chances are not good, and indeed, most universities do not seem to strike luck, it begs a second question as to whether other models of technology transfer could accommodate at the same time industry needs and the financial goals of the TTO.

3. Technology transfer: Luck or strategic behavior?

Stories of blockbuster patents have fueled the ambition of TTO heads and university administrators alike and have also played a role in their anxiety for landing a "blockbuster" patent. Being that such an event is subject to many factors outside of the control of the TTO, a blockbuster has been compared to winning a lottery.

TABLE 2: PROBABILITY OF BLOCKBUSTER PATENT AS A FUNCTION OF RESEARCH FUNDS

	Probability of NOI $\geq$ 10m	
Rank According to Research Funds	As a function of total research funds (TRF)	As a function of federal research funds (FRF)
4	58.6%	72.9%
10	30.4%	24.8%
20	23.8%	22.6%
30	15.3%	14.9%
40	11.7%	11.8%
50	9.8%	11.0%
100	5.3%	5.8%
155	4.0%	4.2%

Estimated using PROBIT mode: Regression of success/failure of blockbuster patent (NOI>$10m) over TRF (intercept -1.766565, slope 0.0013321) and over FRF (intercept -1.744929, slope 0.00185); all estimated coefficients are statistically significant at p=-.05. Data Source: AUTM, 2013

If research were a lottery and a blockbuster patent the jackpot, one would be tempted to say that all universities pay to play but only a few universities get to win. I estimated the probability of such a lottery modeling the success in discovering a blockbuster as a function of research funds, and found that indeed the chances drop dramatically beyond the top ten universities in research funding, at the total and federal levels. While the tenth university has a 30% chance of landing a blockbuster patent in a given year (not bad for a lottery), the 40th has 12%, and the 100th just 5% (see Table 2).[17]

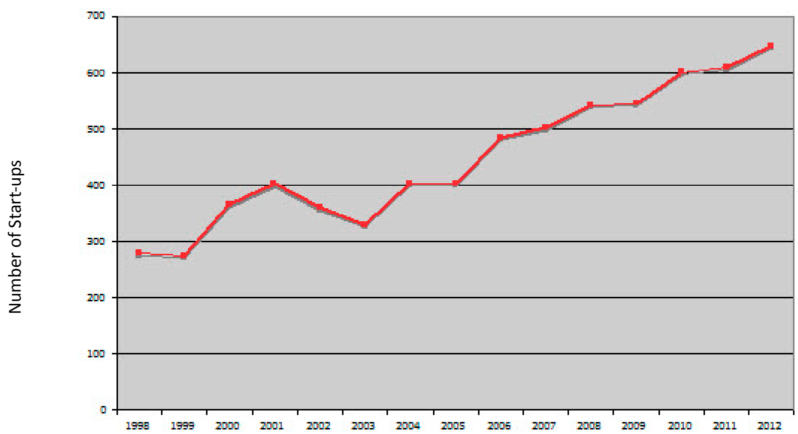
The probability of a blockbuster is disproportionately high for elite universities. In spite of that fact, small universities still have a reasonable chance of winning. TTOs may justify any given year to stay in business on the expected benefit of next year's having a blockbuster patent to license; but they cannot repeat this rationale for too long before university administrators get impatient with them. At the same time, universities can do their part to improve the odds of a blockbuster patent. They can re-direct their research efforts, laboratories, faculty, and students to the pursuit of lucrative patents. Universities may adjust the composition of their research portfolios as some fields are more likely to produce a blockbuster patent than others (particularly biotechnology). They may enter into agreements with large companies interested in outsourcing their R&D in exchange for rights to the resulting IP. Universities may also introduce organizational incentives for faculty by attaching patenting to promotion and compensation. Such reforms, whenever adopted, have met resistance from university faculty members, student movements, and other advocates of humanitarian causes.[18] Particularly, agreements where IP is committed to a private donor before the research has been performed have met with criticism as exemplified by the controversy around the $500 million deal between UC Berkeley and BP.[19]

Whether is to improve the chances of a blockbuster, or to improve the finances of their TTO, or to neutralize the threat to their reputation, universities have developed alternative strategies to manage their IP without attracting strong resistance to commercial activities and university-industry partnerships.[20] Some universities have taken TTOs out of the organizational body of the university and chartered them as separate entities or as units within separate legal vehicles like research foundations. Not constrained by the not-for-profit charter of the university, TTOs can be managed more like businesses and with more room to maneuver, TTOs can be more than simply licensing agents, they can now provide a wider array of services to firms taking licenses.

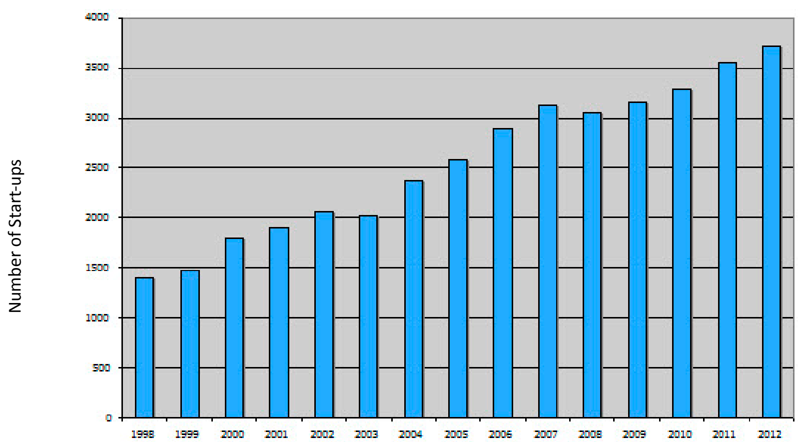
In addition, TTOs have realized that many university patents are embryonic applications[21] and at that point only a small group of people, including the inventor, can understand the technical potential and even less the commercial potential. It is there where TTOs have spotted a business opportunity because they can provide services to faculty-inventors who want to pursue their ideas into commercial products but have little experience in starting up a firm. By "nurturing start-ups," TTOs can add the most economic value to an invention disclosure. Universities have already a few years of history setting up start-ups as part of their technology transfer programs (Figure 3). The universities participating in the AUTM survey reported a total of 3715 operating university start-ups as of 2012, nearly double the number operating in 2000. What is more, in 2003 universities initiated 330 start-ups; the number last year was 647.

FIGURE 3: UNIVERSITY START-UPS

Start-ups Initiated



Operational Start-ups (Cumulative)



Source: AUTM (2013)

TTOs are able to provide a broad range of services including those typically associated with business incubators.[22] In addition to the traditional legal council in patent application, the TTO may provide legal assistance in building and managing the company's IP portfolio, including licenses from owners of prior patented art. Also, the TTO may advise in the legal constitution of the firm, particularly regarding the terms of use of university facilities (such as leasing of equipment) and the terms of employment for faculty-inventors. Partnering with the university incubator, if this exists, the TTO may assist in hiring the managerial team for the firm, and through the incubator, it could offer office space and administrative support. TTOs are also able to plug start-ups into their networks of donors, private investors, institutional investors, and firms already providing the university with market analysts and marketing consultants. Likewise, an experienced technology transfer team may help the start-ups in attracting and negotiating capital influxes, first with angel capitalists, and later with corporate officers, venture capitalists and investment bankers.

There are advantages and disadvantages from the nurturing start-ups model over the model of simply licensing the university's IP. One disadvantage is that nurturing start-ups may consume the resources available to the TTO to find licensors for their high-fee patents. At the same time, high-risk low-fee patents will more easily find a market in the same start-up firms that the university is helping establish. While nurturing start-ups will not displace the standard license-to-highest-bidder model, in an environment of scarce resources the TTO may gradually redirect resources from finding licensors to finding buyers for their start-ups. In addition, while the new model defers income further into the future—because instead of cash fees they will take stock in the new companies (or stock options)—it does not necessarily place a heavier cost-load up front. The costs of nurturing start-ups need not break the bank if small funds can be used to leverage support from local and state businesses and government. The costs for the TTO will not be significant compared to "angel capitalists"—private investors that may include family and friends of the inventors—who bear the brunt of financing initial operations.

Another advantage for the university is that policy makers from their states and from Washington D.C. will perceive this strategy as an affirmative effort to foster entrepreneurship, to attract high-tech industries to the university's region, and to boost economic growth and job creation. These favorable perceptions stand in stark contrast with the perceived excesses in university licensing—as mentioned above, industry complaining that universities are too aggressive negotiating and other stakeholders denouncing reach-through clauses and other unsavory licensing practices. The strategy of nurturing start-ups poses a greater financial risk to the university compared to a more traditional licensing-only business model, but it also lessens the reputational risk associated with commercial activities of the university. At the same time, the university can expect higher returns from its shares and options in a successful start-up and it retains a degree of control over that outcome.

It is too early to tell whether this model will be successful for all universities. However, Figure 3 shows an upward trend for universities initiating start-ups and many are already, in one way or another, providing services consistent with the nurturing start-ups model.[23] Many more universities are likely to follow suit.

4. Institutional Support for the nurturing of start-ups

The nurturing start-ups model is a promising way to improve university technology transfer and increase the impact of universities in the entrepreneurial economy of their states and regions. It is also a way to improve the finances of TTOs; although not a formula for riches in licensing income, it is a smarter way to manage financial risk by reducing reliance on blockbuster patents and increasing, at the same time, diversification and active management of the investment portfolio. The new model is an evolutionary adaptation to the changing economics of innovation, but it goes beyond that. It is an apt response to the political pressure for accountability of publicly funded academic research. Nurturing start-ups signals that universities wish to be better integrated into the market system and more proactive in partnering with the private sector.

However diligent, universities alone cannot make technology transfer more efficient. The institutional environment will largely determine whether the new model of technology transfer will foster innovation and benefit a broad base of society. It begs the question as to what kinds of policies will support universities in their effort to nurture start-ups more effectively. Here are three challenges that universities confront and policies that may help them in their efforts.

The first challenge for the university is how to leverage their limited resources to attract more resources from private and public sources and pool them to help viable start-ups grow to be established and successful businesses.

The federal government should increase funding for the Small Business Technology Transfer program (STTR)—this program was modeled after the Small Business Innovation Research (SBIR) program that mandates research funding agencies to set aside funds from their extramural R&D budget to support early stage small business; SBIR is funded at 2.5% of the agency budget and STTR at 0.3% and aimed at public-private partnerships. The funding increase recommended here should be directed to university start-ups. Congress has taken action along these lines; representatives Chris Collins (R-New York) and Derek Kilmer (D-Washington) introduced a bill in the House on August 2, 2013 (H.R. 2981) to support university enterprises at the proof of concept stage. The bill is funded by reapportioning STTR funds at 0.05% in the next two years and 0.1% henceforth. This initiative is moving technology transfer policy in the right direction but more appropriate funding would only come from increasing the portion that agencies set aside for STTR. Also, current STTR is limited to two sequential rounds of funding (called Phase I and II) where firms advance technical merit, feasibility, and commercial potential. Under SBIR, a third phase funds commercialization efforts. Increase funding for STTR should also expand to Phase III to inject funds to university startups who have graduated from the first two phases and are ready to move to the commercialization phase. In addition, after start-ups successfully complete Phase III, they should be given special consideration accessing other federal support such as loan guarantee programs.

State legislatures and local governments should also provide additional resources to strengthen proof of concept centers at universities. Property tax exemptions and waivers of other municipal fees would be helpful to establish incubators in urban areas, not necessarily within industrial parks but in the geographical centers of capital investment networks. Industry associations and chambers of commerce effectively pool resources to sponsor partnerships between universities and local incubators for the explicit purpose of supporting university start-ups. If innovation is to drive regional development, university start-ups should have market incentives to remain in their place of birth. This invites for a tripartite conversation between universities, local industry, and state and local government to further technological development toward areas where the states and regions have a comparative advantage. Chasing the golden goose of biomedicine may not be a wise path to follow for every research university.

The second problem for universities to succeed in nurturing start-ups is to afford licenses to patents that are key for these firms in developing their own marketable products. It is ironic that Bayh-Dole is the primary institutional enabler of university start-ups but it also has created roadblocks for their success. The reason is that Bayh-Dole does not discriminate between patents for research tools and other inventions and does not impose limitations on the use of exclusive licensing. As a result, some research tools are prohibitively expensive for penniless start-ups that however promising cannot go beyond a certain technical degree of sophistication. There are two ways to improve the current situation. First, Congress can enact an experimental use exception allowing universities, laboratories, and other non-profit research centers to use patents for research and teaching purposes without risking infringement and with clear limits on ulterior commercial uses. The need for statutory power for experimental use is because this common-law defense was "all but eviscerated" in the ruling of *Madey v. Duke University*.[24] Furthermore, to create the environment where start-ups can grow, the statute should extend the exception to start-ups research up to the point they place a product in the market. In that way, the product-monopoly of patent owners remains protected while nascent enterprises can move faster down the learning curve and use those patents in exploratory and feasibility studies. Being able to use a patent for research would then enable start-ups to either design around an expensive patent or negotiate a licensing contract. The second solution to the *status quo* is for the Executive branch—via executive order or memorandum to agencies—to declare a government preference for non-exclusive licensing of research tools and authorize federal agencies to use march-in provision in the Bayh-Dole Act if there is evidence of pricing excesses in the licensing of said tools. The sole threat of intervention would curb pricing excesses and make these patents more accessible.

The third institutional challenge is to counter the asymmetry in the way resources are distributed across the university system. The wide disparities that I have shown above in licensing income are only a reflection of the unequal distribution of all other resources available to universities. Consequently, institutional support to improve technology transfer is likely to benefit universities asymmetrically unless it is distributed using an equity rule. Disparities are only compounded by the fact that elite universities benefit from thriving innovation ecologies around them; they inhabit urban areas with the strongest entrepreneurial culture and with the highest densities of high-tech start-ups and available angel and venture capital. Yet, if all universities are to realize the promise of prosperity for their respective regions, new productive resources should flow more evenly across regions and states. Consider for instance an example for the allocation of the STTR grants proposed above. The allocation of funds to support the task of nurturing university start-ups could be undertaken in two modalities. Setting up two pools, the first pool would distribute funds in the customary modality of open national competition adjudicated by federal agencies, while the second pool should be apportioned equitably to each major public research university (e.g. in proportion to the number of faculty) that then would distribute internally on a competitive basis and for projects relevant to the regional economy.

I would like to return to the letter of university presidents asking the government to close the *innovation deficit*. The case I have presented here has a practical corollary: When universities ask for public support to keep the U.S. prosperous and competitive, they need not be afraid of explicitly declare that the support they need is as much for research as it is for their entrepreneurial endeavors. American research universities are world-class institutions in terms of the quality and quantity of their research and, in spite of the financial woes afflicting them, their intellectual output has continued growing at a fast pace without sacrificing excellence. It is quite possible therefore that the innovation deficit is not a research shortage but rather a systemic failure of imagination, a failure of all participants to come up with new and more effective ways to harness all that new knowledge and know-how being produced. It would be a real problem if the U.S. innovation system were capable to harvest only the low-hanging fruit from universities and national laboratories, the fruit available in the form of patents. The imagination needed is to figure out how to improve our harvesting methods, how to deepen our reach into science, how to rethink research findings as solutions to practical problems, and how to create appropriate incentives for scientists to undertake the pains of fitting their ideas into the puzzles of useful applications. I have argued here that this new imagination is emerging from the universities as a new model of technology transfer—nurturing start-ups—and have underscored the need for government support for this kind of initiative, at the federal, state, and local levels.

There is an additional virtue to university start-ups as a new model of technology transfer. The conversion of intellectual value into economic value is a task far more complex than simply patenting and licensing faculty inventions. Start-ups internalize the full set of interactions between research and productive organizations that lead to the successful development of a commercial product; the full set includes many more things transacted other than patents. Consider for instance the transfer of tacit knowledge of faculty and post-docs that go to work in the start-up or the transfer of codified knowledge in the public domain—it is not a small benefit if start-ups have access through faculty to the well-supplied university libraries. Think of the significant advantage gained by entrepreneurs who can keep up with the latest developments in the relevant field by virtue of being plugged into a scientific network through the regular circuit of conferences and seminars. There is also the access to the collective knowledge of a university from which the entrepreneurs can draw to solve engineering or design problems outside their field of expertise; start-ups are true sites of inter- and trans-disciplinary research. By nurturing start-ups, universities are taking on a more robust approach to technology transfer as they implicitly challenge the view that patents are the only or even the most important catalyst of university-industry cooperation.

The innovation deficit will be closed by a sustained government commitment to foster innovation. More funding for scientific research is crucial to the task but not sufficient, greater emphasis must be placed on fostering the entrepreneurial spirit of universities.

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Endnotes

1. National Academy of Sciences, 2007.

2. National Research Council, 2012.

3. The first letter to the National Academies, sent on May 27, 2005 by Senators Jeff Bingaman and Lamar Alexander, and Congressmen Sherwood Boehlert and Bart Gordon led to the *Gathering Storm* report, released in 2005 and published in 2007. See also the five-year assessment report: NAS (2010). The second letter sent on June 22, 2009 and signed by Senators Lamar Alexander and Barbara Mikulski and Representatives Bart Gordon and Ralph Hall led to the *Research Universities* report.

4. The open letter was published in Politico on July 31, 2013. It can be accessed here: http://www.innovationdeficit.org/

5. National Science Foundation, 2012.

6. In the most recent report from the National Science Foundation's on Science and Engineering Indicators (NSF, 2012) 2009 is the last year for which a detailed breakdown of R&D by source and by performer is available. This is the source for all R&D data used in this paper unless noted otherwise.

7. Data based on a survey of funding agencies. Some of the work contracted to federal labs is further subcontracted to industry and universities consortia, increasing their share. See further details in Table 4-3 Science and Engineering Indicators 2012 (NSF, 2012).

8. Sampat, 2006.

9. Not all universities with a technology transfer offices report to AUTM, nor all reporting declare their opening date.

10. The adjustment is necessary to render comparable universities that report individually to AUTM, such as MIT or Columbia, and those that report collectively, such as the University of California System or the University of Texas System. Observe that the UC system is 6^{th} in the 2012 ranking, but it is only 38 when adjusting by number of TTO employees and 46 adjusting by total research expenditures, likewise the UT system is 10^{th} in the 2012 ranking, but 34 adjusting by TTO employees and 34 adjusting by research expenditures.

11. To be precise, the top 80 universities by research funds control 89% of research expenditures and 92% of gross licensing revenue as reported by universities (AUTM, 2013). The top 40 TTOs by licensing revenue controls 89% of the system's income form patents and 56% of its research funds.

12. Using the AUTM data(AUTM, 2013) net operative revenues were estimated by subtracting disposable licensing income (the portion of licensing income available to the university as discretionary funds) minus legal fees and operational costs. Disposable licensing revenue varies from university to university but in general universities keep a third of Total License Revenue (LIRECD) because they share with the inventor-faculty one third and with her lab/department another third. The cost side includes Non-reimbursed Legal Fees (EXPLGF-REIMLG) and Estimated Operational Expenses. This last variable is a conservative estimate of operational expenses assuming salaries of $150k per full time employee (LICFTE) $100K for other FTE (OTHFTE) and $30k per patent application (NPTAPP). While AUTM started collecting TTO salary information in 2010, I use this methodology for comparability across all years of the last two decades. Acronyms in small-capitals are the variables in the AUTM survey database. For a detailed if dated cost study see Trune and Goslin (1998).

13. Mowery, Sampat, Ziedonis, 2002.

14. Thursby and Thursby, 2002.

15. Colaianni and Cook-Deegan, 2009.

16. Eisenstein and Resnick, 2001.

17. In this model, each annual draw is an independent lottery from previous years, hence the probability does not compound year after year. A more sophisticated model could involve a stochastic process where landing a blockbuster patent is a certain event in the future and each year of failure increases the probability year after year, or where the probability is actualized by licensing incomes of the previous year added to a stable stream of research funds, and thus the probability falls every year a blockbuster patent is not discovered.

18. See Greenberg, 2007; Mirowski, 2009; Washburn, 2005; Winickoff, 2013.

19. Dalton, 2007.

20. NRC, 2010; Debackere and Veugelers, 2005.

21. Jensen and Thursby, 2001

22. Mian, 1994; 1996; Phillips, 2002.

23. See Department of Commercie, 2013; Etskowitz, 2013.

24. Eisenberg, 2003, p. 1019.

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