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Pathways to the entrepreneurial university: towards a global convergence

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This paper analyzes the transition to the entrepreneurial university as part of a broader shift to a knowledge-based economy, arising from a complex interplay between exogenous (top-down) and endogenous factors (bottom-up) of a more or less similar nature, combined in different ways in different countries. Drawing on the experience of four countries (US, Sweden, Japan and Brazil) with different institutional trajectories and degrees of academic entrepreneurial transformation, under varying degrees of state control and levels of university initiative, we argue that a global convergence is currently taking shape toward entrepreneurial universities playing a central role in a knowledge-based economy that moves beyond etatism and pure market relations to an intermediate position within a triple helix regime. The role of public venture capital in financing the transition to the entrepreneurial university and its possible interventions in a counter-cyclical business model, which is also active in periods of economic downturn, are also discussed.

A SPECTRE is haunting the innovation systems of societies irrespective of their national differences, developmental stage or level of success. Hastened by globalization challenges and increased competition, the industrial mode of production has run out of steam in many countries, revealing a global incapacity to manage change. Industrial decline, movement of firms from low- to lower-waged countries or the inability to industrialize induce calls for transition to a knowledge-based socio-economic regime, which requires an institutional framework of university–industry–government, each 'taking the role of the other' while fulfilling traditional missions. Thus, the 'double helix' of industry and government as primary institutions of the industrial society of the 18th century is gradually moving towards a 'triple helix' of relatively equal, interacting institutional spheres. Industry substitutes for government in the contemporary academic mind as a source of deleterious influence, while government is revered as a source of support, reversing attitudes of a previous era. Responding to a critique of academic entrepreneurialism, a Fellow of the Royal Society on London said:

> …major changes have occurred in the scientific world. Many top academics are now also top entrepreneurs, forming their own companies, collaborating with big business, exploiting their inventions and contributing to the wealth of the nation (Mickillop, 2008).

At the heart of the triple helix model, the 'entrepreneurial university' concept has evolved over time and is still taking shape as an 'invisible revolution' in many countries around the world as the result of a

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complex interplay of exogenous and endogenous factors acting in varying proportions in different societies. In this paper, we examine this 'invisible revolution' drawing on the experience of four countries with very different institutional trajectories and degrees of academic entrepreneurial transformation, under different degrees of state control and levels of university initiative: the US, Sweden, Japan and Brazil. We argue that the emergence and consolidation of the entrepreneurial university is the result of a complex interplay between exogenous and endogenous factors combined in different ways in different countries. Exogenous factors include socio-economic crises leading to loss of manufacturing industries and failure to create an alternative energy industry (e.g. the US), economic and social stasis (e.g. Japan), movement of corporations and entrepreneurs abroad (e.g. Sweden) or persisting extremes of wealth and poverty (e.g. Brazil), which are followed by various government policy responses requiring universities to play a larger role in innovation as a renewal and growth strategy. Endogenous factors include internal transformations within the university or other bottom-up organizational and management changes driven by changes in the intellectual property (IP) regimes.

The common objective of the IP reform is to encourage universities to become more entrepreneurial. Despite strong differences in cultural, economic and political traditions, change in IP and university systems shows a subtle interplay of entrepreneurial and managed modes in contrast to studies of government–industry relations that produce dichotomous models of liberal and coordinated capitalist regimes (Hall and Soskice, 2001). Government measures, whether direct or indirect, stimulate economic growth by encouraging start-ups and triple helix interactions. Universities become increasingly willing to participate in order to gain increased resources, whether from the transfer process or by justifying additional streams of funding to achieve this new 'academic' objective.

We start with a brief presentation of key stages in the evolution of the university over time and the transition from individual to collective and organizational entrepreneurship. We continue with a methodology section that describes our data, sources and criteria for the selection of cases. The analysis of exogenous and endogenous factors shaping the transition to the entrepreneurial university in the four countries follows in the next two sections. We conclude with a synthesis of the cross-country comparison and an analysis of a common mode of 'managed entrepreneurialism' that seems to emerge as an outcome of this societal renovation, as well as a discussion of factors that can potentially accelerate the transition process.

From individual to collective and organizational entrepreneurship

A protean institution of medieval origin and an offspring of the church, the university assisted the birth of the modern state in the 18th century and, more recently, of the knowledge-based society. The

incorporation of old and new into a consistent institutional identity has been accomplished across the centuries. A 12th century organizational structure dedicated to conserving ancient knowledge has evolved remarkably over time, in a progression marked by two key transitions:

- A transition from essentially teaching institutions to research universities focused on producing new knowledge by incorporating scientific research as an organized activity in scientific societies and networks of individual investigators in the 19th and 20th centuries (Ornstein, 1928): the 'first academic revolution'.[1]
- The transition to institutions with an economic mission, next to teaching and research, able to generate new knowledge and stimulate employment and productivity growth in the late 20th and early 21st century: the 'second academic revolution' (Etzkowitz, 2003).[2] The conceptual frames of *entrepreneurial science*, *entrepreneurial scientist* and *entrepreneurial university* have been proposed in relation with this transition, in order to characterise the incorporation of economic and social development as a university mission (Etzkowitz, 1983, 1990).

An entrepreneurial university is the keystone of the triple helix model, which comprises three basic elements:

- a more prominent role for the university in innovation, on a par with industry and government in a knowledge-based society;
- a movement toward collaborative relationships among the three major institutional spheres in which innovation policy is increasingly an outcome of interactions among the spheres rather than a prescription from government or an internal development within industry; and
- in addition to fulfilling their traditional functions, each institutional sphere also 'takes the role of the other' operating on a vertical axis of their new role as well as on the horizontal axis of their traditional function (Etzkowitz, 2008).

The transition to the entrepreneurial university also encompasses the transition from individual to collective and organizational entrepreneurship. If entreprenership is esentially the process of taking leadership in putting ideas into practice, filling the gap between invention and innovation, then organizations as well as individuals may serve as entrepreneurs (Drucker, 1985). Indeed, Schumpeter, the founder of entrepreneurship studies, identified the US Department of Agriculture as an organizational entrepreneur for its role in catalyzing innovation in the US agricultural system (Schumpeter, 1951). Entrepreneurship is a collective phenomenon since so-called individual entrepreneurs inevitably recruit collaborators, typically with complementary skills, as a prerequisite to realizing their vision. For example, Massachusetts Institute of Technology (MIT), founded in 1862, was the brainchild of William Barton Rogers, a University of Virginia geology professor who moved from rural Virginia to Boston to recruit supporters to realize his vision of a science-based university infusing industry with new technology.

The university has become a capacious institution, simultaneously home to advocates and critics of a wide variety of political, economic and social formats. The reworking of boundaries around institutions undergoing changes in their mission occurs through a 'game of legitimization' with integrating themes invented to align heretofore contradictory practices. When the research university emerged from the chrysalis of the teaching university in the late 19th century, objections to research were made at Stanford and MIT on grounds of conflict of interest. Teaching and research have since been redefined as confluences of interest, complementary and mutually reinforcing, despite persisting disputes over appropriate balance. In contrast to the doctrine of 'core competency' of firms, universities are multi-functional institutions. Paradoxically, most academics, whether inclined to the left or right politically, are conservative about their home institution. Each new task is strenuously resisted until a way is found, through controversy and debate, for it to contribute to previous missions as well as for the new mission to be recognized as legitimate in its own right.

Methodology and selection of cases

This paper examines the transition to the entrepreneurial academic mode as the result of the interplay between various exogenous (top-down) and endogenous (bottom-up) factors. The exogenous factors analysed here include national innovation crises calling for a greater university role in innovation, steep decline in core funding followed by stringency to seek alternative sources of support, which are often mediated by government policies that lead to the creation of new funding sources and incentives to assist industry, but also typically involve adjustment in the IP regime to realign and foster university–industry relations. The endogenous factors that we examine encompass the internal transformations within universities arising in response to national crises, funding cuts or readjustments of IP rights that encourage universities to realize economic value from research.

The analysis draws on the experience of four countries (US, Sweden, Japan and Brazil) with different degrees of academic entrepreneurial transformation under different degrees of state control and levels of university initiative:

- The US represents a model of low state control and high bottom-up initiative combined with high

state support. The country has a longer tradition of university independence, with less reliance upon guidance from the central government, even though university research and development (R&D) relies heavily on government funding. Although there is expediency (in terms of revenue seeking by universities) and strings that come with government support, such as requirements for university–industry co-operation to obtain an engineering or science centre from the National Science Foundation (NSF), the degree of government guidance (and the willingness of universities and private companies to expect and abide by such guidance) seems much less than the other countries in our sample.

- Sweden represents a gradual transformation with relatively modest initiatives by the state.
- Japan represents a complete reworking of the prior framework for university–industry–cooperation with many state-backed initiatives.
- Brazil is an intermediate case, with a mix of top-down reconfiguration of university mission and bottom-up university generated initiatives.

Sweden, Japan and Brazil have centralized systems of higher education with significant government influence (and government-imposed limitations) over interactions between universities and industry. Japanese universities and faculty were more constrained than Swedish universities before the reforms began in both countries, but this may no longer be the case, as Japanese universities now have, at least in theory, considerable freedom to experiment, not only with respect to cooperation with industry but also on basic personnel and financial matters. Japan has gone farther than Sweden during the past decade in encouraging entrepreneurship and increased university–industry cooperation. Brazilian universities' opposition to an authoritarian military regime during the 1970s and 1980s gained them greater independence even as they suffered loss of research funding. More recently a democratic government has increased research support, coupled with incentives to encourage commercialization (Etzkowitz *et al.*, 2005).

The data set on which the paper draws includes archival materials and participant observation at Stanford Office for Technology Licensing and various studies of university–industry relations sponsored by NSF from the 1980s, for the US; studies of academic research groups based on extensive interviews, for Brazil and Sweden (the Brazilian study, for example, has tracked the development of groups for almost two decades); interviews with technology transfer office personnel, university officials, government policy-makers, venture companies and established companies, as well as documentary materials, for Japan.[3]

Our argument is that the transition to the entrepreneurial university is part of a broader shift to a knowledge-based economy that emerges as a result of exogenous (top-down) and endogenous (bottom-up) factors of a more or less similar nature in various countries, creating a convergence toward a central role for entrepreneurial universities within a triple helix regime that moves beyond etatism and pure market relations to an intermediate position in a knowledge-based economy.

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Exogenous factors: economic and political crises and subsequent government policy responses

The US

In the 1970s the US faced the first wave of loss of manufacturing industries to competitors abroad. Heretofore, manufacturing losses had been experienced internally, for example, with textile and leather industries moving from New England to the South in the early 20th century. This initial shock was the impetus to the development of knowledge-based industry from academic research by mid-century. The necessary and sufficient conditions, challenge, the resources for response and the intervening variable of leadership to create the intermediary organizations to promote technology transfer were present. By the 1970s, the emerging university technology transfer industry was strong enough to seek legislative support to legitimize its existence (e.g. Stanford, MIT, Wisconsin etc.). However, without the impetus of the industrial downturn it is quite likely that ideological objections to the commercialization of university research would not have been overcome.

The resulting model of university technology transfer was a compromise between opponents and proponents of direct government support for industry, a controversial concept in a national system

where industry was expected to be the prime mover and source of innovation, and the firm, led by 'heroic entrepreneurs', was the protagonist. In this format, the university was barely acknowledged and the role of government that was going well beyond well-known military, health and space R&D was repressed, in spite of massive government funding in these areas with significant spillovers, which has been the *de facto* US industrial policy. Below the ideological surface, however, a powerful 'jerry-built' substrate has emerged of federal, state and local government innovation support programmes, each filling gaps in the other.

In response to increased international competition from the 1970s, policy-makers focused on the gaps in technology transfer for academic discoveries with potential industrial relevance, avoiding widespread opposition to direct industrial assistance measures. US academic entrepreneurship predates the innovation crisis of the 1970s, but thereafter became a base for regional renewal through a variety of direct and indirect programmes like the Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), Manufacturing Extension Partnership (MEP), or Advanced Technology Programme (ATP) (Etzkowitz *et al*., 2000). The Carter Administration's 'reindustrialization' proposals for a direct industrial policy of government working with firms were largely abandoned, with the notable exception of the ATP, a response to the European Union Framework programmes subsidizing industrial R&D. The ATP, in contrast to its European model, was severely limited in growth due to ideological opposition to a strong role for government in civilian industrial innovation. In recent years, ATP funding has virtually disappeared and the programme is in suspended animation awaiting a favorable political climate.

The Bayh–Dole Act of 1980 restructured university–industry relations, allowing universities to incubate new technologies and firms with supported from private and public venture capital (VC). Regional high-tech ecosystems grew, initially at MIT and Stanford, and then more broadly across the country. Thus, the US national innovation system, a hidden triple helix, exemplifies a model of entrepreneurial academic transformation where exogenous factors, largely bottom-up driven, have been primarily an overlay to a complex set of endogenous transformations that we will discuss in detail in the section on 'Endogenous factors in the US'.

Japan

When a crisis occurs, answers are sought from those who have faced it previously or simply from any source of potentially relevant models. In the 1990s Japan faced a similar crisis to the one that took place in the US during the 1970s. The production activities of its manufacturing industries were increasingly outsourced abroad, leaving a gap that was temporarily filled by a real estate bubble. When the bubble burst and financial paralysis set in, government–industry links that had structured the economy during the post-World War II era were found to be insufficient to restart the economy in these changed circumstances. Although individual entrepreneurs, e.g. Honda, emerged with a strong public identity in the period after World War II, this was a temporary phenomenon. A shift to a knowledge-based economy was sought, in which universities would play a greater role, moving on from the position of R&D labs for industry they had played during early industrialization, during the Meiji era in the late 19th century, through World War II. After the war, a formal system of linkages devolved into informal practices as a consequence of demilitarization.

In the wake of the national innovation system crisis of the 1990s, a decision was taken to significantly revise and enhance the socio-economic role of universities. Previous strictures had created relatively strong barriers between academia and industry, only partially overridden by informal networks that, in any event, could only support existing industries and firms. The legal framework was problematic for several reasons: (i) it prohibited compensated consulting or outside work by university researchers; (ii) it resulted in uncertain ownership of university inventions and discouraged transparent negotiated transfers to appropriate companies; (iii) it prohibited universities and their researchers from benefiting financially from entrepreneurial activity or even from judicious licensing; (iv) it discouraged the development of promising early stage discoveries; and (v) it severely restricted the use of R&D funds to pay for human resources (i.e. salaries or stipends).

In a series of legal changes driven by the central government between 1998 and 2004, most of these barriers were removed, although mobilizing human resources for government, as well as corporate sponsored research, is still difficult. For example, through the 1998 Law to Promote Transfer of University Technologies, the government began to encourage the formation of technology licensing organizations (TLOs) (the law is also known as 'the TLO Law'). Most TLOs affiliated with national universities were established as independent for-profit corporations, in order to be able to receive royalty revenues, hold stock in start-ups and hire competent staff at competitive salaries – none of which would have been allowed if they had been university offices. Consequently, they tended to be less close to the presidents and directors of research of their universities than was the case for many leading US TLOs. In spite of the fact that TLOs could only manage inventions that the inventors voluntarily assigned to them, they performed an important function of legitimizing negotiated transfers to industry.

The 2000 Law to Strengthen Industrial Technology was the most important reform to date in terms

of encouraging entrepreneurship among university researchers. The law legalized compensated consulting and the holding of line management positions in private companies (provided permission was obtained in advance) and encouraged the commercialization of university discoveries in the case of management positions.[4] In a country still characterized by lifetime employment with seniority-based wages and retirement benefits (including in academia), with extremely rare leaves of absence, this removed the draconian choice facing university faculty who had committed themselves to academic careers, but were also interested in entrepreneurship.

Furthermore, in April 2004, as a result of the National University Corporation Law (Kokuritsu daigaku houjin hou), 87 national universities encompassing most of Japan's major research universities became 'National University Corporations', with a status of independent administrative units within the Japanese government structure. Prior to this reform, national universities were branches of the Ministry of Education, Culture, Sports, Science and Technology (hereinafter MEXT; before 2001, Monbusho) and their faculty members were civil servants. This change of affiliation allowed universities to alter their personnel and financial policies, although this freedom is limited by their continuing dependence on direct government financial support for most of their salary and infrastructure needs. This change in universities' legal status was preceded by a 2002 MEXT policy directive giving the university the right to claim ownership of work-related inventions, and the inventors the right to 'reasonable remuneration' (MEXT, 2002). Thus, as of 2006, ownership and transfer of discoveries in most Japanese universities is nearly identical to the US Bayh–Dole system. Before these reforms, either the government or the inventors owned university inventions, depending on the source of funding that supported the inventions. Inventions arising under project specific funding had to be transferred to the government (with an option to a private sponsor to either license or co-own the inventions it sponsored). Inventors could retain ownership of inventions arising under their standard research allowance or under outside 'donations'.

Sweden

Sweden faced a financial crisis in the early 1990s, in part caused by the hollowing out of leading firms that had moved activities abroad or mergers with firms abroad that had a similar effect in transferring economic activities elsewhere. The Swedish model of a 'middle way' between capitalism and communism based on a government–industry complex of strong private corporations and social welfare policies supported by heavy taxation suffered a severe decline in the early 1990s, as corporations outsourced production and moved headquarters to other countries, threatening the national consensus. Policy-making options were divided between whether to continue focusing on meeting the needs of a relatively small group of older, large corporations, several of which, like Volvo and Saab, had become branches of multi-national corporations, or to shift focus to firm formation as a strategy for discontinuous innovation in emerging technological areas. A start-up culture, not in evidence since the last significant wave of firm formation in the late 19th century, was required to revive the national industrial base.

A partial nationalization of the banking system was followed by the establishment of a set of quasi-governmental organizations in the form of relatively independent foundations, to support strategic research and knowledge-based initiatives intended to lead to a new wave of economic development. Government technology agencies that supported existing industries were reorganized into a new agency (the Agency for Innovation Systems (VINNOVA)) focused on incentivizing triple helix actors, especially at the regional level, to assist in the creation of knowledge-based firms. A relatively weak and diffuse introduction of a 'third mission' for universities was mandated in 1997 and a plethora of intermediate organizations were established at the regional level to encourage university technology transfer. Universities that were creatures of the government, limited to human capital formation and research, both basic and serving existing corporations, were expected by some policy-makers to reproduce the US academic entrepreneurship. The traditionally high level of public funding of R&D in Sweden was called into question as the relative lack of translation of research findings became an increasing policy concern (the so-called 'Swedish paradox').

VINNOVA, the dominant funder of technical research in Sweden, encouraged the formation of heterogeneous research consortia, with a specific name and organizational form (Research and Innovation Environments) as the main mechanism for interacting with industry (VINNOVA, 2006). Funding agencies that support the consortia, rather than technology-based firms, acted as intermediaries between academia and large firms. This reflects the traditional tight relations between the state, industry and the university system in most European countries, and the role of the state as the designer of academy–industry collaboration through various research funding schemes.

Brazil

Brazil, a developing country, faced a different but related crisis to the one that resulted from the decline of industrial economies. From the 1960s, a military regime attempted a dual strategy of encouraging the development of manufacturing and knowledge-based industries that included a build-up of academic research to provide a support structure for high-tech industry. National resources were focused

on building up key industrial and technological fields, such as aircraft and computers, key to national security. An opposition movement eventually succeeded in bringing down the regime and restored democratic government in the 1980s. However, the resources to support the large-scale projects of the previous regime were no longer available, generating a crisis in universities that had become dependent upon these resources to support research.

During the first half of the 1980s, as public funds for science and technology dwindled, universities that had developed a strong research focus came under severe pressure. At the end of the 1980s an effort was made at the national level, through the Reengenharia do Ensino de Engenharia program (RE-ENG (transl: Reengineering of the Engineering Teaching)) to diagnose and propose changes in the engineering education to adapt it to the reality of the labour market. As part of this change, it was proposed to include entrepreneurship in the engineering curriculum. In the early 1990s, the Brazilian Scientific and Technologic Development Council (CNPq) initiated the Genesis Project, as part of the Software Export (Softex) Programme, aiming to develop new technology-based companies in informatics utilizing the incubator concept. The spread of entrepreneurial training from its usual location in the business and engineering schools across the academic spectrum is a particular Brazilian contribution to the emergence of the entrepreneurial university.

The Innovation Law of December 2004, and a more general Act (the so-called 'Law of the Good') passed in 2005 introduced a variety of approaches to innovation reform, including incentives for the creation of university technology transfer offices, expanding upon a strong incubator and science park movement, encouraging organizational experimentation in universities and inducing firms to become R&D intensive. For example, universities became able to allow faculty members to organize conjoint academic and commercial entities functioning simultaneously as research groups and firms. The incubator of the Pontifical Catholic University of Rio Grande Do Sul's Science Park hosts one such quasi-firm, whose staff shift among academic and business tasks during a single day, utilizing the same research equipment.[5] Academic research is funded by research council grants, while the firm is the recipient of soft loans, also from government. The leadership of the research group and firm are faculty members who left the Federal University of Rio Grande Do Sul where such an integrated approach was forbidden.

Traditional public/private divides are being crossed, if not obliterated. Heretofore, subsidies to firm R&D required academic (public university) collaboration; funding may now go directly to a firm or group of firms, with or without the involvement of university researchers. Brazil is taking an increasingly pragmatic and targeted approach to fostering innovation, requiring universities to protect IP,[6] focusing resources in particular fields and offering tax incentives for multinational and national firms to work with universities. Nor are persisting inequalities ignored. Government has expanded a nongovernmental organization–public university incubator initiative to train *favela* residents to organize cooperatives and create their own jobs into a national programme. A triple helix innovation system of co-equals is being constructed on the base of the increasingly strong and vibrant civil society that has grown since the collapse of the military regime from the ashes of a statist triangle.

Endogenous factors

The US

Formal academic technology transfer was introduced in the early 20th century at MIT, based on the relatively independent status of US universities, granted by the US Supreme Court to university corporations, and by extension, to business corporations, in the Dartmouth College case in 1819 (Hofstadter, 1955). An 'academic procession' emerged of competitive institutions, each seeking to outdo peers on existing criteria, ever on the outlook for new ways to differentiate themselves (Riesman, 1958). Introduction of new subject matters followed the professionalization of occupations, and entrepreneurial behavior ensued to gain support for new academic tasks.

Before 1980, academic entrepreneurship, with the notable exception of a few universities like Wisconsin, Stanford and MIT, was largely confined to seeking research support. In subsequent years, the commercialization of research, through patenting, licensing and firm formation, began to spread throughout the research university system. As the time frame between discovery and invention tightened, the capitalization of knowledge expanded and the technology transfer evolved from an individual faculty initiative to an administrative function. In 1969, Stanford University established an Office of Technology Licensing (OTL) believing that the university could do better than the occasional patent. Instead of concerning itself with the legal aspects of IP protection, OTL would focus its efforts on seeking customers and negotiating deals, leaving patenting to external attorneys retained by the office. The marketing model of university technology transfer had its first great success with recombinant DNA, the Cohen Boyer patents, taken on behalf of Stanford and Berkeley and offered to pharmaceutical and biotechnlogy firms at rates low enough to preclude opposition, while high enough to gain significant income for the universities.

The marketing model of technology transfer was introduced at MIT after that university shut down a 1970s programme to provide VC to its faculty to commercialize their research through firm-formation, after incurring the ire of faculty who were

not funded. In subsequent years, the marketing model spread throughout the US research university system even as technology transfer expanded from a relatively few universities to virtually all schools with a modicum of research funding. The rapid growth of academic technology transfer was encouraged by changes in federal law and regulation that required universities receiving federal research funds to make an effort to see that results with commercial potential were put to use on pain of loss of government support.

The Bayh–Dole Act of 1980 restructured university–industry relations. In effect, the US established a partial 'professors' exemption' guaranteeing individual inventors a significant share of the rewards from IP. Ideas for the law and impetus to its passage came from those universities, like Purdue and Wisconsin, early involved in technology transfer. A coalition of small business lobbying organizations, university and government patent officials, led by the predecessor of the Association of University Technology Managers institutionalized, rationalized and legitimated academic patenting. Heretofore, IP, potentially available to all interested takers, was utilized by few since it was expected that successful developers would attract 'free riders' who could not be fended off given the uncertain legal status of federally funded academic research.

Universities have become key players with local and regional business leaders and government officials in promoting these efforts. Academic procedures have been modified to accommodate entrepreneurship, and universities increasingly use their endowment funds as VC, both directly through their transfer offices and indirectly through investments in funds. The technology transfer office operates at arms length in universities like MIT and Stanford that have earlier attained success in creating a high-tech regional conurbation, while aspiring universities pursue more direct methods, characteristic of MIT and Stanford's earlier histories. Academic entrepreneurship is widely accepted and universities increasingly identify themselves with the entrepreneurial university model even as they deepen their commitment to teaching and research. Harvard now plans to outdo MIT in its devotion to economic development at its expanded campus. Johns Hopkins, until quite recently held to be the exception to the rule in sustaining the last 'ivory tower', has taken the lead in establishing a biotechnology complex surrounding its campus. Thus, instead of a conflict of interest, a confluence was defined, with free flow of personnel and ideas between the two entities. Once the university accepted firm formation and assistance to the local economy as an academic objective, the issue of boundary maintenance was seen in a new light. Organizational and ideological boundaries between academia and industry were redrawn, with faculty encouraged to utilize leave procedures to take time to form a firm, and entrepreneurial ventures noted to contribute to research excellence in university promotional literature.

Japan

The changes that have been made in the legal system of Japan (and to a lesser extent in its institutions) in order to encourage the innovation described in the section on the 'Exogenous factors: economic and political crises and subsequent government policy responses' have been substantial and are having the desired effect. Prior to 1998, the cooperation between Japanese national universities[7] and industry occurred for the most part informally, and the main industrial collaborators of the major universities were large, established companies. University researchers, and especially the administrations of the universities, played a passive role. The rewards for collaboration were low and it was nearly impossible for university researchers to be actively involved with start-ups.

The recent change in the legal governance structure gave universities increased independence in a top-down effort to establish a formal technology transfer system and make Japan's universities and their faculty more entrepreneurial. Some managers and researchers are leaving lifetime jobs in established companies to work in start-ups. Successful venture companies are willing to mentor or assist other venture companies. There is evidence that a vigorous entrepreneurial culture in universities is being implemented. However, whether this will be sustained and universities will become vibrant entrepreneurial centres of research, teaching and new business formation now depends on factors beyond the legal framework governing university–industry cooperation. Current areas requiring attention include the system of funding university R&D, recruitment and promotion of university researchers, social attitudes towards entrepreneurship, corporate policies on outsourcing R&D and mechanisms for supporting start-ups.

Currently, the leading drivers of university entrepreneurship at a 'grassroots' level (a relatively small but growing number of professors, competent TLOs and university-based incubators, and independent VC companies) are somewhat peripheral to the university community. As there are few research parks per se, collaboration usually occurs in university labs, with start-ups and small- and medium-sized enterprises (SMEs) playing a greater role in some technology fields. Codevelopment of research upstream as well as commercialization downstream are essential to take better advantage of formal legal IP rights. A wider range of relationships with industry is now permitted than in most US universities. Not only can the Japanese university researchers hold outside management positions, they can also receive sponsored research from companies in which they hold stock or have an advisory or management position. Concerns about possible conflicts of interest are now arising and the current guidelines will probably need to be revized in the light of these misgivings.

Sweden

The government policies and programmes promoting an entrepreneurial culture and new forms of science–industry partnerships described in the section on 'Exogenous factors: economic and political crises and subsequent government policy responses' have encouraged Swedish universities to change from an 'ivory tower' stance and support structure to the existing industrial infrastructure to play a more prominent role in the creation of a new industrial base. VINNOVA, the national innovation agency, is encouraging localities and regions to support knowledge-based development in collaboration with universities. A series of foundations to support strategic research and entrepreneurial ventures were also introduced, and regional technology development agencies have also provided funds to support university technology transfer and firm formation. These initiatives have provided the basis for the transition from traditional university–industry relations to a new model of an entrepreneurial university embedded in a triple helix of university–industry–government relations.

Chalmers (Sweden's MIT equivalent) is currently in the early stages of a shift from reliance on relationships with large firms to a focus on start-ups and SMEs. For example, an entrepreneurship training school has taken several groups of students through the start-up process, leading to the foundation of several firms, as well as providing a valuable educational experience. The rector of Karlskronna Ronneby Technical College developed an initiative to create a software industry. Support from regional authorities and good timing were crucial to the success of the project. At Linköping University, an industrial liaison director organized an association of emerging high-tech firms, connecting them to the university and to each other. He received similar lateral support from regional authorities. This bottom-up initiative, tied to entrepreneurial training, facilitated a wave of firm formation.

Karolinska Institutet, a world-renowned public biomedical foundation, has undertaken significant entrepreneurial initiatives in recent years, translating its research resources into IP for licensing and start-ups. Leadership by the rector and support from senior faculty have been important to this entrepreneurial transformation. Karolinska, like Oxford and the Pasteur Institute, Paris, had a wealth of research resources that soon bore fruit once an effort was made to harvest it. Karolinska has also been active in networking the biomedical research resources of universities across Sweden, and in other Scandinavian countries, to create critical masses of research foci that can be competitive in the global arena.

In this bottom-up entrepreneurial model, universities and academics themselves were encouraged to take on the role of entrepreneurial agents. Universities can form 'holding companies' to purchase IP rights from professors and to own shares in other companies.

The current IP regime in Sweden is a major factor in shaping university technology transfer. The 'teachers' exemption' confirmed in a 1949 law allows scientists (not the universities where they work) to own full rights to their discoveries.[8] This has encouraged many academics to strike out on their own in search of outside investment capital. Since they own the IP, irrespective of the funding source, they can transfer it to an independent company, hand it over to a university organization or use it as the basis for firm formation, as they see fit. This is a key competitive advantage that has spurred a flurry of entrepreneurial activities. Ownership, however, is a formal rather than a real incentive to transfer technology, without a source of resources to do the follow-up research to produce a prototype and prepare a patent application to protect the IP. Moreover, since existing firms are often unwilling to license discontinuous inventions, a source of seed VC is required to form a firm to further develop the technology and move it toward the market. Individual academics seldom have the knowledge and resources to realize benefits from their formal ownership rights (Sellenthin, 2006).

A recent government commission was indecisive, but suggested as one possibility that Sweden abolish the teachers' exemption and make universities responsible for patenting and commercialization of their research (SOU, 2005). Universities have responded enthusiastically to the proposal. However, individual researchers have dissented, fearing that spontaneous collaboration between universities and companies, as well as the formation of new firms will be hindered. Traditionally, for many Swedish academics, interaction with firms occurred through their regular academic role (Benner, 2003). The usual relations involved transferring different inquiries to people that are suited to answering them and dealing with matters concerning students. The traditional form for commercial involvement has, therefore, been as consultants, with a clear separation between consultancy and academic work (Sellenthin, 2006). Restrictions on their professorial role have largely limited their involvement with professorial firms to part-time, one-person consulting operations. The type of involvement is therefore relatively limited in terms of time and financial support, and it seldom develops into long-term interaction with customers, not surprisingly impeding the development of growth firms.

A recent study (Goktepe, 2008) shows two apparrently divergent trends. On the one hand, there is continuing opposition by serial academic firm founders and patent holders to changes in their sole control over IP emanating from their research. On the other hand, during recent years, relatively weak university technology transfer offices have significantly improved their capabilities and are better able to serve a broader range of academic inventors who are not willing to take on the burden of technology transfer by themselves. An enhanced technology

transfer and business development capacity, exemplified by the activist regime at the Karolinska Institutet, provides a window on the potential future of other universities. At present, Swedish universities negotiate with faculty inventors on an individual basis for their IP even as in a pre-Bayh–Dole era, US universities negotiated with federal agencies for control of IP for each federally funded invention, until a comprehensive framework was established, initially by agency–university agreements, subject to cancellation, and then by the more stable framework provided by the law of 1980.

The type of entrepreneurship that has emerged is, therefore, mainly of an indirect kind, where either firms or former students act as carriers of commercial ideas. There are different strategies among university professors representing a range of involvement in commercial activity (Benner, 2003). Integrated academic–entrepreneur is a growing category, though. The number of firms spun off from universities is relatively large in Sweden, estimated to be around 600 in the most recent survey (VINNOVA, 2003). The gap is in the translation of start-up into growth firms.

The third mission has been variously interpreted and can mean anything from educational outreach to better inform the public about academic activities to the establishment of a range of technology transfer mechanisms (HSV, 2005). Traditionally, the university professor as a network-builder is a role where commercial involvement takes place without company formation. It refers to a role as provider of generic knowledge for a whole sector or subsector of the economy in areas where knowledge interplay is difficult to achieve via traditional entrepreneurship. However, these initiatives are typically splintered without a clear focus provided by a highly professionalized technology transfer office within the university (HSV, 2005). Internal academic initiatives, complemented by government programmes, have thus far been more important to the academic entrepreneurial transition than changes in the IP regime.

Brazil

In recent decades, Brazil has oscillated between top-down and bottom-up innovation systems modes. Following the downfall of the military regime in the 1980s, bottom-up initiatives flourished in an era of scarce resources (Etzkowitz *et al*., 2005). Incubators displaced science parks as the key organizational instrument for assisting high-tech development. A good example of the entrepreneurial transition that many Brazilian universities are undergoing is the Pontifical Catholic University of Rio de JaneiroGrande do Sul (PUC-Rio) (see Figure 1), which, as a private university, had the flexibility to make the transition more rapidly than its public counterparts. The various entrepreneurial features developed at PUC-Rio have been instituted on a broader scale elsewhere, even if less intensively. This led to an increasing recognition of a shift in the university mission regarding the skills that academic education should provide students with: from the skills to write an essay, express their ideas and write a research paper, to the skills of drafting a business plan, projecting an objective and formulating a market test for a new organization or project.

To date, IP rights have not been a major issue in the development of university–industry relations in Brazil. Brazil is a story of building organizational capacity, especially in software, where IP rights, while increasingly important, are still subsidiary to innovations in business models and first mover advantages in introducing technical innovations. Nevertheless, Brazil is undergoing a transition to a stronger IP regime, partly under pressure from the US and other developed countries that wish to protect their IP rights in transferring technology to Brazil.

Change also arises from the recognition that Brazil is building up the capabilities to be able to compete internationally in selected areas of technology and thus can also utilize a stronger IP regime to its advantage. This transition is most apparent in the biomedical area that has traditionally relied on reverse engineering, carried out in government research institutes to develop and produce medicines to meet the requirements of government-sponsored health schemes. Emerging capabilities in biotechnology and the wish to protect the IP inherent in the country' vast natural product and plant resources, Brazil's comparative advantage, are the basis for transition from an anti- to a pro-IP regime.[9] More

The entrepreneurial transition at PUC-Rio

PUC-Rio's response to the drastic decline of institutional funding in the 1980s was to organize a strategic planning process. A development office was created to stimulate interaction with society, especially with companies. The development office analyzed the university's difficulties in interacting with private companies and concluded that entrepreneurs didn't know how to use the knowledge generated in the university. An entrepreneurship programme was subsequently established, involving engineering, informatics and psychology professors. An entrepreneurial focus was introduced in the university, based on entrepreneurship training and creation of technology-based companies. The aim was to develop a new type of entrepreneur who would have the ability to utilize the knowledge acquired in the university.

An educational strategy was devised to reorient students from seeking jobs in large firms and government agencies to founding their own firms. A three-staged process of pre-incubation was made available to master and doctoral students who aimed to create a company and define new products or services. Such students were helped by the university's incubator to become entrepreneurs first, in a virtual stage, providing assistance in developing a business plan; secondly, in a physical stage taking place in the incubator; and thirdly, in the research laboratories. PUC-Rio has thus become a university that instead of training people to be employees prepares them to generate employment.

Figure 1.

recently, a national innovation law has systematized these trends, creating a top-down overlay that expands bottom-up initiatives.

Conclusions

A global transition to the entrepreneurial university?

The exogenous and endogenous factors examined in our analysis as drivers of the entrepreneurial process combine, producing either an insidious 'witches' brew' or a powerful 'engine of innovation' depending upon one's point of view (Press and Washburn, 2000). The series of transformations we identified suggests a general tendency of universities to converge towards an integration of various academic roles in a relatively compatible synthesis of existing and new tasks: teaching and the preservation of knowledge, research and the creation of new knowledge, economic development and regional renewal. Aligning multiple roles within a single person or creating new positions to enact them is a classic choice. Integration of multiple roles within the academic position is driven both by cost considerations and the inherent consistency of polyvalent knowledge (Viale and Etzkowitz, 2005). Rather than being divisible into separate spheres, all knowledge is potentially Pasteurian (Stokes, 1997). A balance between separation and integration of roles, simultaneously and *ad seriatim*, emerges as entrepreneurship become an overlay on research and teaching.

The lesson from the US case is the efficacy of combining organizational and legal innovation. US faculty members integrated this new entrepreneurial role with their previous academic roles, just as their predecessors in the late 19th century combined research with teaching. The transition from a legal to a start-up model of technology transfer was facilitated by transfer of rights to discoveries made with federal funds to the research site in the expectation that transfer could best be arranged locally. Administrative costs could implicitly be included in the university's overhead rate on federal grants and monies earned could support academic activities. Students increasingly took the entrepreneurial role as opportunities expanded from biotechnology to computer science. The Bayh–Dole Act incentivized a broad range of universities, well beyond those traditionally involved in technology transfer.

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The Swedish case illustrates the additional level of difficulties that academics met in undertaking firm formation and other technology transfer activities as part of the university 'third mission', given a model of separation between teaching, research and entrepreneurship existing in Sweden, as well as in other European universities. This model of separation is increasingly being phased out and a gradual transition to drawing the various academic roles together in a single position is increasing in Sweden, as well as in other European universities. Students are trained to take the role of the entrepreneur, with faculty members as advisors to firms that emerge out of a research group. Even though the educational system is the main vehicle for academic entrepreneurialism in Sweden as in most European countries, there is also a movement towards more direct involvement of university professors in commercial activities. In contrast to Japan, this rather strong legal framework has, however, not been supplemented by similarly strong implementation mechanisms.

IP emanating from academic research, irrespective of the funding source, is owned by Swedish academics and its disposition is up to them. Given a tradition of industrial interaction primarily with large firms, most IP flows to companies through informal relationships, as in Japan. Discrepancies appeared as large firms dispersed abroad or become multinational subsidiaries. A gap emerged between university research strengths and industrial needs. Under these conditions, a new set of interlocutors for valorising the useful results of academic research is required including development of an organizational capacity for technology transfer and promotion of a university culture receptive to firm formation.

The Brazilian model of pre-incubation in the university laboratory addresses the persisting gaps in translational research to produce a prototype. Realizing that offering public funds for research and firm formation is insufficient, a programme to create a VC industry has been established in Brazil, by training potential entrepreneurs to seek and utilize VC. In Sweden, regional actors are encouraged to join forces in national technology development competitions.

While several major US universities developed an entrepreneurial culture decades ago, Brazil's

Universities appear to have a greater capacity for reinvention than firms that disappear through merger and technological obsolescence

universities and researchers have been forced to develop such a culture quickly in response to cuts in public funding. 2000 marks the beginning of a sustained increase in university start-up formation in Japan. Many of the university start-ups are virtual companies with low invested capital, sales and numbers of employees. But even some of the 'virtual' companies draw upon the research of major university laboratories and networks of researchers that span several universities. The PUC-Rio and Stanford cases suggest the importance of support from the university's top leadership, although in both instances, formulation and execution of strategic direction occurred one level below.

Universities appear to have a greater capacity for reinvention than firms that disappear through merger and technological obsolescence. Large corporations and networks of small firms in traditional industries, increasingly seek academic inputs into product development. Large Swedish firms locate R&D units in science parks adjacent to universities to pursue joint projects and scrutinize potential future employers who pursue projects toward their degree within the firm. A Brazilian government program, allowing foreign firms significant tax reduction for sponsoring research, has made locating a lab in a research park adjacent to a university attractive.

Similar developments have appeared in different ways in a wide variety of other countries. For example, in early post-liberation China in the 1950s, factories were often part of university campuses and industrial work, a student obligation alongside studies. In the 1980s, facing financial stringency, government pushed universities into the market by cutting their budgets, much as Prime Minister Thatcher did in the UK during the same period. In the UK, some universities, like Salford, significantly increased their industrial consulting; other schools lacking the private resources of Oxford and Cambridge, simply reduced expenses. Chinese universities tore down the walls between campus and society and, utilizing administrative and faculty resources, established trading firms selling consumer technology. These firms upgraded to production and then to incremental improvement of their products. Some, like Lenovo, a Beijing University enterprise, and NUSoft from Northeastern University, grew larger than their sponsors. Universities are disentangling these 'university-run enterprises' from their academic structures, transforming them into independent spin-offs and contributing to university income through equity ownership (Zhou and Peng, pp. 637–646, this issue).

Supporting the transition to the entrepreneurial university: 'Anybody got any good ideas?'

Although the presence of a strong research potential is an important prerequisite for the emergence of an entrepreneurial university, this condition is necessary, but not sufficient. Many research-intensive universities in Europe or elsewhere display low levels of entrepreneurial activities due to various factors, including: structural 'division of labour' between technical and more general universities, low R&D potential of local/regional firms and weak interaction with the university, strong cultural and language differences between the triple helix actors etc. (Ranga *et al*., 2008). On the other hand, low levels of university research and weak R&D potential of local/regional firms (e.g. in Central and Eastern Europe) are serious obstacles in the transition to the entrepreneurial university that can be difficult to overcome, in spite of numerous government policies, programmes and funding sources created to support technology transfer and entrepreneurship (Ranga and Etzkowitz, 2008).

A universal recipe for success is not possible, but some ideas to accelerate the way towards the entrepreneurial university seem to emerge from international experience so far. The recent financial crisis exposed the flaws of the post-industrial production and weaknesses in the strategies of creating financial bubbles to power the economy. However, alongside a plethora of negative consequences, an emerging positive result is the growing realization of the need to address the expansion of entrepreneurial universities and associated projects and programmes to strengthen the infrastructure for knowledge-based economies and societies.

To date, the entrepreneurial academic transition has been relatively modestly supported, typically as an extension of providing research funds. Now is the time to massively expand the underfunded technology transfer and translational research capacity that typically now address only a minority of opportunities presented. Every dollar, pound and euro of debt created to bail out the financial industry should be matched with another to build future knowledge-based industries and entrepreneurial universities. Moreover, research in fields like alternative energy also need to be scaled up to create new industries in a shorter time frame (Etzkowitz, 2005).

The road from rhetoric to action may be shorter than one would expect. The October 2008 report[10] of the Information Technology & Innovation Foundation, a Washington-based think-tank promoting public policies to advance technological innovation and productivity internationally, suggests that the US Congress should craft a second economic fiscal stimulus package to follow the conventional spending-oriented stimulus package focused solely

on tax cuts for individuals and spending increases. This second stimulus package would not only reinvigorate the economy, but at the same time would also boost investment that spurs productivity growth and innovation, especially in information technology, which has been the engine of US economic growth for the past decade. Specific proposals that would not only spur spending and economic activity in the short run, but would also help address these challenges going forward include, among others, the provision of US$2 billion to colleges and universities to invest in research infrastructure in 2009, as well as a tax credit of 50% for investments in energy efficient equipment in 2009.

Contemporary knowledge-based societies require universities with a broader mission for innovation than in industrial society. The ability to create new types of organizations and roles is essential, as well as the ability to equip students with the necessary tools to adapt to changing global situations. Broad-based degrees to train students in entrepreneurship and innovation, as well as traditional specialities are required to provide trained people capable of realizing these new opportunities (Etzkowitz *et al*., 2008).

At a time when the international patterns of wealth generation and spending are rewritten, finding the resources to sustain these changes may be a serious challenge. On 12 October 2008, the front page of '*The Deal*', a New York City-based magazine for the investment bank, merger and equities industries showed the Monopoly Game brand figure, who wears a top hat, struck back on his heels, dumbfounded, under the headline 'Anybody got any good ideas?' At a moment when even most avid proponents of a self-regulating banking industry, like Alan Greenspan, admit that their ideas were wrong, there is a return to the ideas of Marx and Keynes. Booksellers in Berlin have been quoted as saying that Marx's *Das Kapital* has been flying off the shelves in recent weeks (Collins, 2008). Keynes has just been recalled from his post-Reagan–Thatcher descent into relative obscurity[11] to provide the answers to address the growing economic crisis.

The dark side of the business cycle model that came to the forefront during the late 1990s when venture capitalists eschewed a relatively long-term strategy of five or more years to exit in 18 months or less, highlighted various negative effects, including the tendency of private VC to invest mainly in periods of economic upturn. A counter-cyclical model of public VC that would invest also in periods of economic downturn may remedy this. From a policy perspective, the downturn is a propitious time to encourage firm formation, and VC should indeed be more active in the downturn of the business cycle than in the upturn. There is an availability of human capital, people leaving failed ventures or being laid off from survivors. Entrepreneurs are active and space is more available. Nevertheless, there is typically a lack of capital invested in start-ups; although funds are available, holders of capital are typically afraid to invest.

Recent years have seen a growing interest in the contribution that public VC could make to uneven spatial economic developments and how its supply can be stimulated and directed to achieve economic development goals (e.g. Lerner, 1996; Murray, 1998). Government intervention in the supply of VC for economic development ends usually takes place through either macro measures (supportive fiscal and regulatory conditions if the aim is to stimulate the supply side without any direct involvement) or micro measures (directly implementing short- or medium-term programmes to fill various financing gaps), or both (Hood, 2000).

The provision of VC by governments emerged in the 1990s in a shift from the loan guarantee schemes that proved to be largely ineffective given small firms' frequent incapacity to provide collaterals, and in an attempt to supplement the limited private VC and support the growth of innovative companies, wealth and job creation. The success of early forms of government VC, established using government funds, was affected by factors like political influences on investment decisions, lack of investment skills, low returns and the risk of crowding out private investors. In a fresh approach, capital participation was adopted, either by providing some or all of the investment funds that were managed by private VC funds managers, or investing in existing private VC funds (a fund-of-funds approach). However, this approach did not overcome the key problems of risk, costs and return factors that discouraged private VC from investing in early-stage firm developments, and an enhancement of the risk–reward ratio was necessary in order to attract private co-investors.[12] From the early 1990s in the UK and the late 1990s elsewhere in Western Europe, a further shift in the evolution of government VC was marked by the complements provided by the 'informal VC market', also known as 'business angels', and the policy support that governments provided them (Mason, 2008).

In the US, a 'low state society' where scepticism of public competence is expressed in formulae about government's inability to pick winners, the state is precluded by ideological strictures from directly taking the role of venture capitalist, and the public VC is forced to take other guises. The idea of the government taking even part ownership in a firm is contrary to ideology in a *laissez-faire* oriented society, except for special circumstances such as the imminent demise of a key firm, when it is allowed but it is viewed as a temporary measure (e.g. the 1980s Chrysler bailout, or the recent financial bail-out of the banking system). Most of the US public VC is hidden behind the research formats and programmes of traditional research granting agencies. Programmes such as SBIR or ATP are the functional equivalent of private VC, in addition to their overt purpose of providing research funds to small business, even if these programmes are not officially designated as such or are precluded from taking equity for ideological reasons. Indeed, the very limit

The entrepreneurial university is a public–private entity in scale and scope. In good times, the private side of the model predominates; in bad times, the public side comes to the forefront

on taking equity, paradoxically, may make these programmes more effective as VC than the investments of many private venture firms, especially those that have moved downstream from the start-up process to later stage investments.

The impact of public VC government programmes is, however, difficult to assess, as, with some notable exceptions (e.g. Thompson and Bayer, 1992 and Lerner, 1996 on the US; Harrison and Mason, 1989 on the UK's Business Expansion Scheme; Globerman and Olsen, 1986 on provincial VC programmes in Canada), there is relatively little evidence available and the arguments it provides are rather mixed. For example, the smallness and limited capacity of public VC to provide follow-up funding have been reported as factors affecting the success of the public sector intervention (Murray, 1998, 1999). Also, VC policies that have been constructed as regional policy interventions in the UK and Germany seem to display only a limited degree of regionalization, despite marked differences between the two states, and may lead to an unintended regionalization of outcomes contradicting the aims of closing regional disparities in risk finance and entrepreneurialism (Sunley *et al*., 2005).

While public research grants to encourage fresh entrepreneurs or capital subsidies to reduce the cost of start-up investment may be successful in expanding the VC sector, they can also discourage private effort rather than promote it. Combining cuts in capital gains taxes with a tax (rather than a subsidy) on start-up capital spending may also incentivise entrepreneurial effort and VC support, leading not to more, but to more successful start-up firms and to more mature firms introducing new goods (Keuschnigg, 2003).

Public VC is a leap into the future, using debt funding to build infrastructure for a knowledge-based society. Keynes' 1930s ideas to renew physical infrastructure provide an insufficient base to renew the economy, so that new ways for achieving this objective need to be sought, and public VC can be one of them.

Google originated as a multibillion dollar firm from a substrate of public VC, an entrepreneurial university and an innovation ecosystem of university technology transfer office, science angels and academic entrepreneurs with common technical expertise, able to recognize the potential of a new technology without first seeing a revenue stream, VC firms and other formal and informal support structures. Universities waiting for their two guys or gals to get together and start the next Google are often now well aware of the precipitating factors and take steps to enhance the potential for academic entrepreneurship.

The entrepreneurial university is a public–private entity in scale and scope. In good times, the private side of the model predominates; in bad times, the public side comes to the forefront. In all times, the global convergence to an entrepreneurial university is the reverse side of the same coin: the transmutation of academic knowledge into economic advantage.

Notes

1. The 'first academic revolution' is exemplified by the invention of the teaching laboratory at the University of Giessen, Germany, in the mid-19th century and the emergence of the PhD qualification as a prerequisite for an academic research career (Jencks and Riesman, 1968).
2. The 'second academic revolution' is embodied in the US 'land grant' model from the early 19th century (Rossiter, 1975), the development of academic entrepreneurship at MIT and Stanford from the early 20th century and its subsequent spread throughout the US academic universe. As early as the 1830s, lobbying by Connecticut's farmers led to the foundation of a combined agricultural research and training organization that became the model for the US land grant university, expanded by federal law of 1862 (The Morill Act) into a national programme. It was originated at the behest of 'scientific' farmers and adapted to enhance industrial innovation in the 1860s, with the founding of MIT.
3. Unless otherwise indicated, data to support the Japanese case are contained in Kneller (2003a, 2003b) and a forthcoming book by Kneller tentatively titled *Bridging Islands: Autarkic Innovation, Venture Companies and the Future of Japanese (and American) Industry*.
4. Applicants need to report the nature of the outside work, hours per week or month and compensation. Prior to 2004, management positions had to be approved by the National Personnel Agency. Since then, all applications are approved at the university level.
5. Production takes place in a bioreactor, on the scale of a large coffee pot, the products are then sent by express air mail to customers in the San Diego biotechnology complex.
6. Indeed, technology transfer officers have been given legal authority to vet papers before publication. Although formal procedures are not expected to be instituted, the law makes clear that the realization of IP potential is an important academic task.
7. This discussion is mainly limited to national universities, which receive over 75% of R&D funding and perform substantially more R&D than private or local government universities. Nevertheless, some private universities, such as Keio and Waseda, are important R&D centres and are actively engaged in collaborations with industry, including start-up formation. The same is true for many government research institutes such as Riken and AIST (Agency for Industrial Science and Technology). Although details differ for national universities, private universities, local government universities and government research institutes, the changes described here are for the most part similar to changes that have occurred for these other types of institutions.
8. The 'teachers' exemption' is a carryover from medieval academic privileges such as the exemption from the citizens' responsibility to quarter soldiers in their homes.
9. The shift in IP perspectives is concomitant with the transition from developing to advanced industrial society, a change that

occurred in the US during the late 19th century (David, 1981).
10. Information Technology & Innovation Foundation 2008. Timely, Targeted, Temporary and Transformative: Crafting an Innovation-Economics Based Stimulus Package'. Issued 29 October 2008. Available at <http://www.itif.org/index.php?id=191>, last accessed 29 October 2008
11. In response to the depression of the 1930s, Keynes suggested that government employ people to dig holes and fill them up again as a means to employ people, pay them and thus revive consumer demand. Actually, government funds were utilized to build schools, dams, post offices and other useful public works, like the Northern Line of the London Uundergrounds.
12. For example, by providing private investors with downside protection, by assuming a disproportionate share of failures, by facilitating enhanced returns or by supporting the operating costs of the funds (Mason, 2008).

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