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Conference report

The Triple Helix as a model for innovation studies

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The Second Conference on the Triple Helix of University–Industry–Government Relations focused on "the future location of research." In this report, the Triple Helix thesis is developed into a recursive model of how an overlay of communications operates on the underlying institutions. Market selections, innovative dynamics, and network controls provide different codes of communication at the global level. Local translations at the interfaces induce adaptation mechanisms in the institutional arrangements. While two dynamics tend to co-evolve into trajectories, a regime of transitions emerges when trajectories can be recombined. The emerging hyper-networks are expected to be in flux. Institutions can then be flexible in temporarily assuming roles of other partners. Niche management and human capital management become crucial.

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THE SECOND INTERNATIONAL 'Triple Helix' conference on university–industry–government relations brought together researchers, practitioners, and policy analysts from the three institutional spheres to the State University of New York at Purchase. More than 160 delegates came from 30 countries in Europe, Asia, and North and South America. The largest contingents were from the USA (50), Brazil (18), and The Netherlands (8). Among the other countries represented were Romania, Sweden, Germany, New Zealand, Japan, Norway, Uruguay, France, Mexico, Italy, and Russia.

The theme of the conference was "The Future Location of Research". Ninety papers were presented, and three dozen panelists analyzed the conference theme at multi-national, national, regional, and local levels during the four-day meeting. Following the first meeting in Amsterdam in 1996 (Leydesdorff and Etzkowitz, 1996) which highlighted European Union (EU) S&T policies, special sessions with US science policy officials such as Dr Arthur Bienenstock, Director of the Science Division of the Office of Science and Technology Policy (OSTP) in the Executive Office of the President, exemplified the US location of this conference.

Theme of conference

How does "the future location of research" relate to the Triple Helix program of research? Why have some regions (such as metropolitan New York) and nations (such as Sweden) with significant R&D resources lagged behind in creating high-tech industries, and how can they best utilize these resources to

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catch up and forge ahead? How do the network perspectives of the Triple Helix relate to empirical materials collected in local practices, and how can these materials inform theoretical specification?

Local conditions provide the resources with which one has to operate in a network mode. Interactions at the network level generate mutual expectations that feed back on the institutional arrangements; for example, by allowing for strategic alliances. The institutional transformations themselves co-evolve with the development of technologies and markets at the global level (Nelson, 1994). The knowledge base of the economy is thus increasingly a part of the infrastructure of society. There is also recognition of the necessity for a proactive, but not totalizing role for the state in science, technology, and innovation policies. In addition to facilitating structural adjustments (Freeman and Perez, 1988) government can function to stimulate network development among nation states and across institutional boundaries.

The functional roles of the bureaucracy have to be matched with the need for political direction and choice. For example, the series of Framework Programs of the European Union has increasingly focused on so-called research, technology, and development (RTD) networks. Where national levels are, for political reasons, not able to intervene as in the USA, other levels, such as international or subnational, provide new opportunities for the specific organization of these interfaces (Gulbrandsen and Etzkowitz, 1998). Solutions anticipate problems, but the institutional layer feeds back selectively on the range of possible solutions (van der Belt and Rip, 1987).

Thus, one plenary session focused on the issue of whether the emerging entrepreneurial university, through its involvement with intellectual property rights, threatens open scientific communication. This issue continues to be debated, especially in the USA, where the Bay/Dohle Act of 1980 requires US universities to put into use the intellectual property rights generated from their federally funded research. The various forms this use has taken include the filing of patent applications and the formation of new firms based on rights that the law transferred from the federal government to the universities.

Richard Nelson (Columbia University, USA) argued in his keynote speech that such a policy has detrimental effects on scientific communication, and that the law should be revised, if not repealed. He held that a new set of norms has emerged which encourage secrecy rather than publication, since the research process has been infused with extra-scientific considerations. Moreover, the translation of research into property adds unnecessary "transaction costs" to the transfer of knowledge from academia to industry, an objective that, he argued, could be accomplished more expeditiously through publication in open scientific literature.

Professor Nelson's arguments opened up a wide ranging debate among the panelists and the audience that is likely to extend beyond the conference. One panelist noted that patenting is itself a form of publication, requiring perhaps even more disclosure of the technical detail necessary for replication than an academic paper. Another panelist, a university Vice President for Research, noted that universities purchase far more from industry than vice versa. Indeed, a trade imbalance may be said to exist, one that the sale of intellectual property rights has hardly redressed.

Nevertheless, these issues are all subsidiary to the larger question of the appropriate role of the university in society. Should the university be an 'ivory tower' of independent reflection, or a generator of economic wealth, or somehow play both of these roles, which it clearly does to one degree or another in different empirical instances? In practice, the debate is over where to place emphasis. It is difficult to prescribe solutions to these issues at a translocal level because there are no single solutions. Trade-offs have to be elaborated, codified, and sometimes suspended or perhaps abolished. To the extent that we are able to communicate and to recodify with increasing complexity and precision, we will be able to move technological innovation forward. Decisions made on the basis of more diverse knowledge and informed insights are changing the landscape of opportunities.

What is a Triple Helix?

In recent years, a number of concepts have been proposed for modeling the transformation processes in university–industry–government relations. For example, national systems of innovation (Lundvall, 1992; Nelson, 1993) have been compared with regional systems (for instance, Gulbrandsen 1997; Gebhardt 1997; de Castro *et al*, 1998). From the network perspective, the governance level can be considered as a variable. Gibbons *et al* (1994) noted that innovation is a fuzzy process: it requires the blurring of boundaries in what these authors have called 'Mode 2' of the production of scientific knowledge.

There was considerable debate at the meeting, not only over the empirical basis of the Triple Helix, but also about its normative implications. At least three main forms of the Triple Helix model were identified.

In Triple Helix I, the three spheres are defined institutionally (university, industry, and government). Interaction across otherwise defended boundaries is mediated by organizations such as industrial liaison, technology transfer, and contract offices

In Triple Helix II, the helices are defined as different communication systems consisting of the operation of markets, technological innovations ("upsetting the movement towards equilibrium"; Nelson and Winter 1982), and control at the interfaces (Leydesdorff, 1997). The interfaces among these different functions operate in a distributed mode that produces potentially new forms of communication as in a

sustained technology transfer interface or in the case of patent legislation.

In Triple Helix III, the institutional spheres of university, industry, and government, in addition to performing their traditional functions, each assume the roles of the others, with universities creating an industrial penumbra, or performing a quasi-governmental role as a regional or local innovation organizer (for instance, Pires and de Castro, 1997; Gulbrandsen, 1997). The industrial R&D laboratory can be considered as a historical example of the internalization of such organizational complexity (Noble, 1977). An intermediate level of agencies and small enterprises is typical of the "post-modern" research system (Rip and van der Meulen, 1996).

The model is recursive, since Triple Helix II tends to produce an inner core of communicative overlaps among the institutions of Triple Helix I that can be institutionalized to a greater or lesser degree. However, the different versions of the Tripe Helix posit different types of intersections among the institutional spheres with significant implications for both theory and practice.

The institutionally defined Triple Helix is premised on separate academic, industrial, and governmental spheres and the 'knowledge flows' among them. Transfer is no longer considered as a linear process from an origin to an application. Historical patterns of interaction can be reconstructed.

While 'knowledge flows,' tracked by scientometrics, are an important constituent of science-based economic growth, more intensive relations of increasing complexity have emerged in the course of the capitalization of knowledge. The emerging Triple Helix III is based on a complex set of organizational ties among overlapping spheres that increasingly break down the boundaries between them (Etzkowitz *et al*, 1998a).

In addition to linkages among institutional spheres, each sphere is increasingly able to assume the role of another. Thus, universities take on entrepreneurial tasks such as marketing knowledge and creating companies, while firms develop an academic dimension, sharing knowledge among each other and training employees at ever higher skill levels.

Triple Helix II adds an overlay of communications to the network that has a dynamics of its own. In addition to analysis in terms of its composition and generation, the resulting feedback can be focused on as another subdynamic (Hull *et al*, 1998). From the evolutionary perspective, historical analysis ("following the actors"; Latour, 1987) is useful as far as it is possible to reconstruct on the basis of current understanding how the actors involved had to learn to overcome the prevailing contingencies. Evolutionary models do not focus on the historical contexts *per se*, but on the operation of the emerging systems of innovation. Thus, the emphasis shifts from construction in terms of agency to the constructed systems in terms of their innovativeness (Luhmann, 1990).

The different versions of the Triple Helix model can be at odds with each other both in theory and practice. Conflicts over the definition of "conflicts of interests" among persons with dual institutional roles provide a strategic research site to assess these differences in perspective. Competing hypotheses derived from different versions of the Triple Helix can be explored through formal modeling and appreciated through institutional analysis. In the longer-term research program the outcomes of model studies have to be evaluated as hypotheses and heuristics, while the case studies inform the modeling efforts about contingencies and boundary conditions.

The Triple Helix model is sufficiently complex to encompass the different perspectives of participant-observers and, from an analytical perspective, to guide us heuristically in searching for options emerging from the interactions

This recursive model of the Triple Helix enables us to relate the various perspectives. Evolutionary pressures induce differentiation in all relevant subsystems. Innovation can then be considered as the reflexive recombination of specific contexts, for example, between a technological option and a market perspective. The specification of these different contexts requires theorizing. For the purpose of innovation, the perspectives have to be translated into each other, for example, in terms of a strategic plan. The translation potentially reinforces the research process by raising new questions, for example, by comparing across different contexts, yet with reference to emerging phenomena.

In other words, the Triple Helix model is sufficiently complex to encompass the different perspectives of participant-observers (for instance, case histories) and, from an analytical perspective, to guide us heuristically in searching for options emerging from the interactions. For example, we can distinguish between a specific configuration of university–industry–government relations and the transformation of the infrastructure in a knowledge-intensive economy. The systems of reference are different: Which evolutionary forces drive the transformations? What stabilizes the institutions? Theoretical analysis reflects on these distinctions with the aim of providing the participants in the respective discourses with windows that will enable them to explore new combinations.

Metaphor, model, reality?

The complex system of a Triple Helix depends as a regime of transition on the local trajectories which

can be observed (Leydesdorff and Etzkowitz, 1996; Etzkowitz and Leydesdorff, 1997). We witness the institutional dynamics between industries, governments, and universities. The dimensions of government, industry, and higher education tend to be reproduced because they continue to serve different functions. The institutions embody the value systems or the codes of these functions.

New codes of communication are being developed at all the interfaces. For example, science is no longer valued only as a quest for truth, but also from the perspective of utilization; legal systems are developed with the aim of supporting innovative processes; industries are transformed and restructured both from the perspective of control and from that of adaptation to new technological options. The institutions are involved in the transitions that they cause by their interactions.

Two discussions threaded through the meeting: one empirical, the other normative. The empirical debate raged over whether universities (or the public research sector), government, and industry were sufficient components of a model to explain the emerging trends. Joske Bunders (Free University, Amsterdam) suggested that NGOs (non-governmental organizations) have played a key role in technology transfer, especially in developing countries. In her research on third-world peasants (for instance, Bunders and Broerse, 1998), she found that NGOs were able to influence how technology was introduced into their societies through self-organization and alliances with first-world social movements.

In our opinion, the Triple Helix is mainly a model for analyzing innovation in a knowledge-based economy. This model accounts for the phenomenon of emergence, that is, it helps us to understand how the innovation system is based on expectations. While the complex phenomenon of innovation is what has to be explained, different theories provide us with a variety of possible suggestions. More than a single explanation is expected because different perspectives are useful. To use an evolutionary metaphor, the perspectives can be considered as the 'genotypes' that reflect on specific interactions within and among the helices, while the complex dynamics of innovation are 'phenotypical,' that is, beyond the control of any given perspectives (Langton, 1989; Leydesdorff, 1998).

In contrast to biological evolution, the 'genes' are not given, but constructed in the social, technical, and economic evolution of modern societies with their tendency to transform themselves and their interactions operationally by rearranging their configurations. In a new regime, the system is reconstructed from a set of its own previous states, including the natural environment and society's communal roots. Thus, technology celebrates community as a social achievement, including its ongoing redefinition of 'nature' and 'culture.'

The enterprise is risky. As Marx noted, 'alienation' is the dark side of the enlightenment process. The reconstructive transformation of nature can lead to the destruction of resources that are vital to the reproduction of the system. However, there is no single 'best practice.' At theoretical levels, we can simplify the reconstruction by taking, for example, the national state, the discipline, or the enterprise as a unit of analysis. Analyses of innovations in terms of national systems, major technological waves, or industries, however, fail to understand innovation in terms of the interactive results among these institutionalized spheres. Interaction presumes communication among differently coded value systems, including the risk of potential conflicts.

One example of the transformations implied was presented to the conference audience by Lucio Biggiero, with his analysis of the Italian Districts from an evolutionary perspective. The Italian Districts have been widely studied because of their economic potential. Biggiero (1998) proposes to study them as hyper-networks: because of the multitude of formal and informal links between agents in these networks, niches can be maintained with extremely high problem-solving capacities. A crucial factor is the maintenance of trust in cross-institutional relations in the face of potential conflicts (Ferraro and Borroi, 1998).

Many of us may recognize the best of our own institutions as hyper-networks. While we may complain about the disappearance of reliable structures, the fluidities enable us to solve problems and also to approach problems from a new angle. Most changes, of course, are not innovative in the economically relevant sense of the term. The recombinations provide the variation.

The Internet has taught us to play with options as variation that enables us to envisage what actually occurs as one possible event among many possible occurrences. As we proceed in this 'virtual reality,' the emerging structure begins to feed back on our 'real' relations. This experience is prototypical for the regime change the world is experiencing nowadays. The virtual dimension does not dissolve the 'real' one, yet it changes our perspective on it (Nowak and Grantham, 1998).

The hyper-network reveals new recombinations as feasible and meaningful. Nevertheless we have to be able to follow up locally on these global options. One important step is to recognize the specificity of the closed shop in which we tend to live. Whether this is a 'national system,' the problems on the agenda from a current crisis, the framework of an established discipline, or the fight for recognition of a specific transfer agency, there is always a world beyond. By envisaging new dimensions to the problem, we enlarge our analytical scope.

'Global' versus 'local'

Future developments are expected to be the outcomes of changes in the local contingencies and their relevant environments. Global developments induce local dynamics, and local recombinations constitute

the variation for higher-order systems. The contextual changes can be perceived reflexively from the perspective of local institutions. The markets and the laboratories select by using their respective codes, that is, in terms of prices and performance. 'The local' and 'the global' are thus important specifications for using a Triple Helix model.

In addition to their direct policy relevance (for example, for reasons of evaluation), case studies inform us about new recombinations and emerging institutional structures. These innovations reflect and anticipate on adaptation to knowledge-intensive developments. How are the contingencies communicated and optimized so that local advantages can be exploited as in niches? These issues couple the Triple Helix model to policy agendas as in the case of regional development, university-based incubator activities and SMEs (small and medium-sized enterprises), the local organization of new departments which cross institutional boundaries, and so on.

The institutional dynamics are analyzed in terms of the coupling which they provide to global developments. In many parts of the world, a continuous 'disorganization' of existing institutional boundaries has been signaled (Turpin and Garrett-Jones, 1997). While, from a local perspective, this may sometimes be felt as discouraging, theorizing provides us with heuristics for assessing the multitude of possibilities that the dynamics generate. Here the evolutionary dimension of the model steps in: the disturbances generate variation which tests the existing lock-ins for other potentially emerging recombinations.

What precisely is evolving in these interactions? Authors from economics have tended to take the firm or the industry as their implied unit of analysis (Andersen, 1994). Historians have often focused on technologies or on the development of the university as an indicator of developments in the knowledge infrastructure. All these units are continuously developing within a larger system; borderlines are transgressed and co-evolutions are generated in the various processes of mutual shapings. These dynamics become complex when a trilateral overlay of interactions among the recurrent bilateral interactions provides options for even more complex forms of stabilization. Globalization or 'the transition to Mode 2' are thus a consequence of increasing network relations, not a cause (Leydesdorff, 1997).

First, the recursive operation of the institutions has allowed for the stabilization of mutual interactions between institutions (for instance, corporations) and technologies along trajectories (Nelson, 1994). The implied trade-offs allow for accommodation to options emerging from fuzzy processes at the interfaces (Dosi, 1982). The multinational corporation, for example, has deliberately exploited the differences among national systems. Additionally, a diversified corporation is to a certain extent able to capitalize on differences in the life-cycles among technologies (Abernathy and Utterback, 1978). The state can analogously be locked into technologies, as in the case of energy policies (McKelvey, 1997), or the state and the economy can be locked into each other, as in the Soviet system.

The new layers of networking induce adaptation mechanisms within the carrying units, with an academic revolution as one of the consequences: most universities nowadays use their R&D potential for economic as well as scientific functions

When the levels of control in a third dimension are distributed, options at other levels may prevail either in the international arena or locally in a given region. For example, a network at the European level provides all the partners with options that cannot be grasped at the respective national levels. Taking the example of the Airbus development in civil aviation, Koen Frenken (INRA, Grenoble) explained in his paper how the addition of another layer to Kauffman's (1993) NK-models enables us to understand why the European dimension allowed for innovation in this industry. The existing lock-ins in the respective national systems could be both maintained and recombined (Frenken, 1998).

The new layers of networking induce adaptation mechanisms within the carrying units. An academic revolution is one of the consequences: most universities nowadays use their R&D potential for economic as well as scientific functions. Internally, the transfer of resources within the university from one function to another is to be legitimated in terms of positive feedbacks (Etzkowitz, 1994). The new functions require additional codes of communication, to be developed in an intermediary layer of S&T policy networks (Rip and van der Meulen, 1996). Inventions of 'rules of thumb' that allow for flexible applications may help to solve conflicts of interest in the public sector and develop standard practices, particularly in relation to intellectual property rights. In other cases, formalization and even legislation may be needed to secure a new environment (Berneman and Denis, 1998).

Corporations which previously had to develop a technostructure within their organizations (Galbraith, 1967), have now developed an interface with public institutions in response to the new regulatory regimes of environmental and other (knowledge-intensive) legislation. Randolph Guschl, Director of Corporate Technology Transfer at DuPont Central R&D, noted that DuPont's expenditure on external technology resources increased from US$20 million in 1993 to over US$45 million in 1995, and this budget is still increasing. Another DuPont representative gave an example of R&D outsourcing to academic researchers in India. Instead of the company having to

carry the entire cost of a group internally, an external group can integrate work for DuPont into a portfolio of related projects, with lower personnel and infrastructure costs.

Frances Via (Director for Contract Research, AKZO-Nobel Corporation, USA) supported the DuPont thesis with examples of how corporations are able to meet a business need faster, more cheaply, and with a better technology by leveraging external technology sources. As Guschl noted, "There are better ways to find partners than to go back to your thesis advisor of 20 years ago."

DuPont asks its scientists to come with three options before making a commitment to an external supplier. This increased focus on identifying potential research providers reflects changes in the corporation, from internally producing its own R&D to drawing more on external sources. It is also reflected in a new focus on licensing and spinning out internally developed technology deemed irrelevant to existing or projected business goals.

A regime of transitions

Knowledge-intensity induces differentiation between a strategic level (a discourse about the questions "what and why?") and an operational level ("how?") in the organizations involved (Chandler, 1962; Galbraith and Nathanson, 1978). Both levels can be made relevant for specific forms of collaboration. The dynamics of the uncertainties involved, however, do not allow for rigidly fixed boundaries. Participants at one level of networking can use collaborations or boundaries at other levels as resources. Conflicts have to be addressed and elaborated into (perhaps provisional) codifications.

The established systems try to retain their contributions by reproducing themselves. Thus, the network is expected to contain tendencies toward both integration and differentiation. Whereas each co-evolution exhibits a tendency towards 'mutual shaping' and thus stability along a trajectory, the complex dynamics of a Triple Helix allow for reshaping of the trajectories on which the next-order system recursively has to build.

The capacity of relevant participants to handle the complexity of the implied communications, is then the evolving unit. Adelaide Baeta discussed the learning capacity of technology transfer in the Brazilian context (Baeta, 1998). Herbert Fusfeld, former President of the Industrial Research Institute (IRI) and Director Emeritus of the Center for Science and Technology Policy at Rensselaer Polytechnic Institute, noted how the meaning of technology transfer has evolved, from how R&D results are moved from central laboratories of companies to their operating divisions, from developed to developing countries, and from outside the company into the company.

Not only the substance of the communications develops, but also their codes. By translating between codes, translators communicate reflexively about communications at the interfaces. While heretofore institutional and functional differentiations have tended to correspond as in a division of labor, now we may use the one differentiation to reorganize the other. The co-ordination mechanisms of society have thus become further differentiated.

Strategic communications open new windows by combining perspectives, while the institutional dynamics adapt selectively, as the retention mechanism. When three uncertainties operate on each other, as among markets, sciences, and control, new combinations enable the survival of niches which are superior to the 'natural' fits, yet unexpectedly and from a global perspective. Niche management and human capital management are core objectives of this complex dynamics (Tong, 1996).

More than any other technology, the Internet has been paradigmatic for a global transition in the communication structure beyond the control of corporations and/or national governments. From this perspective, 'national systems of innovation' are still relevant, but only as one dynamic among other subdynamics of the complex system. 'User interfaces' and 'networks of innovation' can be relevant for the further development of a regional university, but so are the traditional disciplines. The different interfaces codify along other axes. The one dynamic replaces the other only to a certain extent and perhaps only provisionally; otherwise, the new dimensions of communication constitute additional layers (Leydesdorff and van den Besselaar, 1997).

The emerging mix of opportunities is continuously assessed, and agreements and disagreements about the best guesses can then be codified and communicated. In this knowledge-intensive enterprise we can restructure continuously the future location of research. A theoretically informed exchange of examples and ideas is needed, since further learning requires us to reach beyond established boundaries among domains.

Manabu Eto (MITI, Japan), for example, reported on a major conclusion of an evaluation study of collaborative projects in Japan: too much competition among otherwise equivalent partners in one of the dimensions can be a disturbing factor in the collaboration (Eto, 1998). It is necessary to have differences to create new perspectives. Each partner, for example, has to be forced to explain what s/he means when using jargon and abbreviations.

Models and policies of innovation

Among the participants we observed an increasing consensus that there is no single 'best practice.' Common themes, such as differences in funding mechanisms and their structuring effects on exchange mechanisms, brought a wide range of interests among delegates into focus in plenary sessions, while the rest

of the conference was mainly organized in parallel streams.

The focus, however, was all the time on 'innovation' and the knowledge infrastructure, and not on specific industries, a technology, or institutional reform. What can be learned about innovation when comparing across industries, across technologies, across nations? How can we disentangle intellectually the complexities of the interactions involved?

The Brazilian Technology Agency (FINEPE) and the State Science Agency of Rio de Janiero (FABERJ), represented by their scientific directors, have invited "Triple Helix III, The Endless Transition: Relations among Social, Economic, and Scientific Development" to Rio de Janiero in April 2000, to be preceded by a regional meeting in 1999. This outcome was among the consequences of a plenary discussion where policy models and theoretical models were confronted.

Angela Uller, director of COPPETEC at the Federal University of Rio de Janeiro, explained how the unit has become involved in community work. Residents of low-income *favelas* (slum areas) are invited to the university to assist in organizing cooperatives, taking a new role in the formation of low-tech service businesses. The industrial relations arm of the university, utilizing the interface skills gained by linking academic researchers to industry, brings these resources to bear in a creative way to address social problems, going well beyond its original official mission. The example has since become a model for a Brazilian national program.

In this same panel, Rikard Stankievicz (Lund University, Sweden) and Richard Hull (UMIST, Manchester, UK) discussed evolutionary and network models for understanding the implied changes in the concept of engineering sciences in these new social contexts, the different role of the state and local governments in organizing such niches, and so on. Jean-Eric Aubert (OECD, Paris) intervened from the audience with a discussion of socio-cultural differences among nations and world regions that set the scene for the possibility of creating bridges between academic puzzle-solving and social problem-solving. Analyses at the level of the social system can thus be helpful in understanding the boundaries that we may seek to overcome.

Is technology a celebration of community?

A special session organized by the New York Academy of Sciences in New York City focused on the potential for high-tech development in the metropolitan region. At the meeting, James Hayward, President and CEO (Chief Executive Officer) of Collaborative Laboratories Inc, submitted that "technology is a celebration of community." The multicultural environment of the metropolitan area makes it urgent to study communities as the social constructions needed to move technologies forward. Community as the basis of communication can no longer be taken for granted. As far as we are able to communicate across otherwise dividing lines, we are able to find new solutions to old problems, and thus to improve on modes of production in terms of using resources (including human capital) in a more sustainable way.

The social shaping of technology has increasingly become an optimization problem given dynamic market constraints: how can niches be sustained in which technologies can be nourished as a communal goal? How can human capital be made available at the right place and the right time given the complexities of the dynamics involved? What is the role of universities, of industry, of local governments, and of large research facilities in localizing inputs made available by higher-order dynamics such as global changes, intergovernmental organizations, technological developments, and multi-national corporations?

The Triple Helix thesis implies that the paradigm of research in innovation studies has definitively incorporated a network mode including uncertain relations with a plurality of environments. The helices contain communication processes which select on the interactive dynamics perceived at their borders using their respective codes to provide the new information with specific meanings. The different codes can be shared at the interfaces, and sometimes a transient arrangement can be institutionalized. Niches for knowledge-intensive industries are thus created and sustained.

From the evolutionary perspective, R&D and invention can be considered as institutionalized sources of variation, that is, as purposeful attempts at reflexive reconstruction. This variation is selected in market places on the basis of different systems of innovation. Markets may be local or global, and innovation systems may be public or private, regional or transnational. This complex system can no longer be fully understood from a single angle, since each perspective tends to stabilize another reflection. The systems under study are interactive and therefore transient and understandable only in terms of fluxes.

This 'Mode 2' of innovation networks (see Gibbons *et al*, 1994) resounds with Marx's (1848) grandiose vision of modern capitalism as a system in which "all that is solid melts into air" (Berman, 1982). It deviates, however, from Marx's vision in shifting the emphasis from the concreteness of industry to the elusiveness of communication networks which can be understood only reflexively. The helices are differently combined in a phase space of possibilities, in which the systems that have previously occurred provide the trajectories on which participants will have to build when constructing their innovations.

Path-dependent trajectories are expected to collide continuously, allowing for the creation of new dynamics. Following alternation between paths, a new synthesis may emerge if a next-order level of communication can be sustained. For example, contemporary science policy in the State of Rio de Janiero was found to be an amalgam of contrasting themes

derived from competing interest groups and ideologies rooted in historic, economic, and geopolitical differences (Etzkowitz *et al*, 1998b). The awareness among the participants of the evolving complexities has geared this system into the knowledge-intensive mode. The emerging order cannot be observed directly, yet it can be inferred on the basis of reflexive observations. The new direction focuses on the future while being rooted in the past.

Innovation is initially the result of a local interaction between scientific invention, economic diffusion, and political power. Innovation systems are expected to develop further on the basis of reflexive translations. The transformations challenge the analytical understanding as they transform the conditions of the emerging achievements. In other words: what you see is not what you get.

Central concepts have to be reformulated: what counts is not the accumulation of past performance, but the resourcefulness of these assets in relation to further developments. Where industries have matured or major disciplines have been established, the question has shifted toward the issue of how to recombine on the basis of existing combinations into new configurations better equipped to meet the exigencies of tomorrow (Tobias and Birrer, 1998).

The local case studies, are needed for making the inferences about reorganization possible. Observations heuristically guide further research questions. No answers can be provided unless we are willing to accept an expectation as an answer. By reorganizing on the basis of new information, the institutions become more informed and thus more knowledge-intensive. Furthermore, the expectation of a complex dynamics enables us to improve our understanding of path-dependency and thus perhaps to achieve a competitive vantage point. The competitive vantage point is a necessary, but not a sufficient condition, for a next advantage.

The Triple Helix is not meant to mesh the different communications together into the grey semblance of a compromise, but to allow for the reflexive fine-tuning of communications with different value systems in the background. Communications are also expressions of diverse institutional traditions and manifold interests. The thematically focused opening of the communication from a variety of perspectives promotes creativity, enables us to access an increasingly knowledge-intensive economy, and thus to celebrate innovation as a vital human possibility.

References

W J Abernathy and J Utterback (1978), "Patterns of industrial innovation", *Technology Review*, 50, pages 41–47.

Esben Slot Andersen (1994), *Evolutionary Economics: Post-Schumpeterian Contributions* (Pinter, London).

Adelaide Coelho Baeta (1998), "The emerging paradigm for technology learning in the knowledge society", *Industry and Higher Education* (forthcoming).

Marshall Berman (1982), All *That is Solid Melts into Air: The Experience of Modernity* (Simon and Schuster, New York).

Louis Berneman and Kathleen Denis (1998), "Evolution of academic–industry transfer in the United States", *Industry and Higher Education* (forthcoming).

Lucio Biggiero (1998), "Italian industrial districts: a Triple Helix pattern of problem solving", *Industry and Higher Education* (forthcoming).

Joske F G Bunders and Jacqueline E W Broerse (1998), "The Triple Helix enriched with the user perspective", *Journal of Technology Transfer* (forthcoming).

Arthur D Chandler (1962), *Strategy and Structure* (MIT Press, Cambridge, MA).

Eduardo Anselmo de Castro, Carlos Jose Rodrigues, Fernando Nogueira, and Artur da Rosa Pires (1998), "Regional innovation systems — the analysis of the Portuguese case based on the Triple Helix concept", paper presented at the Triple Helix II Conference, New York/Purchase, January 1998.

Giovanni Dosi (1982), "Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change", *Research Policy*, 11, pages 147–162.

Manabu Eto (1998), "New types of cooperative research in Japan", *Industry and Higher Education* (forthcoming).

Henry Etzkowitz (1994), "Academic–industry relations: a sociological paradigm for economic development", in Leydesdorff and van den Besselaar (1994), pages 139–151.

Henry Etzkowitz and Loet Leydesdorff (editors) (1997), *Universities in the Global Economy: A Triple Helix of University–Industry–Government Relations* (Cassell Academic, London).

Henry Etzkowitz, Andrew Webster and Peter Healey (1998a), *Capitalizing Knowledge: the Intersection of Industry and Academia* (State University of New York Press, Albany).

Henry Etzkowitz, José de Mello and Branca Terra (1998b), "When path-dependencies collide: the evolution of innovation policy in the state of Rio de Janeiro — Brazil", *Science and Public Policy* (forthcoming).

Fabrizio Ferraro and Mario Borroi (1998), "The emerging landscape of research: dynamics of trust and cooperation in university–industry relations", paper presented at the Triple Helix II Conference, New York/Purchase, January 1998.

Christopher Freeman and Carlota Perez (1988), "Structural crises of adjustment, business cycles and investment behaviour", in Giovanni Dosi, Chistopher Freeman, Richard Nelson, Gerald Silverberg and Luc Soete (editors), *Technical Change and Economic Theory* (Pinter, London) pages 38–66.

Koen Frenken (1998), "Statistical modelling of the Triple Helix using complex systems theory", paper presented at the Triple Helix II Conference, New York/Purchase, January.

John Kenneth Galbraith (1967), *The New Industrial State* (The New American Library, New York).

Jay R Galbraith and Daniel A Nathanson (1978), *Strategy Implementation: The Role of Structure and Process* (West Publishing, St Paul).

Christiane Gebhardt (1997), *Die Regionalisierung von Innovationsprozessen in der Informationstechnologie* (Deutscher Universitätsverlag, Wiesbaden).

Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott and Martin Trow (1994), *The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies* (Sage, London, etc).

Magnus Gulbrandsen (1997), "Universities and industrial competitive advantage", in Etzkowitz and Leydesdorff (1997), pages 121–131.

Magnus Gulbrandsen and Henry Etzkowitz (1998), "The convergence between Europe and America: the transition from industrial to innovation policy", *Journal of Technology Transfer* (forthcoming).

Richard Hull, Vivien Walsh, Ken Green and Andy McMeekin (1998),. "The techno-economic: perspectives for analysis and intervention", *Journal of Technology Transfer* (forthcoming).

Stuart A Kauffman (1993), *Origins of Order: Self-Organization and Selection in Evolution* (Oxford University Press, Oxford).

Christopher G Langton (editor) (1989), *Artificial Life* (Addison Wesley, Redwood City, CA).

Bruno Latour (1987), *Science in Action* (Open University Press, Milton Keynes).

Loet Leydesdorff (1997), "The new communication regime of university–industry–government relations", in Etzkowitz and Leydesdorff (1997) pages 106–117.

Loet Leydesdorff (1998), "Does the triple helix metaphor provide us with an evolutionary model?", paper presented at the Triple

Helix II Conference, New York/Purchase, January 1998.
Loet Leydesdorff and Henry Etzkowitz (1996), "Emergence of a Triple Helix of university–industry–government relations", *Science and Public Policy*, 23, pages 279–286.
Loet Leydesdorff and Peter van den Besselaar (editors) (1994), *Evolutionary Economics and Chaos Theory: New Directions in Technology Studies* (Pinter, London).
Loet Leydesdorff and Peter van den Besselaar (1997), "Scientometrics and communication theory: towards theoretically informed indicators", *Scientometrics*, 38(1), pages 155–174.
Niklas Luhmann (1990), *Die Wissenschaft der Gesellschaft* (Suhrkamp, Frankfurt a.M).
Bengt-Åke Lundvall (editor) (1992), *National Systems of Innovation* (Pinter, London).
Karl Marx ([1848], 1967), *The Communist Manifesto*, translated by Samuel Moore in 1888 (Penguin, Harmondsworth).
Maureen McKelvey (1997), "Emerging environments in biotechnology", in Etzkowitz and Leydesdorff (1997), pages 60–70.
Richard R Nelson (1994), "Economic growth via the coevolution of technology and institutions", in Leydesdorff and van den Besselaar (1994), pages 21–32.
Richard R Nelson (editor), (1993), *National Innovation Systems: a comparative study* (Oxford University Press, New York).
Richard R Nelson (1998), "The entrepreneurial university: whether, whither, wither?", Keynote address, Triple Helix II Conference, New York/Purchase, January 1998.
Richard R Nelson and Sidney G Winter (1982), *An Evolutionary Theory of Economic Change* (Belknap Press, Cambridge, MA).
David Noble (1977), *America by Design* (Knopf, New York).
Michael J Nowak and Charles E Grantham (1998), "The virtual incubator: managing human capital in the software industry". paper presented at the Triple Helix II Conference, New York/Purchase, January 1998.
Artur da Rosa Pires and Eduardo Anselmo de Castro (1997), "Can a strategic project for a university be strategic to regional development?", *Science and Public Policy*, 24(1), pages 15–20.
Arie Rip and Barend van der Meulen (1996), "The post-modern research system", *Science and Public Policy*, 23(6), pages 343–352.
Sheila Tobias and Frans Birrer, "The science-trained professional: a new breed for the new century", *Industry and Higher Education* (forthcoming).
Jian Tong (1996), "Reflections on human capital theory and niche theory in evolutionary economics", paper at the Triple Helix Conference, Amsterdam, 1996.
Tim Turpin and Sam Garrett-Jones (1997), "Innovation networks in Australia and China", in Etzkowitz and Leydesdorff (1997), pages 33–46.
Henk van den Belt and Arie Rip (1987), "The Nelson–Winter–Dosi model and synthetic dye chemistry", in Wiebe Bijker, Thomas P Hughes and Trevor Pinch (editors), *The Social Construction of Technological Systems* (MIT, Cambridge, MA) pages 135–158.