The Future Location of Research and Technology Transfer

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ABSTRACT. The triple helix model of university-industry-government relations is explicated for the transfer of technology. Drawing upon a broad range of international instances, the stages and phases through which the institutional spheres most relevant to innovation are drawn into a more productive relationship are discussed in comparison to alternative models.

1. Introduction

Innovation is a complex and dynamic process that moves ever closer to the center of the political arena. For example, to better position Vice President Al Gore for the 2000 presidential election, several technological and environmental initiatives were included in proposals for the 1999 US federal budget (Davis, 1998). In the European Union, the subsequent Framework Programs have focused on research, technology, and development (RTD) networks for reshaping relations in terms of S&T policies among the member states. Moreover, the Framework Programs have shifted from a specific attention to particular technologies, such as land and air transportation vehicles, to a broader focus on enabling technologies, e.g., the "European Information Society," thus intersecting with the US information superhighway (IRDAC, 1997).

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Even as programmatic visions converge, the policy dimension broadens as global rivals pursue similar economic, social and sustainable development goals in a dialectic with each other (Plonski, 1993). Technical change, a seemingly autonomous process, is reformulated as innovation (Fusfeld, 1986). Consequently, the interface between basic science and product development increasingly includes aspects of the social sciences as awareness grows that social, as well as technical, innovation is embodied in new technologies such as the Internet and WWW. It is no longer an anomaly that social scientists are recruited to design teams, beyond those of a few leading edge innovation centers such as Xerox Parc and Bell Labs. Innovation within product and process development as well as the innovation process itself has given rise to new interdisciplinary practical disciplines such as the Management of Technology.

As innovation policies developed since the 1970s, the subject has also been theoretically reflected upon by historians of science and technology (e.g., Rosenberg 1976), economists (e.g., Nelson and Winter, 1982), policy analysts (e.g., Rothwell and Zegveld, 1981) and interdisciplinary scholars (e.g., McKelvey, 1994). Gradually, the linear models of technology push and demand pull have been replaced by non-linear ones, with lateral feedback mechanisms operating on intermediate levels in either direction as well as from each end of the process (e.g., Leydesdorff and Van den Besselaar, 1994). In the following we outline a model for understanding and guiding these interactions: the triple helix of university-industry-government relations. The articles in this special issue analyze some of the non-linear innovation dynamics that have emerged world-wide in recent decades.

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2. The systemic substrate of the triple helix

The future location of research and technology transfer reside in a "triple helix" of university-industry-government relations that play off a set of technological sub-dynamics. Taken together these two levels constitute a "socio-technical world." The institutionally realized and the potentially realizable goals within each level mutually influence each other in the course of invention, innovation and policy implementation.

New combinations and recombinations of technological and organizational innovations arise from the creative friction between institutional spheres and technological systems. Although earlier adumbrations were, of course, drawn upon, the computer as a functioning instrument was created from a confluence of military, industrial and academic interests during the Second World War (Flam, 1988). The discipline of computer science was created during the post-war, to more fully understand and realize the potential of the device. The new field arose from a synthesis of elements of different disciplines, including applied mathematics, electrical engineering, psychology and philosophy. More recently, new recombinations have been created between computer science and moleular biology and between aspects of electrical engineering, computer science and mechanical engineering (mechatronics).

Socio-technical worlds: industrial, post-industrial, and information eras succeed each other in an ever more rapid progression that is increasingly non-linear as the possibilities for intersection and recombination grow apace. The non-linear models themselves are complex because several sub-dynamics have to be distinguished. First, innovation is taking place within an economic context. But what should be considered as the relevant markets? Part of the literature has focused, for example, on "national systems of innovation" (Lundvall, 1988; Nelson, 1993).

However, technologies and markets operate globally, and from this perspective national systems are just one among various relevant levels of control (Leydesdorff and Etzkowitz, 1998). Thus, the regional level has become increasingly important in Japan, the US, Latin America, and Europe (Scott, 1993). Typically, in the US the regional (state) level operates in tandem with the national (federal) level, with initiation alternating between the two levels (Eisinger, 1988; Osborne, 1988). In Europe, especially, regional innovation systems have developed in tandem with the emergence of a multi-national system of innovation through the European Union (Braczyk, *et al.*, 1998).

A second sub-dynamic is the recursive one: evolutionary systems build on their previous states. Thus, technologies tend to develop along trajectories. However, there can also be radical changes between generations. For example, the trajectory of propeller piston engines (DC-3 to DC-7) was interrupted by the trajectory of turbofan jet airplanes (Boeing 700-series) forcing McDonald Douglas to completely revise its DC-8. Along each trajectory one can build on a dominant design (Tushman and Anderson, 1986; Anderson and Tushman, 1990). Design principles guide the trade-offs at the technology/market interface heuristically (Nelson and Winter, 1982; Frenken and Leydesdorff, in preparation).

Technological paradigms or regimes encompass technology/market combinations which may have been "locked-in" along trajectories over time (Dosi, 1982; Arthur, 1988). Thus, in addition to having a momentum of its own, an innovation system is thirdly interactive. Network studies of innovation focus on the interactive terms of the non-linear model. Hughes (1983), for example, studied the electrification of western society in terms of networks of power supply (cf. Callon *et al.*, 1986; Bijker *et al.*, 1987).

In short, three sub-dynamics have to be distinguished: the diffusion of technologies through markets, the history of technologies that propels the processes of change and restructuration, and the reflexive levels of control, including government and private enterprise. Each of the sub-dynamics is again complex in itself. For example, technological innovations tend not to come as a continuum, but in waves and clusters (Freeman and Perez, 1988). Both markets and governments can co-shape the technological developments in processes that may or may not co-evolve with each other. As between technologies and markets, trajectories may emerge in the interaction between national governments and large-scale technologies, for example, in the energy household (McKelvey, 1997). Lock-ins between nation states and market forces are typical of systems which are not paying sufficient attention to the dynamics of innovation.

3. Defining the triple helix

The triple helix regime operates on these complex dynamics of innovation as a recursive overlay of interactions and negotiations among the three institutional spheres. The different partners engage in collaborations and competition as they calibrate their strategic direction and niche positions. RTD projects have an increasingly limited time horizon before pay-offs are expected, but scope can be extended through partnerships (Gibbons *et al.*, 1994). Perceptions of each other's strengths and weaknesses can be improved by making them also the subject of systematic research. Meta studies of innovation and research management, as well as technical R&D, provide continuous updating about the corporate actor's own strengths and weaknesses and about relevant environments. Expectations and their interactions are thus increasingly the basis of a knowledge-based economy. The overlay reshapes the institutions in R&D-networks of university-industry-government relations since new technological and scientific options often require innovation in institutional arrangements and alignments.

The "triple helix" denotes that this social world is more complex than the natural one. Watson and Crick required only two helices to model DNA; three helices are needed to model university-industry-government relations. The triple helix model incorporates dynamic elements in cross-institutional activities. The institutional spheres of the state, the university, and industry were formerly separate entities that interacted across strongly defended boundaries. Increasingly, individuals and organizations are taking other roles than were traditionally allocated to them. For example, some academics have become entrepreneurs in forming their own firms. This results in a blurring of boundaries between academia and industry and an overlapping of the institutional spheres. Similar bilateral processes can be identified between industry and government and among the triad of university, industry, and government.

The triple helix presumes that the different spheres interact more intensively (Fig. 1). It is a

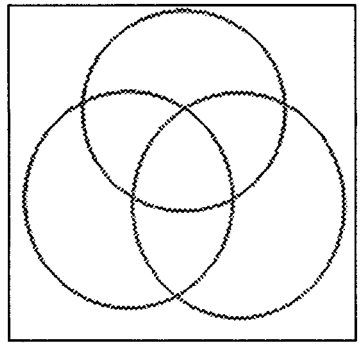
Figure 1. Three interacting spheres.

model in which the three entities are no longer non-intersecting, with relations across strongly defended boundaries. Nor, as in a Venn diagram in which one circle totally encompasses the others as in the Soviet Union where enterprises where subsumed within the state. Rather, the different institutional spheres retain a measure of autonomy even as they come under the influence of the other. Thus, governments may play a regulatory role in industry, even breaking up companies into constituent elements under certain conditions as mandated by anti-trust laws in the US without going so far as nationalization. The triple helix denotes this set of institutional relationships as interacting spheres, that overlap, as one sphere 'takes the role of the other' even as they retain considerable autonomy.

The various negotiations among the spheres operate on a roughly equal basis. Industry and government have traditionally been the leading institutions in advanced industrial societies and academia is moving up into this category, as more activities in both government and industry become dependent upon advances in knowledge. There is also more cross over and co-operation within as well as across institutional spheres, given both the increasing complexity of tasks and the rapidity of technical advance, for example, in generations of computer chips. Both R&D and marketing move into networks because individual companies can no longer perform all the work, even to bring many products to market. So they have to form partnerships within industry. Sometimes the research they need is longer term so that even if a government program just focuses on funding companies, the companies find that they have to give subcontracts to university researchers.

Similarly, in some newly emerging areas of science the time dimension is being collapsed (Narin and Noma, 1985). Whereas there were formerly generations between theory and invention, e.g., between Maxwell/Hertz and Marconi (Aitken, 1976), in some areas of research the time is now so short that it can be one and the same person as is commonplace in biotechnology (Orsenigo, 1989). When this time distinction is collapsed the researcher and the entrepreneur may come to be the same so that new arrangements have to be negotiated in which information can flow from a lab in the university to a company. A firm founded by a faculty entrepreneur may be capitalized in part by the university and so in each of these helices, in each of these spheres, we have a penumbra created in which the university is not only a teaching institution, or even only a research institution.

The university is also an institution in which economic development takes place in research groups, incubators, and science parks. Innovation also occurs in firms which are very closely tied to the university and that, to a certain extent, operate in academic modes. For example, advertisements in *Science* magazine offer positions as post-doctoral fellow in companies. That may seem strange at first but the ads are there and people apply for the positions. They expect and receive some of the same quality of life as in academia with respect to encouragement of publishing and attendance at scientific meetings. After a post-doctoral period of a few years, they might move to an academic position or they might stay in industry.

4. Resolving problems in the helix

Increasing interaction across the institutional spheres also opens up greater possibilities of conflicts of interest. Clearly one has different interests at stake if one is a teacher generating research and still others when one becomes an entrepreneur forming a business. The university may even become a partner in that business by investing, further complicating the picture. These are certainly conflicts that will emerge over how these relationships should be conducted.

In fact, the conflicts are a key indicator that a potential transformation in triple helix relations is at hand, even that one is in the process of creating new interfaces. Social change that challenges existing norms rarely takes place without resistance. Typically there is at least a rear guard action to defend existing normative structures such as for example the notion of the university as an "ivory tower" far removed from the productive sector. As relations move closer, those who wish to engage across institutional boundaries often come into conflict with those of their fellows who wish to remain apart. In the US such conflicts are typically formulated as "conflicts of interest and commitment." Without evidence of conflict, it is more likely that the spheres are operating at a distance.

Indeed, some analysts and policy makers view the institutional spheres of industry, government, and university as each having a separate and unique configuration, with little or no overlap of mission and activity. For example, one may defend the position that the university contributes to innovation in a subordinate role as provider of trained personnel and disseminator of knowledge through publication (GUIRR, 1996). Large firms are sometimes skeptical of a more direct role for the university in innovation as a creator of new technology and new firms. Not surprisingly, well established firms are opposed to encouraging the creation of potential competitors, at least until they find they can establish productive technology transfer relations with these new firms, up to and including acquisition and merger.

When "worlds collide" issues of institutional purpose, the utility and propriety of inter-institutional relationships come to the foreground. The issue is often debated in terms of the definition, ownership and sharing of "intellectual property rights." Over time, conflicts will be resolved either by restoring distance or by developing a new formula for closer integration of the spheres, typically through organizational and normative change. Disputes can be a productive indicator of change. The real issue is: what methods should be put in place to resolve conflicts once they come about since their creation is a predictable part of the process of change. Indeed, policy makers who wish to encourage innovation, want to learn not only how to resolve these conflicts, but also how to create them in order to encourage innovation through invention of new formats for technology transfer (Etzkowitz, in press).

For example, early in the twentieth century a series of conflicts occurred at MIT over faculty members consulting for industry. Typically conflicts within a sphere arise over new activities of some members at the interface with another institutional sphere, in this instance academia and industry. A committee was formed to resolve the problem. After considerable debate, a compromise was arrived at between the opponents and proponents of consulting. Professors were allowed to divide their time between industry and academia. They could consult one day per week, earning whatever they could. The rest of the workweek was to be devoted to the university. That is not to say that this rule was ever air tight but it meant that one could have a substantial involvement outside the university that was legitimate.

When such resolutions are not arrived at, individuals are left in a situation of uncertainty. For example, although academic-industry relations are officially encouraged, with offices established to link firms to the university, professors at Portuguese universities are sometimes unsure if it is appropriate for them to consult with firms or, if so, how much effort they should devote to external activities. The issues have not been debated publicly and rules have not sufficiently been devised to enable a division of responsibilities across institutional spheres. The lack of a conflict with opportunity for resolution and change has left a status quo relatively intact thus far. The Portuguese academic-industry relationship is at an early stage of development (Da Rosa Pires and De Castro, 1997).

Normative and organizational change do not always occur in tandem. There can even be a reversal in direction on one level as compensation for acceptance of change on another. For example, in Sweden the issues of university-industry-government relations have been aired in a leading newspaper. The debate featured letters signed by a significant proportion of the professoriat, challenging the validity of a "third mission" for the universities (Benner and Sandstrom, in press). A new government higher education policy, on the one hand, proposes to down play the "third mission" theme, also plans to turn over ownership of intellectual property rights from the individual faculty member to the university, thereby establishing a direct institutional responsibility for technology transfer (Sorlin, 1998).

The University of Tokyo has taken a step in this direction, through a group of professors who have formed a company to purchase and commercialize the intellectual property created and owned by faculty members. This is likely an intermediate step toward a new law that will restructure the relationship between faculty inventors, the university and government research funding agencies (Kneller, 1999). Indeed, the US went through such a transition, legitimating the emergence of helical technology transfer relations among the institutional spheres. Organizational experiments in technology transfer, undertaken from the early 20th century onwards, were rationalized and legitimated in the Bayh-Dole Act of 1980 (Etzkowitz, 1998). Nevertheless, the growth of academic technology transfer is still controversial and subject to skeptical scrutiny (Mowery, 1998).

5. Statist triadic models

In addition to interaction of relatively independent entities, there are other tri-lateral models for integrating the societal steering, production, and research functions. In one such format, the state encompasses industry and academia as a totalizing and controlling entity, whether it be in a strong version as in the former Soviet Union or a more modest version as in Latin America. Triadic models, in which the state subsumes the other spheres, are currently being displaced by the Triple Helix model of relatively independent spheres.

A theory of science-based innovation, the "scientific-technological revolution," was espoused in the Soviet Union and its satellites (cf. Richta, 1968; Nikolaev, 1975). However, disconnects existed between industry and research so that results were usually not transferred to the productive side. This was not because of a lack of relationships, both formal and informal, but because there was little need for innovation. Often, significant technical advances were accomplished, but political decisions were made not to put them into practice (Meske, 1996).

With the exception of military and space, the emphasis on quantity production meant that industrial research organizations merely had to produce the appearance of innovation. Actual change was too disturbing to the system of civilian production to be allowed until the system broke down through the weight of its stagnation and technological stasis, especially in comparison with the pace of innovation in the advanced industrial countries (Egorov and Carayannis, this issue).

In the post-communist era, the state is completely removed from innovation issues in some Eastern European countries in transition, reacting to past dominance. However, this is likely to be a temporary phenomenon. Such countries eventually find that idealized models of state abstinence are no longer practiced in bastions of laissez-faire ideology (Kuklinski, 1996). Nevertheless, statist triadic models are sometimes conflated or confused with the triple helix and it is important to distinguish between their key differences. For example, in the early 1990's, the leadership of the Romanian Academy of Sciences thought that it was impolitic to consider academic-industry relations as an innovation model since it was too reminiscent in its broad outlines of the previous communist system and could be interpreted as an attempt to return to the past.

Latin American innovation theorists and practitioners often looked to the Soviet Union for inspiration. Indeed, a significant number of technical personnel, not only in Cuba, received their advanced degrees in one Eastern European country or another and became experts in reverse engineering. Combining external information gathering techniques with close analysis of a product, this particular form of technology transfer offers a potent method of "catch-up," especially when international regimes of intellectual property protections are not accepted (Etzkowitz and Brisolla, in press).

According to the Argentinean, physicist and science policy theorist Jorge Sabato: when research and production are incorporated within the state it is expected that they should be well coordinated by virtue of this fact (Sabato, 1994). Nevertheless, Latin American countries such as Brazil and Argentina ran into problems with trying to create entire industries whole cloth behind protective tariff walls. While achieving some success, especially in mid-tech industries such as the automotive sector, a local computer industry could not keep up with the pace of technological change in the most advanced countries. Even the automotive industry stagnated with an existing technology, without pressure from external competition. Eventually, the gaps were too large to be ignored and autarchic policies broke down.

6. Niche formation

Regions and countries have to start by identifying niches in science-based industry to renew their economic and social development (Campodall'Orto, 1996). Vertical integration is increasingly difficult as an industrial strategy when technological innovation affecting each industry arises from an ever broader range of technical inputs, e.g., computerization or biotechnology. Under such conditions, an industrial sector or individual company requires a capacity to detect lateral early warning signals of relevant technological advance in apparently unrelated sectors, and ability to process such intelligence and arrange technology transfer. Even the largest companies no longer attempt to develop all their technology internally, but increasingly establish units to arrange joint ventures and collaborations with companies, universities, and government laboratories.

The end of technological autarchy and the effort to achieve self contained national innovation systems (the typical Cold-war configuration) is at hand. Even the US realizes that it cannot be at the forefront in every area of science. The new approach is to maintain involvement across the board and to select a relatively few strategic areas in which to concentrate resources. This is an obvious approach for small countries which must be forced to adopt such a strategy because they cannot hope to cover all areas. Nevertheless, until quite recently relatively small countries such as Venezuela supported basic research institutes that tried to maintain coverage across the scientific spectrum (Vessuri, 1998).

Concentration on "core-competencies" has become a national and corporate creed as technology overtakes land, labor and capital as the primary source of economic growth. With the downturn of oil revenues, IVIC (The Venezuelan

Institute for Scientific Research) has been forced to concentrate on its base, the sciences most relevant to the country's major natural resource, petroleum. Focusing local technical resources on innovation requires a new set of intermediary mechanisms to be constructed that do not assume technology transfer to take place merely by virtue of incorporation of industrial functions within the state (cf. Maculan and Zouain, this issue.)

Renewing existing strengths and nurturing new ones is a common basis for industrial policy, worldwide. For example, as research moves closer to potential utilization in Sweden, there is considerable and ever tighter targeting on a few areas, e.g., pharmaceuticals, software and some areas based on traditional industries such as engineering or natural resources such as wood. Is such an autarchic model viable for the future? One trend is for even the largest companies in small countries to merge (e.g., Sweden's Astra Pharmaceutics and the UK's Zeneca Ltd) in order to create a critical competitive mass on the European or international level. Of course, the criteria for sufficiency of national scale continues to grow (e.g., DaimlerChrysler) even as strategic goals become more tightly focused on global niches.

Finding an appropriate balance between the local and the global, between emphasizing existing industrial strengths and potential sources of future growth, is at the heart of contemporary innovation policy (Landes, 1998). The contradictions between these various sets of conditions and goals are especially apparent in older industrial and newly emerging regions, in countries in transition and in small countries. For example, startups have difficulty in expanding sufficiently in small countries and are felt not to be able to reach their full potential within national boundaries. Some new Swedish software companies are thought to have become stunted at the 20 employee level, given the scale of the national market. These various exigencies exert strong pressures toward establishing lateral relationships, both at home and abroad.

The simultaneous regionalization and internationalization of science and technology overcomes the contradiction experienced in Portugal, a downsized country that has accepted the loss of its last colonies. Even a small nation is under pressure to be involved across the board in all areas of science and technology. Prof. Jose Mariano Gago, Minister for Science and Technology expressed Portugal's dilemma, "A nation has to be concerned with supporting all areas of science; if not it is a region." On the other hand, "… if it focuses on regions, the effort could be too small to be significant" (Gago, 1996). For Portugal, combining its resources with those received from European Union structural programs has proved to be the way out of this dilemma.

7. Top down vs. bottom up

What is the appropriate balance between "top down" and "bottom up" modes of decision making in innovation policies and practices? Of course, there must be a basis for selection and there is always a question of how should that take place. Should the decision making process be bottom up: leave it to the market? Or top down: let government or large companies decide. Various formats of technology risk/reward analysis have been established to support both of these modes. These include the "due diligence" scrutiny of individual candidates for potential investment by venture capital firms, the formulation of "technology roadmaps" at the industrial sector level, and the use of Delphi and Foresight techniques for ranking choices and developing consensus within national innovation systems.

In between top down and bottom up, there is an emergent intermediate category exemplified by US government programs such as the Small Business Innovation Research Program (SBIR) and the Advanced Technology Program (ATP) of the National Institute of Standards and Technology. These programs have developed an approach to innovation policy that is in between top down and bottom up. Thus, they do not depend solely on proposals sent in for peer review within disciplinary areas nor are they entirely based on directives coming down from government officials. Instead, within general areas of technology, either pulled from critical technology lists or from phoning around, areas are found which are the basis of future economic development. On those topics meetings are called inviting representatives of industry, government and universities, people on that topic who wish to get involved on that issue (cf. Kobayashi, forthcoming).

At ATP meetings with representatives of academia, industry, and government, from particular technology fields, the question is: "What are the barriers to moving this technical area ahead and what are the possibilities for addressing them?" If a consensus develops that there is a potential area to which grant funding could usefully be addressed, then a "focused program" is announced. A middle level "meso" model is taking shape in between top down and bottom up approaches.

Nevertheless, even a bottom up model depends upon the workings of the interaction among the helices. A market economy is embedded in institutional structures and cultural values as well as rules and regulations instituted by government and guaranteed by legal traditions and an independent judiciary. The market as an allocation mechanism thus relies extensively on government for its legitimacy and efficacy. Similarly, there is increasing recognition of the necessity for a significant, but not totalizing role for the state in creating the pre-conditions for science-based industry as well as an awareness that government plays a strong, if not always obvious, role in science and technology policy.

When state structures are absent, other institutional spheres may play part of the role. For example, new regional universities play a quasi-governmental role in regions that either lack state structures or have gaps in their purview. Thus, the University of Aveiro in Portugal brings together representatives of local industry to help formulate an innovation strategy (Da Rosa Pires and De Castro, 1997), while the University of Massachusetts, Boston initiates programs to address environmental problems of Boston's waterways.

The emergence of the regional level in science policy is a significant development. Fifteen years ago it was almost unheard of to have science and technology policy at the regional level. Of course, it becomes an important factor, in part, because it is seen to contribute to the creation of jobs, an area in which regional governments in the US have traditional responsibilities. For that reason, countries such as France that have not traditionally had regional governments, created them in order to have entities closer to local realities that can play an entrepreneurial role in economic development (Mustar, 1995). In regions that lack effective or interested governmental structures, universities often bring together entrepreneurs, businesses and universities into local versions of the triple helix. Governmental representatives may participate in these discussions as they do in New York City where the New York Academy of Sciences has played the leading role in organizing a series of workshops and conferences on the potential for creating a new high-tech economy in the region (Messina, 1999).

8. Helical paradoxes

The triple helix includes a human capital dimension. This means that people will be moving from one sphere to the other and not staying within a single sphere and certainly not within a single organization for their entire career. This is a particular issue in countries with traditions of lifetime employment such as Japan where experiments are underway in detaching employees from large firms to start new ventures with technology that the firm does not plan to develop itself. In this model the "employee" retains the option to return home if the new venture does not succeed but, on the other hand, if it is successful, the parent firm retains the option to buy out the offspring (Oenehara, 1998). Similar issues of encouraging new firm formation are commonplace in many European countries, for example, Germany and Sweden where long term commitment to a single company and of firms to their employees is also the norm. In such venues, extensive in-house training tailored to the company's traditions and production processes is commonplace. As bonds loosen internally and as firms become more involved in lateral relationships, there is increased interest in generic advanced training, with its attendant professional social ties, such as that provided by universities. For example, the government funded KK Foundation in Sweden has developed a "research school" Ph.D. program, joint funded with companies to broaden the scope of senior R&D personnel.

Another phenomenon is that organizational innovation is taking place not only at the national level but at the multinational level. There is the increasing importance of the European Union to defining innovation themes such as "the European information society," the emerging importance of Mercosul in Latin America in delineating science policy, e.g., the designation of Rio de Janeiro as a "science city" and NAFTA where these issues have been discussed at conferences but not yet acted upon (Laredo, 1997, 1998; Gulbrandsen and Etzkowitz, this issue).

Many of the concepts on which the triple helix is based have been around for a long time. For example, the idea that the economy would ultimately be one based on science and technology was set forth on the mid-19th century by Karl Marx. At that point he had only one example, Perkins work on dyestuffs that was translated into an industry, not in his home country which was England, but in Germany. This outcome exemplifies the paradox that the location of research may not be the same place as the location of the industry that grows out of that research.

How to capture research and make it into a local industry has been a driving motivation of S&T policy. That is why regional, national and multi-national S&T policy makers are interested not only where research locates, but of what comes out of that research and how to keep it locally to generate jobs. Despite significant cross-national funding of research, how to capture the local benefits of research is the issue that one wishes to address from the perspective of return on investments. The question: "Do the funds generate industry and jobs in the region, nation, or multi-national entity?" becomes a criteria for their investment in the first place.

At the same time, this is another paradox of the triple helix and of technology transfer organizations: that one can never totally capture the future benefits of research in one's own region or country. The founders of a technology transfer unit at the National Autonomous University of Mexico (UNAM) discovered that the best home for a university originated technology was with a company in Italy. On the other hand, Resistol, a Mexican chemical company identified a future product source in a startup emanating from a university in Ohio which it then funded in order to move the development of the technology forward toward the goal of establishing production in Mexico. Of course, there are strategies that can assist companies by creating clusters that help them adhere locally. If you try to require, rather than encourage local development, the overriding goal of enhancing innovation may be stifled. This is the reason why in some sense at the same times that universities are becoming a bit more secretive, industry is becoming a bit more open. People and ideas flow and the flow cannot be stopped and therefore what emanates from researchers in one country will flow inevitably to another and can be translated into uses elsewhere.

9. The endless transition

Various models have been set forth in which it was presumed that there was an ultimate goal, albeit divergent and opposing as in Marxian or capitalist frameworks, that if it was arrived would mean achieving the perfect end state of the model. Thus in recent years it has been proposed to the former socialist countries, so called countries in transition should reach a condition where the institutional spheres would be separate. This was portrayed to them as the "western model" with the role of the state much diminished. Typically this advice presumed that the state would no longer have an innovation policy and business would be in its separate area according to the laissez-faire format.

It is coming to be realized that there must be a continuing role for the state in not only funding science, but also in participating in discussions on what that science should be, where it should be situated institutionally and geographically and how it should be related to the economy. Technology transfer and the location of research are too important to be left to an invisible hand.

Countries which were thought to be in transition to laissez-faire capitalism find that they are actually in an endless transition to new relations among the institutional spheres. Rather than now having an endless frontier, we have an endless transition and not only in Eastern Europe, but also in Latin America, the US, Japan, and Europe (Etzkowitz and Leydesdorff, 1998).

There will be no fixed point to which we arrive at in this transition. One indicator of this is the triple helix conference series itself. One reason to participate is to learn about what other countries are doing. What is the latest innovation in incubator facilities or science parks or ways of setting rules for university-industry interactions? Although there are important cultural differences that will shape the way the different helices are created, there will be much that can be imported and exported across national lines.

10. Organization of the theme issue

The various contributions to this issue have been selected from the more than hundred papers presented at the Second Triple Helix Conference at the State University of New York at Purchase. The issue opens with a set of reports about ongoing developments in various parts of the world. A second part is devoted to theorizing, and in the third part we turn to policy issues at the global level.

Part I ("The Transfer System in Transition") opens with a case history by Magnus Klofsten, Dylan Jones-Evans, and Carina Schärberg entitled "Growing the Linköping Technopole—A Longitudinal Study of the Triple Helix Development in Sweden." The Linköping region is often mentioned as an extremely successful region for technology transfer and technology integration. The paper highlights the crucial role of universities in this process.

The reverse arrow is highlighted in the paper by Maria Nedeva, Luke Goerghiou, and Peter Halfpenny entitled "Benefactors or Beneficiary—The Role of Industry in the Support of University Research Equipment." The current situation in the UK is considered as a prime case of the need for universities to engage in relations to industry since the national government is no longer willing and/or capable to supply sufficient funding for keeping the research facilities at the highest quality levels.

In the paper that follows—entitled "Changes in Brazilian Public R&D Institutions Management: The National Institute of Technology Case-Study"—Anne-Marie Maculan and Deborah Moraes Zouain turn to R&D in the public sectors and discuss strategies of commercialization and deconcentration in previously strongly state-controlled configurations. Similarly, Igor Egorov and Elias Carayannis in their contribution "Transforming the Post-Soviet Research Systems Through Incubating Technological Entrepreneurship" suggest new modes of technology transfer that can reflexively be transferred from the West to the Eastern European and CIS countries.

Part II, entitled "Reflections on Technology Transfer," opens with an article by Erkki Kaukklonen and Mika Nieminen (University of Tampere, Finland) entitled "Modeling the Triple Helix from a Small Country Perspective: The case of Finland." These authors try to develop a systems approach. This approach is contrasted with a network approach in the paper by Richard Hull, Vivien Walsh, Ken Green, and Andrew McMeekin (Manchester, UK) entitled "The Techno-Economic: Perspectives for Analysis and Intervention." The two papers have in common that one argues that innovation processes are "on the edge of chaos," that is, not-integrated. The various dimensions of the process (e.g., local/global) enable us to systematize the issues involved and thereby to move the innovation forward through negotiation, consensus building, and co-codification.

In their paper entitled "Winning by Co-opeting in Strategic Government-University-Industry R&D Partnerships: The Power of Complex, Dynamic Knowledge Networks" Elias Carayannis and Jeffrey Alexander propose a dynamic learning-driven framework using game-theory for evaluating strategic research, technology, and development networks. Their model is based on the experiences in the U.S.A. such as the NSF's Engineering Research Centers. How can theorizing help in architecting intelligent organizational interfaces across the spectrum of strategic R&D collaborations?

From a European perspective, Henk Dits and Guus Berkhout (The Netherlands Society of Technological Sciences and Engineering) argue in their paper entitled "Towards a Policy Framework for the Use of Knowledge in Innovation Systems" that the process of knowledge-intensive exchange is different from institutional negotiations hitherto. If the various steps in the processes of translation are not sufficiently distinguished, the results may easily become muddled and confused. This particularly can be illustrated if policy focuses on too high levels of aggregations so that the substantive process of variation can no longer be mediated.

In Part III ("Policy Models of Technology Transfer"), four world regions are compared in terms of current developments in transfer processes. First, Magnus Gulbrandsen and Henry Etzkowitz focus in their contribution entitled "Convergence Between Europe and America: The Transition from Industrial to Innovation Policy" on the realization of a knowledge-based economy in the Western world. The transnational conditions induce processes of internal differentiation, isomorphism and increasing complexity on both sides of the Atlantic while these systems are in continuous competition.

How this works out for third and second world countries is illustrated by two respective contributions. Joske Bunders, Jacqueline Broerse, and Marjolein Zweekhorst (Free University, Amsterdam) discuss the role of NGOs as transfer agencies in collaborations between R&D systems and endusers in Bangladesh in their paper entitled "The Triple Helix Enriched with the User Perspective: A View from Bangladesh." How foreign investments are accommodated in the People's Republic of China and Taiwan is focal in Christiane Gebhardt's contribution entitled "Asia Is Taking a Hard Look: University-Foreign Company Relations in China." The focus on human capital in the transfer process is most notable in the Chinese case.

In summary, we are witnessing global developments making the "capitalist mode of production" more knowledge-intensive. This has important implications for our evaluation of potential collaborations. New time-horizons, virtual dimensions that can be actualized, and strategic partnerships and interventions have to be taken into account. As one is able to internalize this complexity, a necessary condition for the creation of sustainable niches is increasingly fulfilled. The requirement of human capital complements this condition by making it possible for the systems involved to react and then to take a proactive role. An overlay of mutual expectations feeds back on the institutional layer that is continuously under examination and subject to reorganization. The Triple Helix model enables us to conceptualize both the problems of innovation and the related processes of technology transfer.

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