"I wanted to see with my own eyes the origin of success" Dimitry Medvedev, President of Russia, 23 June 2010 during visit to Stanford University.

Stanford and Silicon Valley: The Co-Evolution of Technology Transfer and Regional Absorptive Capacity; 1930-2005[1]

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Abstract

Technology transfer is one modality of the emerging entrepreneurial university paradigm, based on the premise of polyvalent knowledge with conjoint theoretical and practical implications. This paper analyzes university technology transfer at an exemplary institution using case studies based on archival and interview data. The objective of this study is to explore the relationship between university strategy and regional absorptive capacity. Although Stanford University is an exemplar of "best practice" in technology transfer, paradoxically its very success has created gaps in transfer that may be addressed through organizational models that have been developed at other universities that seek to replicate the early success at Stanford and MIT.

Keywords: university technology transfer; regional absorptive capacity; knowledge-based economic growth; Office of Technology Licensing

Introduction: Licensing Life

"Licensing life" is the process by which the comercialisable outputs of the laboratory become tangible or intangible products and contribute to economic development in parallel with the codification of knowledge. "Licensing Life" links "Laboratory Life" to economic life, closing the loop between the creation of knowledge and its translation into use. The laboratory may be viewed as a bounded entity, producing data and transmuting it into publications, through a micro social/technical process (Latour and Woolgar, 1979); regulated by the classical norms of science (Merton, 1942). Inputs, financial and otherwise, and outputs beyond publications, such as technology, may be "blackboxed.' Nevertheless, "Laboratory Life" is embedded, on the one hand, in collegial peer review and, on the other, in "Funding Agency life," the working of governmental and other organizations to distribute resources that make laboratory life possible.

[1] An earlier version was presented at the Technology Transfer Society Conference, Palm Desert California, 24-26 October, 2007

A laboratory, by itself, can only metaphorically "raise a world"; however, coupled with a technology transfer office and an entrepreneurial environment, a new social world can be created in the form of a technology-based start-up. If laboratory life is the transmutation of data into the production of articles, licensing life is the transmogrification of the inventions based on that data into economic activity. Scientists and their inscription devices to collect and record data are the protagonists of laboratory life, with journals as the object of their efforts, and the government research funding and peer review, post office, or Internet as intermediary. Licensing life embodies a more complex intermediation process including the patent system, venture capital and angel funding. Moreover, licensing and laboratory lives are increasingly inter-twined: the laboratory becomes part of a productive force rather than a relatively isolated entity that generates knowledge as sole objective (Van Looey et.al. 2004).

A highly successful trajectory at Stanford University primarily relies on highly entrepreneurially oriented faculty and a rich entrepreneurial ecosystem. Stanford's Office of Technology Licensing (OTL) has generated 594 million dollars in revenues since its founding (Page, 2009). Although its primary expressed goal is seeing that the practical results of academic research are put to use, OTL also expresses pride in its income generation accomplishments in public presentations, citing ten patents that have each generated more than $10 million in income for the university and a current income of $50 million per year. A visitor's tour of its offices highlights plaques showing the highest income patents. Behind the façade of successful innovation and financial success is a more complex reality of widely different levels of interest and involvement in technology transfer among faculty. This paper identifies a "paradox of success" in technology transfer at Stanford University: the unrealized potential in discoveries of less entrepreneurially oriented faculty who would benefit from a more developed support structure, characteristic of the best university transfer regimes, lower down the entrepreneurial and research university scale.

The Role of Technology Transfer in the US Innovation System

Technology transfer is conventionally viewed as an expression of the linear model, proceeding form research to invention and innovation. However, technology transfer and the linear model is part of a broader non-linear framework that incorporates the linear model but also includes feed-back mechanism from societal needs, transfer processes and invention back to blue sky research. New knowledge increasingly appears in polyvalent forms, with theoretical, practical and interdisciplinary implications forming a common center of gravity, the manifestation of the triple helix of university-industry-government interactions (Etzkowitz and Viale, 2010). The supposedly discrete categories of basic and applied research, never watertight, with handovers between them along a linear path, are superseded by "polyvalent knowledge" with theoretical and practical implications inherent in the same research finding. In a classic instance of polyvalence, agricultural researchers at U.S. land grant universities in the 1930's discovered hybrid corn by extending their government funded research programs, designed to solve immediate crop problems, to address fundamental questions in genetics (Griliches, 1960).

The implication of this case is that researchers may pursue a variety of crosscutting objectives simultaneously rather than operating according to either/or motivations that separate advancement of fundamental understanding from solution of practical problems.

In contrast to the concept of Pasteur's Quadrant in which basic knowledge with practical implications is confined to a delimited sphere, we expect polyvalent knowledge to envelop the traditional quadrants of basic and applied research (Stokes, 1997). Indeed, the exemplary exponents of these quadrants Niels Bohr and Thomas Edison do not entirely fit their respective quadrants. Bohr took the practical consequences of research in nuclear physics into account and lobbied politicians to influence its utilization. Edison, the consummate "cut and try" inventor was also the discoverer of the "Edison effect." A triple helix of university-industry-government relations, as the basis of innovation policy, can be identified in countries that are emerging from statist and laissez-faire regimes. An assisted linear model is replacing the passive linear model (Etzkowitz, 2006). A meta-innovation system comprising bottom up, top down and lateral initiatives, from university, industry and government, individually and collectively, increasingly translates research into use and foster social as well as technological innovation (Etzkowitz, Mello and Almeida 2005)

The theoretical framework for US technology transfer was created in the context of the 2nd World War during which theoretical scientists and engineers combined forces to produce new weapons as an extension of basic research e.g. the atomic bomb well as from military requirements to detect hostile aircraft e.g. radar. Although the scientists expected that they were putting aside their theoretical pursuits for the duration of the war-time emergency they found, somewhat to their surprise, that new theoretical ideas were arising from their involvement with practical problems. The efflorescence of theory from practice was a phenomenon earlier noted by a young engineering professor at MIT, Vannevar Bush who brought back ideas from his consulting practice for elucidation with his students. Later, as a high level war-time science and technology administrator, looking towards peacetime and operating in an ideological environment in which a role for government is highly suspect (cf. the recent US health care debate) Bush disentangled science from its social context and placed it on a metaphorical plane to attain his broader objective: government support of research for a variety of purposes in the post-war, superseding the narrower wartime focus that had provided temporary large-scale funding for scientific research (Baxter, 1946).

Bush's post-war linear model is the partial revival of the wartime non-linear "triple helix" that the US has since more fully recuperated through the Bayh-Dole Act and other measures. In the "game of legitimation" that Bush was playing, he had to, with one hand, place research on a neutral ground "the frontier" while with the other, execute a sleight of hand and link its benefits back to the housing, military, health and other impetuses to research with practical goals that each received their special chapter in the *Endless Frontier* Report (Bush, 1945). A "linear model" served that purpose well although Bush was likely not a believer and certainly not a practitioner of linearity (Balconi, 2009). Vannevar Bush was an engineer, consultant, entrepreneur, teacher and researcher, in other words, the prototypical MIT professor. Bush was a student of the "consulting engineers" who had been recruited to MIT to introduce research in the late 19th and early 20th centuries. They also brought their consulting practices with them into academe and synthesized a new academic entrepreneurial model (Etzkowitz, 2002). As noted earlier, Bush made a practice of bringing back to his MIT graduate students theoretical issues arising from his industrial consulting projects and working them out together (Bush, 1970).

One of these students was Fred Terman, who brought the model back with him to Stanford as a young professor where he expanded upon it in his own work, with students such as Hewlett and Packard, and later as an academic administrator in forming new research groups and then departments with conjoint theoretical and practical objectives. Bush and Terman are implicit exponents of "polyvalent knowledge" that is simultaneously theoretical and practical, publishable and patentable, rather than flowing through a constricted linear pipeline. Bush made a step-change in the academic entrepreneurial model, in the run-up to the 2nd World War, when he went to Washington DC to head the Carnegie Institution and led an effort that gave academia a central place in war-time research, with industry and the military. Academic scientists, especially those who led these labs, lost their fear of government funding, as inevitably leading to government control of science. War-time experience in a collaborative leadership role, with industry and government, provided grounds for acceptance of state research support and an entrepreneurial role for the university in society as the engine of innovation, the implicit thrust of the *Endless Frontier* Report.

Government has since found it necessary to revise its role and play a more active part "downstream," by crafting innovation policies and programs to insure that research results, however generated, are actually put into practice. Indeed, even in a country with multiple research agencies like the US, this has been the approach as NSF 's remit was extended into engineering and then to the provision of public venture capital (Etzkowitz, Gulbrandsen and Levitt, 2000). Behind the laissez faire presumption of the linear model that academic research results would seamlessly pass to industry through graduated students taking employment and industrial researchers following the journal literature, a more focused organizational approach to technology transfer, utilizing the patent system, had grown from its origins at MIT in the early twentieth century According to a university official, "…the national innovation strategy is to put federally-funded R&D on a conveyer belt that gets the R&D commercialized either by tech transfer to established companies or by wrapping the R&D into a university start-up……[i]

The Evolution of University Technology Transfer

University technology transfer has evolved through several stages: from a legal, to a marketing, to an entrepreneurial model, with each new phase expanding upon and incorporating previous ones. The necessity to patent to protect the university's reputation, and insure user safety, as well as obtain licensee investments to translate prototype into product, was recognized at Toronto and Wisconsin, respectively, with Insulin to relieve diabetes and the milk purity test (Bliss, 1984; Apple, 1989). A marketing format followed at Wisconsin and Stanford to search for potential users beyond the purview of the inventor. This phase included brainstorming to simultaneously extend patent claims and identify additional markets. Entrepreneurial faculty at Stanford and MIT also translated inventions into firms before the development of formal technology transfer. Some schools create an incubation and entrepreneurial training process, designed to replicate, in a collapsed time frame, the early informal developments at Stanford and MIT (Hakatenaka, 2004).

A technology transfer regime may be instituted directly by a national government, as in Japan, through a funding program replete with benchmarks and qualification procedures, or indirectly as in the U.S., through legal changes incentivizing universities to develop transfer capabilities. The Amendment to US patent law of 1980, better known eponymously after its sponsors Senators Birch Bayh and Robert Dole, gave universities ownership of intellectual property rights to federally funded research, an explicit role in technology transfer and included inventors in the reward scheme (Stevens, 2004). [2] Heretofore uninterested universities established a technology transfer office, showing an interest in putting research to use and thus meeting the criteria for continued receipt of federal research funding. Despite low expectations these new offices sometimes achieved a highly successful patent, as at Columbia University, thus gaining support of the university's administration for expansion of their activities. Other offices, less lucky or lacking a prolific faculty adopted a "pump priming" strategy, encouraging researchers to explore the commercial potential of their research (Etzkowitz and Goktepe, 2010). In yet other cases, offices remained dormant (Feldman and Desrochers, 2004) until reorganized, for example, as part of a strategy to develop a biotech industry next to Johns Hopkins University.

Most studies of US university technology transfer utilize the data provided by the Association of University Technology Managers annual survey to analyze financial returns from transfer and related issues e.g. Thursby and Thursby, 2007. [3] On the other hand, an emerging literature analyzes organizational and policy issues of university technology transfer. George (2005) examines the evolution and strategic direction of an early office, Jain and George (2007: 557) shows the broader role of a TTO in "…building legitimacy for a novel technology." Nelson (2005) analyzes the interaction of OTL and Stanford's music department as it incorporated the logic of transfer in a subsidiary and complementary relation to musical composition. Colyvas and Powell (2006) discuss the stages of legitimacy and acceptance of technology transfer among faculty members, utilizing OTL archival materials. Overall this paper makes three contributions: an analysis of innovation and gaps in a best practice case, a simple model

[2] The director of the University of Wisconsin Alumni Research Foundation, that university's TTO, wrote the first draft of the Bayh Dole Act demonstrating that the relationship between local and national levels is often a two way street (George, 2005).

[3] See Bozeman (2000) for a comprehensive survey of the technology transfer literature.

of the relationship between regional absorptive capacity and university technology transfer productive capabilities and potential; and a counter-intuitive argument that learning from aspiring universities and regions can enhance success cases

There are multiple pathways to an entrepreneurial academic mode. Entrepreneurial universities have arisen from diverse academic traditions. MIT derived an entrepreneurial academic model from a synthesis of the US Land Grant and European Polytechnic traditions. Nevertheless, MIT also incorporated specific elements of the liberal arts tradition in order to give its technical students a broader purview. Stanford, like New York University, originated as a synthesis of the liberal arts university tradition and a private university model oriented respectively to technological and commercial local economic development. The Pontifical Catholic University of Rio de Janeiro took an entrepreneurial turn in the face of loss of research funding from Brazil's former military regime. At many universities, an entrepreneurial initiative is encapsulated in a particular organizational mechanism like an incubator facility or technology transfer office that, at least initially, is segregated from the rest of the university.

Integrating the transfer process in an entrepreneurial academic culture has become a virtually universal goal in divergent academic systems. Organizational capabilities are enhanced in systems that leave intellectual property rights in the hands of the inventor as in "the Professor's exemption" in Sweden. Differences are often less than perceived. The US Bayh-Dole Act, in effect, created a "partial professor's privilege," guaranteeing university inventors a significant share of rewards in contrast to firm employees, dependent upon employer's generosity.[4] Thus, the inventor is granted a significant interest even as formal rights are placed under the control of the university. In the former instance; the university may negotiate to acquire intellectual property rights, in the latter, the university is strongly dependent upon inventor cooperation to realize value from formal rights. An optimum technology transfer modality balances inventor interest and involvement with organizational competence and support.

US university patenting continued on a steady upward trend until quite recently. A slight downtick in 2005 and following steady state has led some to conclude that universities are giving up technology transfer (Leydesdorff and Mayer, 2010). Others note a general slowdown in patenting as an artifact of changes in US PTO practice and personnel to process applications (Techno-L, 2010). The institution of a preliminary patenting procedure, allowing a year of protection to explore the viability of a full application, has allowed offices to be more selective in their patent applications. Perhaps, more significant is the continuing rise of university originated start-ups (AUTM 2010) and the expansion of technology transfer to an integrated model that supplies faculty inventors with entrepreneurial partners and seed funding from internal university resources, in effect, packaging start-ups (Tedeschi, 2010). The modest decline in university patenting may

[4] Even in a highly academic science oriented firm like Cetus, Kary Mullis, the inventor of polymerase, a major biotechnology innovation, received a payment of only $10,000. On the other hand, he received broader rewards as part of his employment contract (Rabinow, 1997)

signify regime change from a marketing to entrepreneurial mode of technology transfer in which patenting is a significant but less important part of university technology transfer success than firm formation and growth. Or, it may simply be an artifact of resource stringency induced by the Great Recession of 2008 in which case we may expect an uptick as its effects recede.

Method

As a Visiting Scholar/Participant Observer in OTL, Jan-August 2005, I attended regular bi-weekly staff meetings during that period as well as special events such as presentations by the Director of University Relations at Hewlett Packard and representatives of the University of Wisconsin transfer office, The Wisconsin Alumni Research Foundation (WARF), who were essaying establishing a marketing outpost in Silicon Valley. At the suggestion of the Director of OTL, I focused on interdisciplinary cases, accessed files, interviewed OTL staff members and participated in informal conversations with them during coffee at Starbucks and over lunch in cafes on California Street. Following a triangulation strategy, I interviewed the faculty inventors and research staff involved in the cases and going one level up interviewed Stanford research administrators responsible for oversight of technology transfer. I consulted the Terman Papers in the University Archives to better understand the origins of technology transfer at Stanford. I interviewed members of law, venture capital and consulting firms and organizers of angel networks in Silicon Valley, the contemporary "eco-system" within which OTL operates. This paper also draws upon a 2004 predecessor study including interviews with directors of 20 US university technology transfer offices in aspiring high-tech regions (Etzkowitz and Goktepe, 2010).

Technology Transfer Before the Office of Technology Licensing

An entrepreneurial culture had taken root at Stanford, well before establishment of a technology transfer office, in contrast to universities where foundation of an office is an initial step in developing such a culture. As Dean of Engineering and then Provost, Terman expanded the economic base of the university in order to develop and attract talent. He began this project as a professor, capitalizing his research results through agreements with firms, exchanging disclosures for funds to support graduate students and encourage them to stay in the region. One of these fellowships allowed the duo of Hewlett and Packard to be reunited at Stanford, after a stint in the east, complete their masters' degrees under Terman's supervision and then go on to start the firm bearing their name.[5] At Stanford basic research grew up in tandem with commercialisation, with

[5] While Terman is often credited with initiating firm formation from Stanford in the 1930's this phenomenon had precedent in the founding of Federal Telegraph (a firm where Terman interned as a young man) and Magnavox. A key to HP's early success was the concomitant rise of the Hollywood film industry, which required audio-visual technological innovations that coincided with Stanford research and development. Thus, HP's first sale was to the Disney Company

firms interactions with faculty at times supporting academic interests to a greater extent than their own (Lecuyer, 2005)

Professor Terman ran the virtual equivalent of a technology transfer office from his faculty office in the Electrical Engineering Department during the 1930's. Terman owned the rights that he generated according to university policy and practice[6] His key interlocutor on the industry side was a Stanford graduate who was head of the International Telephone and Telegraph (ITT) research lab in New York City. He negotiated an arrangement to provide a certain number of disclosures per year in areas of interest to the firm in exchange for funds to support graduate research assistants at Stanford. It was up to ITT to decide whether to patent and incur the costs of patent protection. He was also contacted by firms in the UK and Scandinavia and made similar deals. Thus, Terman notified a firm in the radio industry in Sweden that, "I expect that during the next 6 months to a year I will have a considerable number of disclosures to submit for your consideration. I have recently worked out an agreement for handling my developments in the US and certain foreign countries so that there is now considerable incentive to take the time necessary to write out descriptions of new ideas as they occur."[7]

A colleague in the electrical engineering department expanded upon the advantages of a firm's outsourcing some of its research to a university as there were,
"…no overhead or indirect costs and this of course, constitutes the most obvious financial advantage of having Stanford do part of your research work. I know that the other advantages, including an independent point of view on problems and broadening of the total background of experience and associations, are well known to you. …the availability of fairly skilled grad student assistants at low cost…[8] A modest income earned from research findings with intellectual property potential, marketed to interested firms, helped support graduate students in electrical engineering. The disclosures to ITT were not translated into patents but appeared to serve as a way for an industrial lab to keep tabs on academic research and provide it with a modest subsidy.

Terman developed a "steeple of excellence" university development strategy, creating research groups in emerging fields of conjoint theoretical and practical potential. The objective, the key to Stanford's advance, was to achieve academic and economic development simultaneously. Terman held that, "…great institutions are created by a great faculty, not by paneled walls, acres of floor space, a co-op program, or even fancy gadgets in lecture rooms. What counts is first outstanding leaders on the faculty, second, intelligently planned support to enable these outstanding individuals to achieve their full

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[6] His situation was equivalent in practice to the legal status of the Swedish "professors privilege." Indeed, Swedish sources often cite the similar status of the Stanford professor, until fairly recently, as justification for their regime.

[7] Terman Papers, Stanford Archives Box 12 Folder 3 140239
Terman to Holstensson

[8] Prof Skilling to Buttner, ITT 7, September, 1944 Folder 2 III correspondence 1940-42

possibilities in the environment in which they are placed, and third an outstanding group of students to be educated at both undergraduate and graduate levels." This process could be jump-started by, "raiding other institutions for about six outstanding mature men whose reputations were already well established, and whose fields were representative of the major fields of engineering." [9]

Initially pursued in a few technical areas and then across the university, this strategy transformed Stanford into a leading university in an academic generation of two decades. Fields were selected that had both scientific and economic potential and made best use of scarce resources. Sometimes, the way forward was not clear. For example, according to the Dean of Medicine, "At the same time the situation in physiology is such that we cannot expect at this time to recruit a really top drawer man…. In time, a major strengthening of the Physiology Department is needed to make it comparable with Biochemistry and other medical sciences. However, this is not in the cards at the moment." [10] Other times, as in steroid chemistry, the way was clear and several promising candidates could be recruited simultaneously, making Stanford an almost instantaneous leader in a highly promising field (Djerassi, 1992). Carl Djerassi, recruited to the chemistry department from the Syntex pharmaceutical firm in Mexico, maintained his position as the firm's research director as part of his employment agreement when it moved much of its activities to the Stanford Research Park.

In the early post-war, the founders of Varian Associates created a firm that was a seamless web with an academic laboratory. Indeed, it has been suggested that the company had more academic autonomy than the university research group that was subordinate to the needs of high-energy physicists (Lenoir, 1997). Faculty members consulted, served on the Board, set strategy and sent their graduates to work in the company. Some company researchers moved in the other direction and took up academic positions. Patents developed in the university were the basis of the firm, with Varian undertaking patenting on behalf of the academics in exchange for an exclusive license.

Stanford's "Science Park" emerged as an un-intended consequence of the transformation of an agricultural region into a high-tech conurbation. A shopping center, designed for a growing suburban population in the early post-war, utilized university land to generate rental income and support academic development. As receipts increased, Terman calculated how many professors could be hired. An Industrial Park, conceived as a follow-on venture to capture industrial firms relocating from San Francisco, succeeded despite these firms' lack of interest. Science-based firms, like Varian Associates, which had originated at Stanford, wished to locate close to the University to maintain a collaborative relationship. Provost Terman understood the significance of their decision and made a research profile requirement for entry. This organizational modification gave

[9] Fred Terman to Paul Klopsteg, Northwestern University 20, March 1953 Terman Papers Series 3 SC160 Box 61 folder 24
[10] Dean Always, Medical School to President Sterling 29 July 1959 Terman Papers Series 3 SC160 Box 61 folder 1

birth to a science park movement that has evolved from a property development to a firm incubation model (IASP, 2007).

Institutionalization of Technology Transfer at Stanford

A supportive environment for faculty entrepreneurship has been a recruitment advantage for Stanford as entrepreneurially oriented faculty gravitated towards Stanford before culture changed at other universities. [11] Indeed, well after other universities had extended their control over intellectual property rights from federally funded research, Stanford, "… placed the rights, when possible, in the hands of faculty, staff, and students. The policy was changed in the mid-1990s, however, to mandatory ownership by Stanford University (Gilmor, 2004: 154). Nevertheless, de facto policy to this day implicitly favours licensing to faculty start-ups.

OTL was founded in 1969 as the result of a proposal from an employee of the university's contracts and grants office. OTL's hallmark has been a marketing model of technology transfer. Neils Reimers, founding director of OTL held that tech transfer offices were too focused on patenting rather than getting inventions into use. He instituted procedures to identify a wide range of firms that might be interested in an invention, followed up by contacts, traditionally by telephone and more recently via email.[12] The marketing model was transferred to MIT in the mid 1980's after that school experienced difficulties with a venture capital model in which the university was deciding among various candidates to invest its funds, angering faculty who did not receive an investment.[13] It has since become the prevalent US model.

OTL sees its mission as facilitating transfer within the context of traditional academic goals of education and dissemination of knowledge. OTL advises faculty with an explicit "No" not to delay publication but also recommends that they disclose as early as possible, noting the grace period offered by the US patent system between publicly announcing a result and having to file for protection. On the one hand, members of the Office see their success as derived in large measure from the "entrepreneurial spirit" and collaborative culture of the Stanford faculty in contrast to University systems that are excessively hierarchical, with everyone "always looking after themselves." A licensing officer explained that, "We're not doing the licensing solely for the money; we're a university." On the other hand, "We don't want a company just to take something." The result of such balancing is negotiation of a moderate rate on the principle that maintaining good will is more important than obtaining maximum value.

In between mind and market; Lab and Wall Street (or the City), a "permeable zone" emerges where two cultures intermingle (Kohler, 2002:11). A panoply of organizational

[11] In interviews at the physics department at Columbia University in the 1980s, respondents noted that their most entrepreneurially oriented colleague had left for Stanford.
[12] Author interview with Neils Reimers, August, 2005
[13] Author Interview with MIT Treasurer, 1986

hybrids to transfer scientific projects with economic potential have been invented such as incubator facilities, venture capital firms, science parks and technology transfer offices. Many persons who work in these venues embody qualities drawn from both cultures. The gap eventually inspired creation of various X initiatives to encourage cooperation between engineering and the sciences. An OTL program offering modest funds to graduate students to work on translational research in between medicine and engineering has also been established. In an earlier era, new sub-disciplines and departments such as applied physics were put in place to fill the gap between physics and electrical engineering.

OTL plays an informal role in firm formation, initially by assessing the potential of the new technology as part of its marketing activities of contacting firms to see if there is any interest in licensing the new technology. This “marketing activity” also provides a basis for assessment of the start-up potential of the technology. Long-term licensing associates have good contacts in the Silicon Valley venture capital and legal communities. When they see an invention with significant potential for firm formation; they put the inventor into contact with potential sources of assistance, even if that help has not been requested. At that point it is up to the inventor “to pick up the ball.” OTL does not directly engage in business development, a task that university technology transfer offices explicitly undertake in emerging high-tech regions. Contemporary Stanford tech transfer practice relies on an informal dynamic to pull technology out of the university, without the need to provide in-depth support.

Mind the Gap: Inventor’s Involvement

Technology transfer is based on the premise of a co-operative inventor, interested and willing to assist in the process. But what happens when this is not the case? A senior licensing officer recounted a failure case due to dependence on this assumption and inability to get the transfer process to move forward by finding a substitute for an un-cooperative inventor. The officer took it personally in recalling the incident saying that the, ”Camera still hurts me when I think of it…it was a way to get the right color as the human eye sees it.” However, the inventor was interested only in the research aspects of the problem and wanted to move on to other tasks. He was willing to take only the most minimal role in the transfer process as an adjunct actor rather than as a proponent.

The licensing officer undertook some of the proponent role and managed to organize an ad-hoc demonstration of the invention but it was a one-off event. The SONY Lab in Palo Alto provided the necessary equipment and technicians for a demonstration event but took back the equipment after an initial test. The licensing officer suggested to the inventor, “you can rig it up yourself” but he said, ‘I do research, I won’t waste time to spend a week doing something for people who don’t see the light.’ I never asked him, will you give me the software, I didn’t think of that, so damned pissed off he didn’t want to spend a few days to whip up a demo.” Without the active participation of the inventor the transfer process did not move forward, despite OTL spending a considerable amount to acquire patents.

A new technological vision, no matter how great the potential, may wither on the vine. The Licensing Officer recounted that almost every company contacted asked to see it but, "I couldn't demonstrate it. If had a demonstration, it would have been biggest project I handled in 20 years here." "I even tried more; I mentioned my idea to put it on a chip. I knew that engineering students in our school, at one time or another have to design and manufacture a chip. I told him to get together with so and so in engineering, an inventor, and get a student to make his chip. They never got together." Unfortunately, the licensing officer did not see it as part of his remit to introduce the project to the engineering school himself. Lacking a start-up process or take-up by an existing firm, the patents languished and were eventually abandoned. Thus, apparent success may mask underutilized potential. Some inventors who disclose are unwilling to support the transfer process, thereby reducing transfer potential in the absence of substitute support measures. The involvement of the inventor is required to move the translation process forward; the greatest incentive to bind an inventor to the innovation process is participation in a start-up. Nevertheless, a substitution process is possible but does not always take place.[14]

The Faustian Bargain

In the Faust legend there is a bargain with the devil and an exchange of a soul for arcane, highly desired, knowledge. Some critics argue that the university has made a similar arrangement by involving itself in technology transfer (Washburn, 2005). Due to the early stage nature of most academic originated technology, transfer often takes place to a new firm that the university may play a key role in founding. The Cohn Boyer patents for recombinant DNA were a notable exception to this rule; the technology had obvious utility (Feldman, 2005). Some firms immediately realized its potential and could be induced to license merely by making the fee reasonable; others could be convinced that the technology was relevant to their objectives. Although Reimers retrospectively viewed the license fee as a "tax," the value added by OTL was the demonstration to firms that the invention was relevant to their business.

However, it is often the case that OTL's marketing identifies potential areas of use and even users but does not result in an actual license. Firms typically view university originated technology as too early stage. They want to see it in use and better yet, already generating revenues. Thus, they would rather pay many times more to buy a start-up that has gone through the development and innovation process rather than undertake this task themselves, even though a license could have been obtained for a fraction of the cost. For example, an interdisciplinary collaboration in technology transfer that we examined was

[14] Indeed, substituting students for faculty in moving technology out of the university through an education model has been formally organized in the Stanford-Edinburgh Link entrepreneurship training programme (Clouser, forthcoming)

spurred by the need for engineering expertise to build a device for automating a biotechnology discovery process, with academic and industrial applications.

A medical school professor had conceptualized a means of speeding up biotechnology research, but did not wish to take the time to build the device himself. Nevertheless, he wanted to see it built to achieve proof of concept, as well as utilize it to advance his research agenda. To solve the development problem, he walked across campus to the engineering school and talked to various professors. For the most part, they were not interested either in reducing the concept to practice believing the problem too far removed from cutting edge research. However, one professor had a graduate student whom he believed might be interested in the task. The student had come to Stanford for a PhD with the intention of developing a technology that could be made into a firm. The medical professor had no interest in commercialization of research; indeed was philosophically opposed to it.

Nevertheless, the wish to see his invention realized was stronger than his skepticism. The medical and engineering school professors and the engineering student agreed that the student would undertake development of the invention for his thesis and then form a company. The technology was developed and duly disclosed to OTL. The OTL staff member assigned to the project reported that I, "have shopped [the technology] to over 40 companies, initial interest great, but no negotiations resulted. [15]" The technology was too early stage to interest an existing firm no matter how relevant they found it. OTL was now willing to, "…proceed with a license to Synteni, the start-up organized by the student who had waited, nervously and impatiently, while the discussions with other firms took place.

The way forward was a start-up. The licensing officer reported that the medical school professor, "… is aware of the situation and agrees." [16]Thus, the firm formation process moved forward, received venture capital support and the technology was successfully developed. The start-up was eventually purchased by one of the firms that had expressed great initial interest but was not willing to license and develop an early stage technology. A startup encourages a sharp focus on the new technology. [17] Even in a large firm oriented to technological advance; focus is inevitably on close to the market innovations.[18] Firms find it difficult to maintain focus on internally generated inventions; there are always new ideas coming along and calls to shift focus due to changes in strategic direction or the appearance of unexpected opportunities. These forces operate

[15] OTL Files, Contact Report Hans Wiesendanger with Pat Brown, co-inventor PiI, 150395

[16] The professor made the "blue prints" available on his website to fellow academics who may wish to build not buy but even academics, let alone firms, typically prefer to purchase the equipment ready made or hire the service. Despite thinking of himself as a pure academic; he wished to see his ideas put to use and expressed pride in having created a billion dollar industry.

[17] According to the AUTM Survey, 29% of university inventions follow this route.

[18] It is difficult to get serious attention paid to a nascent technology, without the impetus of a significant crisis such as Japanese competition that drove U.S. semi-conductor firms out of the commodity DRAM market towards the newly emerging microprocessor, with its higher value added potential (Berlin, 2005).

even more strongly when an invention has been brought in from outside and lacks an internal base of support. Awareness of these difficulties has led many firms to either support a start-up process through corporate venturing, or wait until an externally generated technology is embodied in a start-up that can be purchased and made into an operating division.

Step Change: The Google IPO

Google exemplifies the shift from transfer to existing firms to firm-formation due to the vastly greater amount of funds that can be earned from a successful start-up. OTL had the opportunity as a result of its marketing process to license the Google search technology to an existing firm. The state of the art of the technology was not a barrier. A search industry existed with the capability to recognize the potential uses of the Google algorithms. OTL, based on the criteria of realizing the full financial worth of Google search opted to encourage the formation of a new firm. Indeed, the process was well under way, with the support of a "university angel," a technically knowledgeable investor who could perceive the potential of the invention before it could be located within a business model.

The discussion process with potential customers helps licensing officers identify additional uses for the technology as they seek to broaden both the patent claims and the licensing market, integrating the legal and marketing approaches to technology transfer. Brainstorming with licensing colleagues and discussions with potential customers identifies uses for the technology beyond the scope of the inventor's purview and provides indications of its potential worth. When OTL "shopped" the Google technology to search firms, there were two salutary effects: the interest of the firms provided the investors and OTL with signals of the potential worth of the technology as a vehicle for independent firm formation; and discussion with search firm technical people gave the Google inventors confidence that their technology was better than alternatives, strengthening their resolve to start-up.

The Google IPO transformed the perception of OTL within the Stanford Administration. The unexpected scale of the earnings from Google transformed the administration's expectations of technology transfer.[19] A quarter of a billion dollars held the potential for new buildings and programmes, making possible initiatives orders of magnitude beyond supporting graduate students, the original objective of Terman's technology transfer effort of the 1930's. The dream of supporting the university from its intellectual resources took on an air of reality, complementing traditional funding streams from tuition, grants and donations. Thus, the scale of the Google IPO led to a rethink of transfer, especially within the Management Corporation that invests the university's endowment. [20]

Although quite successful in comparison to most transfer offices which earn modest funds or are a cost item on the university budget, OTL operated largely below the "radar

[19] Interview with Stanford Administrator responsible for OTL. July, 2005

[20] Interview with representative of Stanford Management Corporation, August, 2005.

screen" of senior administration. It was a taken for granted unit, neither considered a problem nor worthy of special attention. Issues that had arisen earlier about its place in the university structure had been settled, with OTL remaining within the research administration arm of the university where it had originated, rather than moving over to the business side, with its higher salaries and more direct earning focus. An earlier policy precluding Stanford from accepting equity in spin -off firms, such as CISCO and SUN, to avoid possible conflict of interest was changed at the instance of the Board of Trustees. However, to avoid possible influence on departments, the usual share of funds to academic units where IP originated was placed in a special fund to support graduate student fellowships.[21]

The Stanford Management Corporation viewed the $250 million which the university earned from its ownership of a very small percentage of the equity in the firm as a relative failure. The IPO had realized billions but the university had gained only a very small part of the earnings. The Management Corporation proposed that the university reserve the right in OTL's standard licensing agreement to make a modest investment in each new firm that OTL licenses a university originated technology. There was "pushback" from the Silicon Valley venture capital community which felt that the Management Company was interfering in its sphere. Thus, Stanford's increased share was kept in a modest range to avoid offense.

The Google case exemplifies the context in which OTL operates in the current ecosystem of Silicon Valley where it is one player among many in facilitating technology transfer and spin-offs. Indeed, disclosing to OTL is sometimes a matter of checking a necessary box, rather than seeking assistance, as part of a transfer and firm formation strategy developed by inventors and their angel investors. OTL also leverages the ecosystem, introducing neophyte inventors to venture capitalists, attorneys and other persons who might assist firm-formation. It is up to the inventor to pursue the lead as OTL takes a relatively passive approach once the introductions have been made. If the inventor decides to "transfer" by taking a position in a firm and bring their technology with them, as in the movement of "Orkut" to Google, so be it.

Technology Transfer and Regional Absorptive Capacity

The confluence between public benefit and revenue models focuses attention on the region surrounding the university. A TTO director said that, "our mission is to promote technology to benefit the public; to the extent it results in revenue it is a good thing."
In a region without previous high tech development, the TTO director may be the first person with an official responsibility for this topic. Even though his or her remit is focused on the university, an entrepreneurial director will soon expand it to include helping create the conditions for high-tech development in the area. Once local economic development considerations are taken into account, the issue broadens from the difficult enough one of finding a licensee to one of identifying a local source to develop the technology.

[21] Interview with senior OTL officer, April, 2005

As one director put it, the objective is, ……" to not just license technology but to capture and keep it in…[the state]." A TTO director in a peripheral region said that, "We now have a situation where faculty can do pre-incubation in their labs, we lease them space and sublicense equipment. The next step is either have a research bay or small lab that their company can rent and then graduate them out to incubator and other facilities run by the community." Another director described various sources of funding to explore commercial potential, including the university's own resources," a small internal fund that can fund projects like that 50k per project" as well as external sources such as angel and state government funding.

In contrast to firm absorptive capacity that is held to be a function of prior related knowledge (Cohen and Levinthal, 1990); developing regional absorptive capacity often entails breaking with previous practice (Saxenian, 1994; Huffman, Quigley. 2002). Regional absorptive capacity is operationalized as an entrepreneurial support structure of angel networks, venture capital opportunities, public relations and law firms oriented to support firm formation and cluster development but may take various forms. (Cooke, 2001; Norman, 2005). As an observer of the rise of Google noted, "The presence of venture capitalists in the neighborhood made it easier for students and professors at Stanford to get funding and advice than for their peers at any other university" (Vise, 2005).[22] On the other hand, when capacities are weak, new organizational formats may be invented such as the venture firm in early post-war New England or the "Courtyard for Agro-experts" in contemporary China (Tu, Gu and Wu 2005). In a region lacking a university, regional authorities developed a model of joint living and lab spaces to allow academics to visit for a limited time period, conduct research and consult on local agricultural problems.

University technology transfer strategies adjust to regional circumstances. A relatively low-key approach can work in a "thick" region, with strong entrepreneurial support capabilities while a more pro-active approach is indicated in a "thin" region, where absorptive capacity is weak. In the latter case, a TTO may take a leadership role to promote the creation of an external support structure and may also have to fill internal gaps when inventor interest is limited. Conversely an office may take a relatively passive stance when regional absorptive capacity and inventor interest is strong. However, this may result in untapped potential among moderately entrepreneurially oriented faculty, suggesting the applicability of support structures that are commonplace in aspiring universities to success cases as well.

The technology transfer gap has been filled by measures offering varying types and levels of support. Two approaches are typical: (1) intensified search to enhance the disclosure rate and; entrepreneurial assistance to improve innovation chances. A half time position in technology transfer and an academic department has been instituted in the Columbia University Medical School as a unique arrangement for an individual faculty member.

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[22] Indeed, a venture capital firm advertised in the student newspaper in 2005, offering any Stanford student a 15 minute appointment.

This "dual-life " scheme, formalized the "scouting function" of ARD, the original venture capital firm that served as an informal TTO and incubator for MIT in the early post-war. A serial entrepreneur, working at OTL as a part-time licensing officer in between start-ups, frustrated with the paucity of licensing opportunities for a technology that he strongly believed in, formed a firm with special permission.[23] This "one-off" instance of a de-facto "entrepreneur in residence program" may regularly be found in Swedish university incubators. The two modes may also be combined. Thus, the "Chalmers Innovation System" includes a masters program in innovation and entrepreneurship to which student teams apply with commercialization ideas that they often source in academic research groups (Jacob et.al. , 2003). A Swedish hospital encourages Nurses to be aware of the commercialization potential of devices they have invented and pairs them with "idea Pilots" and advisors to speed the innovation process (Nahlinder, 2010). These experiments may be synthesized into an intensive transfer regime, to encourage a higher proportion of staff to become involved, including those not traditionally thought of as innovators, as well as raise the innovation rate.

Aspiring schools typically view institutions they wish to emulate after success has already been achieved. They view the current policies, arrangements and procedures in place and assume that their replication will induce a similar result in their own institutions. However, what has been worked out at this later time may not be appropriate to an initiation phase. In the early stages of developing technology transfer, aggressive steps were taken. In a mature phase, once successful relations were developed, policies mandated strong boundaries. In an earlier era a Stanford administrator noted that it was, "… not uncommon for a post doc working in a Stanford lab to be spending a couple of days a week at a faculty start-up before it dawned that that this was not consistent with the basic principles of the institution." "What we are trying to avoid is the kinds of connections between a Stanford faculty member's academic program, resources, facilities, people and their outside entity. We are trying to keep a barrier between those."[24]

The director of technology transfer at MIT, Lita Nelson states that there is a "Chinese Wall "between academia and industry at her university Strict rules are in place forbidding faculty members from playing an active role in firm formation. Decades earlier, the original venture capital firm, ARD used underutilized space at MIT as "incubator" for the firms that it was assisting MIT faculty members to establish. Currently, it is said that Ms Nelson merely turns the next card on her rolodex to notify an area venture capitalist of the latest campus invention with start-up potential.[25] The paradox is that if an aspiring entrepreneurial university adopts Stanford's and MIT's current practices, it may impede their chances of success. The precursor era of a success case is likely more relevant to the current situation of a follow-on region. Moreover, the best practices of an aspiring entrepreneurial university may be relevant to improving the practice of an international

[23] Koepenick, J. Interview with author 4 April 2005
[24] Stanford administrator, Interview with author, 2005
[25] Personal communication from Ashley Stevens, Director of Technology Transfer, Boston University, August, 2007.

success case. The old adage quoted by the former Dean of Research at Stanford, "if it aint broke don't, fix it" might well be replaced by "Even if its working well, make it better.

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