The triple helix model of innovation[a]

University-industry-government interaction

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In a knowledge-based society, university, industry and government have equal roles and form a triple helix in stimulating innovation. A stable regulatory framework is a necessary but not sufficient condition. The transformation of a university from a teaching to a research and thence to an entrepreneurial institution is vital. Government must help to support the new developments through changes in the regulatory environment, tax incentives and provision of public venture capital. Industry takes the role of the university in developing training and research, often at the same high level as universities. If knowledge-based industries are lacking, university-government interactions can help jump-start their creation; if they are present, they can help expand their growth. This article outlines a comparative analysis of the emergence of an entrepreneurial university.

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Introduction

We are moving towards a new way of using knowledge in the economy - there is a shift from the "hands off" linear model to an "assisted" linear model of innovation, with initiatives taken by triple helix coalitions.[1]

In a knowledge-based society, the university attains equal status with government and industry, the two leading institutional spheres from the 18th century, moving from its role as a secondary supporting institution into a primary institutional sphere. The university is increasingly central to discontinuous innovation in knowledge-based societies, superseding the firm as the primary source of future economic and social development.

Interaction among university, industry and government is the source of the origination and/or the development of incubator movements, interdisciplinary research centres and venture capital, whether private, public or social. These organizational innovations are as important to the flow of innovation as technological advances.

This university, industry and government as relatively equal interdependent and interacting institutional spheres is the basis of a triple helix society.[c]

The emergence of a double helix of government-industry relations - a bi-

institutional model of society - represented the great transformation of the 19th century.[2] On the one hand, the market became the organizing principle of social relations while, on the other, government moderated exchange relations to ensure a living wage.

The institutional transformation was reflected in the development of new legal frameworks that provided a basis for resolving conflicts arising from the emergence of new modes of production. The Speenhamland Law of 1795 and the Bayh-Dole Act of 1980 exemplified the compromise among conflicting interests that established the inter-institutional relationships of their respective eras.

Speenhamland laid the basis for social relations in the UK's emerging industrial society, placing limits on exchange relationships in labour and guaranteeing workers a living wage. The US Bayh-Dole Act (and similar laws in Japan, Denmark and other countries) provided a framework for knowledge-based innovation, guaranteeing a sharing of intellectual property rights among academic inventors and the universities that provided the infrastructure for science-based innovation.

A stable regulatory framework for knowledge-based societies is a necessary but not sufficient condition for organizational innovation. The transformation of the university, whether through internal or external impetuses from a teaching to a research and then to an entrepreneurial university is a key element in creating a viable triple helix.

Government focus on innovation as well as traditional governmental activities is also a prerequisite. If there is a lack of knowledge-based industries, university-government interactions can help jump-start their creation; if they are present, these can expand their growth.

This article outlines the triple helix model - through a comparative analysis of the emergence of an entrepreneurial university that plays a leading role in economic and social development - the coming great transformation.

The triple helix model

The potential for future economic development increasingly lies in the university, not only because of its research potential that may be underutilized - the so called "European paradox" - but also because university has the students, an ever-renewing source of new ideas.

Students may also be trained and encouraged to be entrepreneurs and be inspired to take up new roles as firm founders in a society lacking a strong entrepreneurial tradition, like Brazil, or to help create new enterprises, as in Sweden, a country that became overly dependent on a small set of large corporations.

Some of these firms are declining while others are moving significant parts of their enterprises abroad. New sources of economic growth are required. In current international competitive circumstances, innovation is too important to be left to the individual firm or even a group of firms, the individual researcher or even a cross-national collaboration of researchers.

Innovation has expanded from an internal process within and among firms to an activity that often occurs in other institutional spheres as well. It may take place within institutional spheres not traditionally thought of as having a direct role in innovation, such as universities.

Universities, so far primarily seen as a source of human resources and knowledge, are now looked to for technology as well. Many universities have internally developed the organizational capabilities to formally transfer technologies rather than to rely solely on informal ties.

Universities are also extending their teaching capabilities from educating individuals to shaping organizations in entrepreneurial education and incubation programmes. Rather than serve only as a source of new ideas for existing firms, universities are combining their research and teaching capabilities in new formats to become a source of new firm formation, especially in advanced areas of science and technology.

The Triple Helix model comprises three basic elements:

- A more prominent role for the university in innovation, on 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 y axis of their new role as well as an x axis of their traditional function. Functional integration, as well as differentiation among institutions, takes place though interaction among the spheres.

Hybrid organizations are being invented that embody elements of two or more institutional spheres to accomplish new goals. One example is the incubator facility that plays a dual role in the university, embodying industrial and academic elements.

The incubator director serves as the translator between these two spheres, speaking the language of both spheres and having insider knowledge of each. The incubator facilitates linkages between start-up firms emanating from the university, on the one hand, and sources of support in the industrial and governmental spheres, on the other.

Thus, the university moves from playing a supporting role in training people and providing knowledge to other institutions to playing a leading role in creating an industrial penumbra around itself.

The triple helix transition

The triple helix begins from different starting points: from separate institutional spheres that operate apart from each other; or from any one encompassing and directing the others. The global trend is towards a mode in which the various spheres are autonomous but overlapping, not entirely distinct but not completely merged either.

As this transformation takes place, there is a shift from bilateral to trilateral interactions, from single and double helixes to university-industry-government joint projects; like the land grant universities in the USA and the research schools programme in Sweden, where PhD candidates are moved into firms to do their dissertations and a firm's researchers are moved into universities to obtain higher degrees.

A typology of innovation systems incorporates various national perspectives. First, there is Triple Helix I, a statist triple helix in which the state encompasses academia and industry and directs the relations between them.

The second, Triple Helix II, a *laissez-faire* triple helix, consists of separate institutional spheres, where government, university and industry operate apart from each other. In this model, the university provides basic research and trained persons. It is expected that firms in an industry should operate completely apart from each other in competitive relationships, linked through the market. Government is limited to addressing problems that can be defined as market failures, with solutions that the private sector cannot or will not support.

Triple Helix III, an interactive model, consists of overlapping, yet relatively independent, institutional spheres.

Developed and developing countries both experiment with finding better mixes of functions and institutions in a triple helix of university-industry-government relations.

For example, academia plays a role as a source of firm-formation and regional development in addition to its traditional role as a provider of trained persons and basic knowledge.

Government helps to support the new developments through changes in the regulatory environment, tax incentives and provision of public venture capital.

Industry takes the role of the university in developing training and research, often at the same high level as universities.

Most countries and regions are presently trying to attain some form of Triple Helix III, with university spin-off firms, trilateral initiatives for knowledge-based economic development and strategic alliances among firms (large and small, operating in different areas and with different levels of technology), government laboratories and academic research groups.

These arrangements are often incentivized (but not controlled) by government, whether through new "rules of the game," or through direct or indirect financial assistance.

A laissez-faire triple helix, in the USA and Canada, is typically based upon a "university-pushed triple helix", which may emerge in quite different circumstances, as case studies of MIT and Stanford University show.[3]

New England had a strong industrial foundation in the late 19th century; whereas the Bay Area, around Palo Alto, lacked an industrial base. Both of these universities were successful in initiating new regional industry and innovation, making the university a leading power in economic and societal innovation. On the other hand, a government-pulled triple helix in China exemplifies a statist model in which government operates as an organizer and initiator of innovation.

Government role

A triple helix based on university-industry-government interaction emphasizes the relative independence between university, industry and government. However, the triple helix model in China is quite different from the one in North America. On the one hand, neither the university nor industry sector is strong enough to become the organizer of regional innovation. On the other hand, the ownership relations among university, industry and government mandate that only government can become the organizer. Thus, government pulls the other two spheres to achieve regional innovation.

A rapidly growing public university system forms the basis of a government-pulled triple helix in China. While there are merging trends in recent years, the number of universities went up from 1,071 in 2002 to about 1,794 in May 2005. This figure includes 13 universities in Hong Kong and Macao. Among the total 249 private universities, only 25 can provide Bachelor degrees; the others are a step below this level. None of the private universities have a graduate programme. Obviously, the private academic sector is weak and at a lower level than the public.

In this top-down university system, research activities and university research enterprises (UREs) are almost entirely controlled by the central government. The 36 institutions ranked as "research universities" in 2006 are among the 72 universities affiliated with the Ministry of Education.

A state industry system is the other leg of the government-pulled triple helix model in China.[4] Although China has tried to transform from a planned to a market economy since 1978, governments - central, province and local - have tremendous administrative control.

Private enterprises are increasingly significant as an economic factor, but the public-owned system retains a dominant position. Even the "private enterprises" are quite different from the private sector in capitalist countries, since government agents still oversee market dealings, and executive intervention plays a very important role. Social activity still embodies the state's will, and more often than not, only the top leader's ideas.

The USA can be considered as the typical laissez faire triple helix regime. There is a strong focus on voluntary organizations and foundations filling the gap between government and the private sector, rather than the institutions themselves being expected to take on additional responsibilities, at least at the first instance.

Thus, initiatives tend to be bottom-up, with government becoming involved later, when the need for generalization is both obvious and politically feasible. Thus, the land grant academic model that originated in Connecticut in the 1830s was expanded with federal government support in 1862, after states rights advocates (who strongly believed in a limited role for the federal government) had left the Congress.

In the *laissez faire* model, the spheres are supposed to be separate from each other. In the USA this separation was reinforced by a legal decision in the Dartmouth College case that occurred in the early 19th century. The Board of the college split into two groups in a dispute over the direction of the institution. The new group that took over wanted to change the purpose of the university. The old group held to the original purpose.

The USA is a litigious society so the dispute ended up in the courts. The Supreme Court ruled that once the state had given out a charter to the university it could not go back and change it again.

This, in effect, meant that once an organization was set in motion, the power of the state to intervene was severely limited. Although this decision was originally made with respect to a university charter, by precedent it was extended to industry. Thus, corporations were given great legal latitude and their independence and autonomy was reinforced by this legal process.

Under *laissez faire* conditions relations among the institutional spheres tend to be indirect, going through one sphere to reach another that is ideologically precluded from dealing with it directly. For example, when government wants to act or reach industry in the USA, except in times of great national emergency, it cannot do so directly. During the economic downturn of the 1970s, there were proposals for reindustrialization, for government to become directly involved in aiding existing industries and building up new ones, but these were quickly defeated.

It was at this point that the patent system was reorganized to give the patent rights from federally funded research to the universities, with the condition that universities had to take steps to put them to use. Government revised the relationship of universities to industry by using the carrot of the research funding system, a government-university relationship that had grown greatly since the second World War, which required that funds provided to universities through the peer-review research system also had to be involved in a technology transfer system. Thus, the technology transfer models that had been invented at MIT early in the 20th century, but had only been utilized by a relatively few universities until that time, were diffused throughout the research university system after 1980.

University-pushed model

Founded in the mid-19th century, MIT was the first entrepreneurial university. It drew for its development upon various streams of academic formats invented in, or imported into, the USA during the early and mid-19th century, for the purpose of establishing a close relationship between the university, technology and the economy, initially in agriculture and then in industry. MIT as a research university primarily balances teaching and research but, as an entrepreneurial university, adds the task of economic development and maintains these three academic missions in a creative tension with each other.

MIT also exemplifies a creative synthesis of academic research formats based upon contrasting models of innovation.[3] In the 1930s, it played an important role in the regional development of New England, in renewing existing, and creating new industries and technologies. Led by President Karl Compton, MIT proposed a strategy of forming new firms and pushing technology, industry and economy foreward by using the university's research.

According to the BankBoston Report (1997)[5], if the companies founded by MIT graduates and faculty formed an independent nation, the revenues produced by the companies would make that nation the 24th largest economy in the world. The 4,000 MIT-related companies employ about 1.1 million people and have annual world sales of $ 232 billion. That is roughly equal to a gross domestic product of $ 116 billion, which is a little less than the GDP of South Africa and more than the GDP of Thailand.

The MIT model was introduced by Frederic Terman to Stanford, encouraging the rise of another entrepreneurial university and the emergence of Silicon Valley as a leading high-tech region. In subsequent decades the entrepreneurial university/regional innovation model spread to other regions with universities that have attempted, with more or less success, to replicate the MIT and Stanford examples. Formerly these successes were taken to be unique instances; however in recent years the elements of building an entrepreneurial university and a high-tech region have become increasingly transparent and thus amenable to replication.

Catholic University of Leuven

Another example of entrepreneurial university, very much inspired by the MIT model, is the Catholic University of Leuven (K. U. Leuven) in Belgium. Located in Flanders, the Dutch-speaking area in the north of the country, K. U., Leuven is the largest Belgian university, with over 30,000 students and over 8,000 staff, of which almost 4,500 are researchers. The university is a member of the League of European Research Universities (LERU), a group of 20 European research-intensive universities committed to the values of high quality teaching, within an environment of internationally competitive research. It is structured in 14 faculties, 50 departments and about 240 subdepartments, and spreads over four campuses in Leuven and its suburbs (humanities, biomedical sciences and exact sciences, and one undergraduate campus).

K. U. Leuven is a private institution, but receives 85 per cent of its budget from the Belgian Government, both in a direct and an indirect, competitive way.[6] Over the last decade, it recorded the highest research expenditures among Flemish universities, with values steadily increasing from year to year (• 230 million in 2005). Of the total research budget of the university, 55 per cent is channelled to research in the exact sciences, 25 per cent in biomedical sciences and 20 per cent in the humanities and social sciences.[6]

A key factor in K. U. Leuven's successful transition to an entrepreneurial university is its technology transfer unit - K. U. Leuven Research and Development (LRD) - in charge of all aspects of commercialization of research results and science-industry interface: contract research, patents, licences, spin-offs, science parks, etc.

Since its inception in 1972, LRD has played an essential role in the development of entrepreneurial capabilities within the university, exerting an important learning effect for several generations of faculty and researchers, who have evolved in their careers alongside, and often based on interaction with, LRD.

The LRD organizational structure is based on the concept of research divisions (or research groups), consisting of university researchers (professors and senior/junior researchers) from different university departments or even different faculties, who work together to integrate their different partnerships with industry in a research division at LRD.

At present, there are 42 LRD research divisions, staffed by about 220 faculty members and 480 researchers, active in engineering (54 per cent), biomedical sciences (24 per cent), bio-sciences (9 per cent) and sciences (7 per cent). The humanities and social sciences, although under-represented, have increasingly developed their entrepreneurial activities within LRD in recent years. Contact between LRD and the research divisions is ensured by a group of "innovation co-ordinators", working partly for LRD and partly as researchers or junior faculty members within one of the LRD divisions.[6]

Although fully integrated into the university structure, LRD enjoys a large budgetary and human resource autonomy, which allowed a much higher degree of flexibility and freedom than in other units covered by 'traditional' university administration. This has worked as an important incentive for the research staff of LRD divisions.

This autonomy, reflecting the combined academic and business managerial approach of LRD, is in significant contrast to other Flemish universities, which manage technology transfer, patents, spin-offs and collaborative projects with industry through 'regular' university administration. The different organizational modes reflect the different approaches taken by Flemish universities in the construction and development of interface services, a concept based on the February 1995 Decree of the Flemish government, which was meant to stimulate university-industry-society exchanges.

The 'research division' concept created an interdisciplinary matrix structure within the university, based on the coexistence of a double reward and incentive system. Research excellence and teaching ability are rewarded through the hierarchical lines of academic promotion in their respective faculty and university departments, based on research quality and teaching performance.

Entrepreneurial excellence is rewarded through the LRD incentives of budgetary flexibility and financial autonomy of the research division, as well as through financial incentives for individual researchers. These come as salary supplements resulting from participation in contract research, consultancy and licensing agreements; and participation, both intellectually and financially, in the university spin-offs.

LRD divisions have complete autonomy in managing the revenues from their entrepreneurial activities and are entitled to accumulate financial reserves based on the benefits generated via these activities. This is quite a unique situation, compared to other universities, which usually centralize the benefits resulting from university-industry linkages.

In pursuance of its mission to promote wealth creation through technology entrepreneurship, LRD has developed a broad range of advisory, co-ordinating, administrative and clearing services that made it a trendsetter for academic entrepreneurship in Flanders and abroad. These include:

- Contract research: Professional advice is provided both to determine opportunities (innovation advice and technology brokerage) and to negotiate and elaborate research agreements (definition of workplan, pricing, intellectual property rights, etc.). This is the oldest and most profitable activity, providing, for instance in 1999, about 24 per cent of the university's R&D budget.[7]
- Intellectual Property Rights management: An active patent and licensing policy is pursued to generate additional funds for further research. In 1999, an internal Intellectual Property Liaison Office, a patent fund and a network of formal collaboration with European patent attorneys were created.

  At the end of 2003, the university patent portfolio comprised about 171 patents (granted and pending applications), which met LRD 'selectivity' standards for developing a pool of scientifically and technologically valuable expertise. This activity is supported by a full-time in-house professional staff, assisted by a patent attorney.[6]

  K. U. Leuven ranks first among Belgian universities and research institutions in terms of EPO patent applications during 1995-1999, and second in terms of patent applications per research personnel.[8] In terms of USPTO patents, K. U. Leuven ranks second, after the Inter-university Microelectronics Centre (IMEC) (*Source: INCENTIM, 2002*).
- Establishment of new research-oriented and innovative spin-off companies: Professional advice (assistance in business plan development, formalization of cooperation agreements, staffing policy, accounting, etc.) and support, as well as access to venture capital - through the Gemma-Frisius Fund K. U. Leuven; and accommodation in the Innovation and Incubation Centre and Science Parks is provided to entrepreneurs who want to set up a new, research-oriented business that makes use of the university's knowledge or technology.

  LRD manages two Science Parks, which form a real "Technology Corridor", accommodating tens of high-tech companies active in ICT, biotechnology and the development of new materials, as well as venture capital and legal support firms. LRD currently co-ordinates 58 spin-offs active in several fields, ranging from ICT, mechanical and electrical engineering and microelectronics, to data processing, medical and pharmaceutical products.

  The variety of activity domains has been a deliberate strategic option to ensure a broad range of competencies and cross-fertilization for innovative entrepreneurship. However, a higher concentration of activities in ICT and business and engineering counselling became more visible in the 1990s, due to IMEC's presence and the successful development of some early university spin-offs active in ICT.[9]

  The LRD approach in managing academic spin-offs consists of a close collaboration between entrepreneurs and scientists, with thorough negotiation of the intellectual property and analysis of the 'freedom-to-operate', followed by strong support to the development of a business plan. Once the spin-off becomes operational, LRD keeps a position in the company Managing

Board, irrespective of the shareholder structure of the Board. The LRD model has been closely followed by other Flemish universities, but on a smaller scale. Another significant difference between K. U. Leuven and other Flemish universities lies in their different contribution to the spin-off start capital, which is much higher for K. U. Leuven spin-offs than for other universities.

- Promotion of high-tech entrepreneurship and innovation by stimulating networking initiatives, such as Leuven.Inc (Leuven Innovation Networking Circle), and technology clustering, such as DSP Valley and L-SEC (Leuven Security Excellence Consortium).

  Leuven Inc. is a specific element in LRD's management of spin-offs. This is a non-profit organization founded in November 1999 by LRD in partnership with Arthur Andersen, IMEC and two major Belgian banks, and in collaboration with the Cambridge Network. It was designed as a pivotal element for networking LRD with academic spin-offs, the local business community and the international community, for stimulating local prosperity and the growth of knowledge-intensive companies in the region.

  Its main target was to stimulate the sharing of business experience between its members - over 20 academic research groups, entrepreneurial start-ups, established local companies, etc., through a series of events directed at informal networking, such as the 'Gemma Frisius Investment Forum', Entrepreneurs' Cafés, Roundtables, Info Sessions, Visionary Workshops and keynote seminars.

This wide array of activities, developed over 30 years of existence, illustrates LRD's search for the "right mix of context, structure, transfer and innovation mechanisms" that universities need in order to become significant players in managing entrepreneurial activities.[7] Influenced by a complex range of factors, from local academics' initiatives to economic and policy factors at the regional and national level that supported innovation and knowledge-driven entrepreneurship, LRD structure and activities provide a good example of the way in which triple helix interactions work in real-life.

The **university** factor has been an important one since LRD's inception in 1972. In the early years, in the absence of an explicit regulatory framework for entrepreneurial activities elaborated by the government, entrepreneurial activities at K. U. Leuven were driven by the personal initiatives of some academics, usually with previous training in US universities or companies and thus more familiar with entrepreneurial practices.

They created the first LRD divisions as a means to develop contacts with the private sector based on their own skills and experience. Due to a sustained learning process and consolidation of research experience and managerial skills, many early LRD divisions not only experienced a successful evolution - remaining up to the present time among the most productive research groups - but also encouraged the development of new collaborative projects and the creation of new LRD divisions. Later on, starting in 1997, university support became much more important, materializing into incubation facilities, business counselling, networking opportunities, etc.

The **government** factor became more explicit only from 1987 onwards, with the adoption of several regional and federal measures for establishing an innovation and entrepreneurship framework. These measures targeted not only academia but also industry, through IWT - the central organization of the Flemish community in charge of implementing policy instruments for R&D, technology and innovation in companies.

The collaboration between LRD and IWT is also suggestive of triple helix interactions: the permanent chairmanship of IWT has been held since 1999 by a K. U. Leuven representative - the Managing Director of LRD - while several academics participate in IWT expert groups and the IWT Board. On the other hand, IWT acts for the implementation of government policy by developing a whole set of regulations regarding the co-operation of companies with academic research groups.

The **industry** factor is also very important. R&D collaborations of Belgian firms are primarily oriented to Belgian universities, followed by foreign companies and foreign customers, which can be explained by the significant presence in the country of foreign multinationals that are willing to share with universities the increasing costs and risks of performing basic or pre-competitive R&D activities, and the need to develop links with foreign customers in order to access new markets.[10]

From a regional perspective, universities appear to be the most important partner for R&D collaborations in Flanders. The relatively greater involvement of large foreign multinationals with high R&D potential in collaboration with universities, compared to the small R&D-intensive firms (often technology-based university spin-offs), also reflects new trends in the international diffusion of university research (mostly in its basic research aspect); an accelerated internationalization of basic research benefits; and insufficient exploitation capacity of domestic companies or inadequacies of local economic or innovation policies.[11]

The LRD case shows that entrepreneurial academics have not only benefited from the innovation measures adopted by the government, but also, in many cases, have played a catalytic role in their adoption. This synergy is explained by the central position of LRD within a complex web of social, cultural, political and economic interactions, which illustrate the co-evolution of academic and industrial R&D under the impact of government policies.

Laissez faire triple helix

In a *laissez faire* model with strong boundaries, institutional spheres are strongly believed to have a single purpose. Organizations within each sphere are expected to remain within their respective boundaries.

Thus it is held that universities should focus on knowledge production; while patenting and licensing of technology is believed to be an appropriate activity of the industrial sphere, extraneous to the purpose of the university.

In the *laissez faire* triple helix, relations among the spheres occur indi-

rectly, with one sphere influencing another to affect a third sphere.

This indirect approach leads to hybridization as the elements of two spheres are combined to create an organizational mechanism to affect the third sphere. Thus the dictum of functional differentiation, that no system can function for another, is superseded.

University of Saskatchewan

The University of Saskatchewan in Canada is one of the key actors in the transition from a *laissez faire* to an interactive triple helix. It houses the second largest research park in North America - Innovation Place - and is home also to the only national synchrotron facility in Canada. Complementing the research commercialization and technology transfer activities of its research institutes and centres are the translational research activities of other academic faculty. In a 2001 survey, it was found that, between 1990 and 2001, there was a significant increase in the formation of university spin-offs. In 2001, there were about 33 University of Saskatchewan spin-off companies. As many as 64 per cent of spin-off companies were created in the 1990s. Of the 33 spin-off companies, 55 per cent are based on research activities in the Life Sciences, 30 per cent on the Physical Sciences and 15 per cent on Information Technology.[12] The 33 spin-off companies together employed about 1,400 people and contributed over $ 190 million to the economy of Saskatchewan in 2001.[12]

Though links between universities and industries go back to the 19th century, there was no coherent policy and effort at that time to explore innovation. As a result, the various institutions were left on their own with no real science and technology policy.[13] While there was some informal fostering of free exchange of expertise among different sectors through government initiatives,[14] the lack of bottom-up science initiatives and policies, such as the one University of Saskatchewan has put in place through its integrated plan, tends to hinder the development of an interactive triple helix model in Canada.

However, the move from *laissez faire* to a coherent triple helix began when the federal government solicited the help of the University of Saskatchewan in its search for a solution to the disease of wheat rust, which between 1916 and 1930 was costing the provincial economy about $ 25 million in losses per year. In addition, the university's alumni and Chemistry Nobel laureate Thauberger Thorvaldson helped addressed the corrosive effects of alkaline groundwater on concretes, especially in a prairie setting, through the development of a sulphate-resistant concrete.[14] While direct private sector involvement in research was virtually non-existent at this period, what did emerge was the support of umbrella organizations and industry-surrogate sponsors.[14]

With the increasing shift in the global economy to the organization and management of scientific innovations,[15,16,17] the University of Saskatchewan has taken on a primary role in re-energizing economic growth and development. The University's drive to be the research hub of Western Canada has propelled innovation as the prime mover of Saskatchewan's economy. This is reflected in the transformation of the university from an ivory tower institution into an entrepreneurial university. The University has grown from just one college building into a home for more than 70 research centres, institutes and facilities.

Role in regional innovation

The University of Saskatchewan has Western Canada's only College of Veterinary Medicine. One of the success stories of the university in making the transition from largely *laissez faire* to entrepreneurial university is the formation of a not-for-profit organization called Vaccine and Infectious Disease Organization (VIDO). This quasi-firm has established strong linkages with industry and government research agencies and has been spearheading the university's transformation as an entrepreneurial university.

Under its former director, Dr. Stephen Acres, VIDO developed the vaccine Vicogen™ to protect against *E. coli* K-99 enteritis. Protection against rotavirus and corona virus was soon added to make a multi-component vaccine for the control of calf scours, Ecolan-RC™. As VIDO developed a variety of infectious disease products, it spun off a start-up company, BioStar, which was successful in raising approximately $ 25 million of venture capital to further develop the products arising out of the centre's research efforts.[18]

With advances in biotechnology and other generic technologies, this quasi-firm developed the world's first genetically engineered vaccine for an animal species and as a result of its continuous research excellence, it has been awarded more than 70 patents, with 25 pending.

In addition to developing vaccines, the centre is also active in the transfer of research to benefit society through its work with various management and agricultural organizations. The centre's research has led directly to economic diversification through the establishment of value-added agribusinesses. This research institute has directly created three spin-off companies (BioStar Inc., BioWest, and StarBiotech), and has assisted other start-ups that became successful.[18]

In light of its success, the University is now home to Canada's first synchrotron - a modern, $ 174 million scientific project that, in addition to other university-based research incubators, has the potential to make Saskatchewan a science hub. The synchrotron facility will not only attract large corporations, top-notch scientists and students, but also further the university's role in regional economy growth and development renewal.

In furtherance of its economic development mantle, on 4 February 2004, the University announced a $ 500,000 investment in new entrance scholarships. Funds for these new scholarships came from revenue generated by the retail land-grant development known as the 'Preston Crossing'. This is a development based on the lease of land to retail chains to locate in a one-stop shopping area.

A similar initiative at Stanford used some of the university's extensive land holdings for a shopping centre in a burgeoning suburban region that was emerging adjacent to the university in the 1950s, providing funds to expand the university's research and educational capabilities.

While the economic impacts of these developments are ongoing, university-industry-government relations in terms of promoting the commercial viability of research holds the key to regional economic development and redevelopment of the province of Saskatchewan. In a recent in-depth interview, a professor said that the "implications for academic research could not have been clearer. The university-based science park and the synchrotron were not located on campus to perpetuate the ivory tower function of the university". They were meant to create the "opportunity to gradually grow out of the university-based labs... to get academic research commercialized".

Another professor added that university-industry-government collaboration "reduces the barriers, makes it easier, and is critical if you want to achieve the highest level of possible activity".[19] From a very small agricultur-focused university, the University of Saskatchewan has a significant role in the development of a coherent triple helix policy in Canada. The university has systematically transformed itself into an entrepreneurial university while still performing its core traditional functions. Government's role, although limited to incentives and support, was critical to the triple helix transition.

Statist triple helix transition

The statist model typically tried to coordinate multiple functions through central planning and coordination mechanisms. This is the model of the former Soviet Union, but it can also be found to some degree in various European and Latin American countries. France traditionally exemplified a strong version of this model, but is now in the process of devolving some of the powers of the central government to regions. The Chinese "government-pulled triple helix" exemplifies the statist transition process.

Following the Soviet model, ever since the 1949 establishment of the People's Republic of China, and right until 1978, universities in China mainly engaged in teaching. Research, especially for the military, was primarily carried out by research institutes separated from university and industry. Since the first National Conference of Science and Technology held in 1978, and especially from President Deng Xiaoping's 1985 statement that "science and technology is the first force of production", universities started to engage in regional economic development. This direction was recently reinforced by President Hu Jintao's directive, at the second National Conference of Science and Technology in 2006, to build an innovative society.

As for industry, it had to pay more attention to reforming ownership under the influence of a "following strategy", rather than encouraging innovation. The performance of enterprises is predominantly influenced by government, including those firms that have been transferred to private owners.

In China, university and industry, as innovation triple helix actors, are pulled or controlled by government. A problem with this model is that government does not have an innovation mission directly nor a limit on ownership of the enterprises that it creates. However, in January 2006, at the National Science and Technology Conference held in Beijing, government emphasized industry as the main actor of innovation and indicated that the university should contribute to innovation, especially industrial innovation.[20]

Development in Liaoning

At the very beginning of New China as an industrial area, Liaoning Province produced the first furnace steel, the first large-scale electricity transformer, the first jet plane, the first 10,000 mt Chinese-designed ship, the "new pattern" locomotive, etc. However, the region has not adapted to new technology. For example, chemical heavy engineering still accounts for 75 per cent of Liaoning product structure. Most industries and products are traditional low-tech. From an economic growth standpoint, this represents high investment, high consumption of resources, but high pollution, low output and low efficiency.[21]

From 2000, policies of the Liaoning Province Government[d] provided the goals and action guide for people. For example, in the Action Outline on Renewing Liaoning, the government proposed to promote one or two high and new-tech developed areas from province to national level, and every one of the 13 cities must have such an area. Government also supports a university-industry link through policies and laws. For example, in 2001, the central government decided that the top university of the province, Northeastern University, should be jointly led by the Ministry of Education, the Educational Office of Liaoning Province and the Educational Bureau of Shenyang City.

In this way, management power was decentralized from the Ministry of Education. As a result, increasingly close cooperation between university and industry has improved local new technology development and industry formation at a surprising speed.

The university is encouraged to serve local innovation in three ways: providing entrepreneurship courses; helping industry resolve problems or jointly establishing some R&D centres with it; and supporting university-run enterprises (UREs), especially from the research in its labs. Industry is encouraged to rely on university research to achieve new technological innovation and products. The provincial government also tries to build a platform for enterprises to access universities, by directly supporting university and industry through making financial resources available to them. Moreover, government plays an important role in regional innovation through building a Science and Technology Development Zone, a Technology Market, a platform for an information service and a network for large instrument use, which attracted over 100 institutes, universities and enterprises to participate.

The future of the triple helix

The triple helix concept arose from an analysis of the university-industry double helix, and the realization that government was an essential part of the innovation equation, even when it was either suppressed for ideological reasons or given too great a weight due to political exigencies. The university, the key institution of knowledge-based societies, can be replicated and expanded more easily and quickly through knowledge transfer, than the industrial

factory system, which is dependent upon physical technology transfer. The spread of knowledge-based innovation collapses the time frame of the first great transformation, measured in centuries, into mere decades.

Why did a university-pushed triple helix emerge in the USA, where the university is not only an actor, but also a good organizer in innovation? Firstly, university is stronger than industry and government in producing novel knowledge and forming new platforms for science-based industries.

In the USA, it is unacceptable for the government to participate directly in industry, except for war-time emergencies or a peace-time equivalent, such as the threatened loss of the semiconductor industry of Japan in the 1980s.

Secondly, the science policy, driven by Vannever Bush's *Endless Frontier* report, has greatly helped university development during the last 50 years. Research results continuously spill over from the university, assisted by various public and private programmes and university initiatives. Public venture capital in the guise of federal programmes, such as the Small Business Innovation Research Program (SBIR) that support basic research with commercial implications; state government programmes that may support commercialization and firm formation more directly; and university technology transfer offices that provide assistance in firm formation and licensing are elements of a meta-innovation system that bridges the so-called "valley of death" from lab to market.[1]

Thirdly, government does not have to make money directly; therefore, there is less stress on its officials than in China. In the end, industrial innovation pays more attention to product development rather than basic research. However, breakthroughs from basic research can result in significant innovation, forming new firms and industries. This is the most important advantage of the increasingly central role of the university in technological innovation.

A government-pulled triple helix has the following characteristics:

- Government initiates and controls significant projects for social innovations;
- All or most research universities, key research institutes and large-scale enterprises are affiliated to (central or local) government;
- The top leader's thought gives direction to all of the country (party and government); and government policy and resolution are the batons to carry out the leader's will;
- Government organizes primary innovation agents, such as high-tech development zones (including science parks and incubators), markets for technology and intellectual property, and an information network.

A government-pulled triple helix has advantages and disadvantages. The advantages include, but are not limited to:

- More easily achieving large-scale innovation projects;
- Reorganizing regional innovation resources and filling gaps necessary to assist innovation in a region;
- Forming consensus in regional innovation;
- Artificially fostering university-industry links by government authority;
- Protecting university interest in entrepreneurship through policies; and
- Organizing activities more conveniently and building innovation platform within the region.

Disadvantages include, but are not limited to:

- University-industry joint innovations tending to be "shows", rather than real ventures - after all personnel, equipment and funds in the two parties are both from the state;
- University and industry possibly losing the flexibility to deal with problems in the innovation process;
- The two parties relying excessively on government, resulting in passivity and inertia;
- Financial burden on government becoming excessively heavy, as university and industry cannot play any significant role in knowledge production and technology innovation; and
- The government's needing to "pull" university and industry forward.

An active civil society is the key element that characterizes a fully functioning triple helix. In the statist model, civil society is often actively suppressed; and in the *laissez faire* model, it is relatively inactive. The triple helix does not operate at its full potential as a top-down model. A triple helix coordinated entirely by the state only provides a limited source of ideas and initiatives, from only one place in society. On the other hand, neither is a *laissez* faire linear model tenable. For the triple helix to operate fully, there must also be initiatives arising bottom-up and cross-ways from the various institutional spheres.

An assisted linear model of organizational, as well as technical, innovation embedded in a flourishing civil society is the objective. Although Agnes Heller[22] argues that there is a universal movement in this direction, the emergence of civil society is usually the outcome of a struggle with proponents of previous helix models and collaboration among actors seeking an enhanced version in which all partners have a say.

The thesis of national innovation systems has its counterpart in national traditions of science, that distinctive formats can be identified within the boundaries of a nation state. Nevertheless, just as science as an **international** phenomenon has outweighed national variants, the triple helix of university-industry-government relations is emerging as a common format that transcends national boundaries.

This means that, not only do universities play their traditional roles but also they take on some of the roles of other institutional spheres, such as the role of the entrepreneur, in helping to see that knowledge is put to use; both by establishing organizational mechanisms to transfer knowledge and technology and by playing a strategic role in regional innovation.

As the university takes up this new role in promoting innovation, it becomes transformed as well. As firms take their new role in continually adapting and raising their technological level, they become a bit closer to what a university does. As government plays a role as public entrepreneur it becomes a bit more like the industrial and academic spheres in realizing the importance of knowledge in creating this new economy and new society.

These innovations originate in local, regional and national contexts but they are soon globalized, reinterpreted and applied in other contexts. Such organizational innovations to enhance the utilization of knowledge in society represent an endless transition, since they are always subject to revision to take into account changed circumstances and new opportunities. Already under way from the mid-20th century, the triple helix of university-industry-government interactions constitutes the second great transformation.

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Footnotes

a. Triple Helix VI, "The Entrepreneurial University" organized by the Entrepreneurship Centre of the National University of Singapore, May 2007, is the first to be held in Asia. Please check www.triple helix65.com for further information.

b. Triple Helix Group, Newcastle University

c. We refer to University rather than Academia since the latter term is sometimes also utilized to include more specialized organizations such as research institutes which may be located in government or industry as well as the university. We focus on universities as the generative source of the triple helix of innovation due to their special characteristics such as human capital flow-through and multiple missions for education, research and economic and social development.

d. These Resolutions include: Resolution on enhancing Technological Innovation to Develop High-tech and Achieve Industrialization; Regulations on advancing Enterprises' Technology in Liaoning Province; Administering Measure to Develop New Products in Liaoning Province; Resolution on accelerating Non-government Economy; Implementing Notion on encouraging and promoting Middle and Small Enterprises of Liaoning Province; and Action Outline on Renewing Liaoning as an Old Industry Base. ❐