INTRODUCTION: UNIVERSITIES IN THE GLOBAL KNOWLEDGE ECONOMY

A TRIPLE HELIX OF UNIVERSITY-INDUSTRY-GOVERNMENT RELATIONS

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The development of academic research capacities carries within itself the seeds of future economic and social development in the form of human capital, tacit knowledge and intellectual property. Channelling knowledge flows into new sources of technological innovation has become an academic task, changing the structure and function of the university. Realizing the benefits of this potential resource occurs through organizational innovations such as technology transfer offices, incubator facilities and research centers with industrial participation. The change in emphasis from a sole concentration on the production and dissemination of knowledge to technology transfer and firm-formation places the university in a new alignment with the productive sector.

The new social contract between the university and the larger society is being negotiated in much more specific terms than the old one. The former contract was based on a linear model of innovation, presuming only long term contributions of academic knowledge to the economy. Now both long and short term contributions are seen to be possible, based on examples of firm formation and research contracts in fields such as biotechnology and computer science. A spiral model of innovation is required to capture multiple reciprocal linkages at different stages of the capitalization of knowledge.

What dynamics are involved; how are industrial and R&D policies affected? Should government strategies focus on channels of information, in the hope of creating systematically effective and dynamic interdependencies without becoming directly involved in specific technologies or projects? Alternatively, should government policies focus on encouraging and subsidizing strategic alliances among companies and universities to overcome blockages or `reverse salients' in particular technologies with significance for future product development?

A Triple Helix of University-Industry-Government Relations

The modern university, which combines teaching and research, emerged in the early 19th century. Historically, the institution went through a revolutionary transition in the late 19th century; from being largely a higher-education institute, the universities increasingly came to have social functions in both research and teaching. With hindsight, this differentiation of functions can be understood in terms of changes in the knowledge infrastructure. The emergence of the industrial research laboratory and the scientification of industrial production had created a labour market for experimentally trained academicians (Noble 1977; Van den Belt & Rip 1987). Universities offered a specific place for integration and differentiation among functions in the knowledge infrastructure like scholarly learning, theorizing, and experimental practices.

The first half of the 20th century has sometimes been characterized in terms of the extension of this higher-education system under the patronage of the

nation states (e.g., Parsons & Platt 1975). During much of the latter half of the century, the expansion served to accomplish these purposes on a larger scale, with expectations of long-term practical relevance (Bush 1945). Increased international economic competition, the end of the Cold-War and the emergence of new models of knowledge based economic development have called this taken for granted `ivory tower' role of the university into question.

Universities and industry, up to now relatively separate and distinct institutional spheres, are assuming tasks that were formerly largely the province of the other. The role of government in relation to these two spheres is changing in apparently contradictory directions. Governments are offerring incentives, on the one hand, and pressing academic institutions, on the other, to go beyond performing the traditional functions of cultural memory, education and research, and make a more direct contribution to `wealth creation' (e.g., HMSO 1993). Governments are also shifting their relationships to economic institutions, becoming both more and less involved.

In some countries with a laissez faire capitalist tradition such as the U.S. government is playing a greater role in innovation in the civilian economy (Etzkowitz 1994) while in former socialist societies government has withdrawn from its previous position of total control of science and technology policy; adopting a stance more in accord with laissez faire principles (Etzkowitz 1996). Multi-national institutions such as the European Union, the World Bank and the U.N. are also moving to embrace concepts of knowledge based economic development that bring the knowledge, productive and regulatory spheres of society into new configurations. In this volume, we elaborate on the role of the sciences

in this changing environment with a focus on the university's position in the newly emerging knowledge infrastructure.

Recombinations Among Knowledge Flows

During the early post war era the laboratories of large industrial firms provided a relatively self sufficient technological support system for product development (Fusfeld, 1986). During the past two decades, increased international competition, a faster pace of technological development, and downsizing of firms to core competencies have made companies more receptive to external sources of innovation (Soete, 1991; Miles and Snow, 1992).

An innovation gap has emerged from the shortening of firm's R&D time scale and the resources available for this function (scale) and the increase in competencies and technological inputs necessary to accomplish innovation (scope). This innovation gap lies between individual firms attending to their short term needs for product development and longer term research, often located in university and government laboratories, with potential to incrementally improve existing products as well as create future products and processes.

The current necessity to combine external with internal sources of innovation has revised the role of the industrial laboratory within firms, reducing their scale, on the one hand, while increasing their scope, on the other (Rosenbloom and Spencer, 1996). As individual firms externalize many of their innovation activities, the unit of analysis increasingly becomes technological systems viewed as networks of agents interacting in a specific technology area (Hughes, 1987).

These changes in the economy induce change in other parts of the knowledge infrastructure. Under the previous condition exchange across institutional boundaries was typically organized through arms-length transactions, often by mediating organizations such as a non-profit organization to arrange transfer of technology (cf. Gieryn 1983). Under this regime, informal arrangements such as consulting ties betweeen companies and individual professors in tacit exchange for fellowship and departmental research funds were the norm.

Under changed conditions, with universities increasingly viewed as actors in national and regional innovation systems, distinct boundaries are elided and replaced by a web of ties. Academic institutions increasingly internalize and decentralize intellectual property management and technology transfer activities, inserting the university as an entitity in between the faculty and their industrial interlocutors. As new arrangements are put in place, old formats also continue to be utilized, creating a complex interplay among organizations and roles with ensuing conflicts and confluences of interest.

As the university acquires an industrial penumbra; industry takes on some of the values of the university, sharing as well as protecting knowledge. New institutional infrastructures, combining inputs from diverse sources, are emerging as an overlay upon individual firms for the purpose of generating and diffusing technological knowledge flows into clusters of firms (Carlsson and Stankiewicz, 1991; Egelhoff and Haklisch, 1991; Powell, 1996). Research groups within firms increasingly become elements of research joint ventures and long-term strategic alliances, bringing them together with government laboratories and university research groups to acheive a common strategic goal.

Mixing and matching both of these strategies in different scientific disciplines, technological fields, and industrial sectors is a further possibility. Such a `hands on' strategy, however, requires a greater science and technology policy capacity on the part of the state, industry and academia since judgements of the level and type of intervention in particular areas becomes more critical. These are the central questions of academic, industry, government relations in societies of different traditions of political-economy, and level and type of economic development, which we wish to raise in this volume.

Theoretical framework

A `triple helix' of academic-industry-government relations is likely to be a key component of any national or multi-national innovation strategy in the late twentieth century. The focus on interactions between institutions of fundamental research `on the supply side' and corporations has not only been reflected in technology policies, but also in technology studies. Linear models of `demand pull' or `technology push' have been superceded by evolutionary models that analyze the developments in terms of networks (e.g., Nelson & Winter 1982; Dosi et al. 1988; Leydesdorff & Van den Besselaar 1994). Non-linear dynamics has provided us with co-evolutionary models: How do technologies and institutions co-evolve (Nelson 1994)? Under which conditions do they `lock in' (David 1985; Arthur 1988)? When can a `lock in' be considered as part of an emerging infrastructure and when should it be avoided (cf. David and Foray 1994)? And over time: How is the social infrastructure adjusted to cycles of emerging techno-economic developments (Freeman and Perez 1988; Barras 1990)?

Three sources of variation have been acknowledged in technology studies: (1) industrial sectors differ with respect to their relations to the technologies that are relevant for the developments in those sectors (e.g., Pavitt 1984); (2) different technologies induce different patterns of innovation and diffusion (e.g., Freeman & Perez 1988; Faulkner & Senker 1994); (3) systems of innovation (e.g., national systems of innovation) integrate and differentiate the various functions differently (Lundvall 1988; Nelson 1993). The variations, however, are both functional and institutional. The functional communications can sometimes be codified in new institutional settings; the institutional sectors (public, private and academic) that formerly operated at arms length are increasingly working together, with a spiral pattern of linkages emerging at various stages of the innovation process. Institutional and national boundaries may be transcended in the course of creating a new innovation environments, including the development of new (inter-)disciplinary discourses. At the other end, start up firms are a common outgrowth of the integration among the three sectors: arising from academic research groups, national laboratories, and the laboratories of large corporations.

Innovation processes take place across national boundaries, through cooperative arrangements among regions and firms (Kohler-Koch, 1993). Innovation systems, previously a characteristic of the nation-state (Nelson 1993), are being supplemented by regional and multi-national innovation systems within the European Union and elsewhere. At the regional level, this is not a new development. The New England regional innovation system, named after a post war ring-road `Route 128' originated in the mid-nineteenth century with

the founding of MIT, a new type of technological university designed to infuse industry with the results of what is now known as `strategic research.' At the cognitive level, however, scientists from different disciplines and specialties are challenged across established boundaries, in order to reflexively search for new forms of (functional) integration.

What is new is the spread of technology policy to virtually all regions, irrespective of whether they are research or industrially intensive. The various systems which previously could be considered as functionally differentiated, tend to be integrated at various levels of structure. Grasping the competitive advantages seems to require the purposeful adjustment of the various levels of integration and control (Porter 1990). Many international and multi-national programs of the UN, the OECD, the World Bank and the European Union assist economic development by relying on academic-industry-government relations to achieve their goals. Thus, a new mode of production is emerging based on linkages among academia, industry and government (Gibbons et al. 1994).

Another indicator of this development is the growing convergence among North America, Japan and Europe in science, technology and industrial policy. The Europeans, having concentrated on assisting larger firms through pre-competitive research initiatives, are moving toward greater emphasis on startups, a U.S. specialty until recently. The Japanese, having brought the art of targeting `critical technologies' representing future industrial growth to a high level, are developing their academic basic research and graduate training capacities. The U.S., with an overcapacity of basic research supply and undercapitalized intellectual property resources, is acting to assist larger, as well as smaller, companies to take technologies off the shelf and

into the factory for production, both as defense conversion and economic development policy. For its part, Europe is spending 13.1 billion ECU on its Fourth Framework Program (1994-98) to become more competitive with the U.S. and Japan.

Policy programmes tend to call for collaboration and integration. However, one expects a complex dynamic system to reproduce also differentiation, since differentiation allows for more complexity. Along which dimensions or at which levels does one observe integration, and along which differentiation? How are the two mechanisms balanced and reflexively optimized? And by which actors in the network? Is the newly emerging network system a further differentiation on top of the existing systems or is it a new (e.g., more complex) mode of knowledge production and control in itself? How do changes in the knowledge infrastructure affect the intellectual organization of the disciplines? What are the consequences for reshaping of the university system: which are the emerging functions, and which are the contexts? What are the implications for higher education?

The Laboratory of Knowledge-Based Economic Development

In this study we develop the relevant dimensions for an analysis of university-industry-government relations: (i) the construction of the Triple Helix, (ii) the mechanisms of co-evolution of technologies and institutions, (iii) the operation of the resulting system, and (iv) the future role of university research in it. In a final chapter we turn to the further specification of the Triple Helix model.

While a number of studies have focussed on experiences in the US and the UK, less empirical information is available about the effects of the assumed transitions from national systems to international frameworks of S&T policy making, for example in the emerging European Union (Nelson 1994). In Part One, three contributions raise the question of the construction of the knowledge based regime in three world regions. In a first chapter, entitled `The New Role of the University in the Productive Sector', Judith Sutz (Montevideo, Uruguay) argues that the unmediated relation between science and the economy is the really new thing in the emerging Triple Helix:

> `The increasing demand for funds from universities and research institutes gets a similar response worldwide: support yourselves! That is to say, connect yourselves with industries and the government, offer your knowledge and your capacity to generate new knowledge and charge for it. Only in this way will you be able to extend your laboratories, hire young people, and increase your salaries.'

Previously, governments tended to intervene and direct the processes of adjustment and to orchestrate the construction of the knowledge infrastructure. But policy makers have become more reflexive about the limited effectiveness of their interventions. Each of the three partners involved is aware of the need of negatiotiations with the other two. Judith Sutz elaborates the differences and the asymmetries in the nature of these communications. The relations are driven by various needs of resources (money, knowledge, legitimation); the resulting patterns of interaction are largely unintended.

The analysis of the emerging Triple Helix is generalized in the next chapter by comparing industry and university networks in Australia and China. Tim Turpin and Sam Garrett-Jones (Wollongong, Australia) emphasize ongoing disorganization of the boundaries between universities and industries as a communality among these two otherwise so very different countries. The rapid

extension of sectors at the interfaces in the knowledge economy (like Cooperative Research Centers and `interface sciences' as biotechnology, artificial intelligence, and advanced materials) indicates that the system is in transition. While universities in various countries have suffered budget cuts of sometimes more than twenty percents, this does not necessarily indicate decline. Thus, one is in need of a model that focuses on the transition mechanisms in the complex set of interactions.

In the last contribution to this part, Philippe Laredo discusses the effects of EU Research Programmes. Europe's supranational networks came on top of national programs that tended to focus more on strategic priorities (like biotechnology) than on university-industry relations. In the US, on the other hand, university-industry relations have been a priority for lower-level (i.e. state) governments with a focus on regional development (Berglund and Coburn 1995). Thus, different dynamics can be discerned on each side of the Atlantic Ocean (OECD 1988; Leydesdorff & Gauthier 1996). They have in common that the administrative structure has become internally differentiated among national, regional, and supra- national levels.

This complexity in the political system is needed, since a knowledge-based economy can no longer be controled at a single point. In Part Two of the volume, we focus on the complexity of the process of techno-economic developments that is channeled through these institutional apparatuses. Maureen McKelvey (Linköping, Sweden) explains the model of co-evolution between cognitive and institutional environments by elaborating on the example of the emergence of biotechnology. Different phases in the science-technology cycle require

different interfaces with the private- public axis in order to allow for effective utilization.

The disregard of variations in technologies, markets, and institutions is further elaborated in the two other contributions to this part of the volume. Andrew Webster & Kathryn Packer (Anglia University, Cambridge, UK) first present data from a survey among British academics about patenting. William Kaghan & Gerald Barnet (University of Washington, US) discuss the `metonomies' which may follow if one uses policy models from one type of technology (e.g., the laboratory model) in order to control another (e.g., computer software). Dysfunctions in the policy process call for new mechanisms of communication between the relevant partners in the construction of technological trajectories and techno-economic regimes.

In Part Three, we focus on integrating mechanisms, their carriers, and the expected effects. Terry Shinn (GEMAS, Paris, France) opens this part with an introduction into the concept that he coined `research technologies'. From the late 19th century onward, the need for instrumental standardization and control has created a niche for `interstitial communities' with a professional ideology of `servicing.' Shinn describes the development of these communities in Germany, France, and the US respectively. His conclusion is that the system operates in terms of both differentiation and integration as two sides of the same coin: codification and black-boxing allows the system `to reopen the debate'.

Petra Ahrweiler's (Bielefeld, Germany) paper, entitled `Negotiating a New Science: Artificial Intelligence', can be considered as an elaboration of

Shinn's thesis. Using extensive interviews with leading scholars of the AI community in Western Germany, she argues that this community had to integrate actively scientific programs, economic interests, and political legitimation. The concept of a Scientific- Political-Economic (SPE) community is proposed for the explanation. In a third contribution to this part of the volume, Loet Leydesdorff elaborates the notion of differentiation in terms of a regime of communication that emerges when the needed integration can no longer be community-based. Integration can then be considered as the result of translations between otherwise differentiated spheres. Adjustments of the mutually exchanging systems in terms of changing codes of communication are specified.

In the fourth part of the volume, the position of universities is discussed in relation to the emerging regime of the Triple Helix. First, Magnus Gulbrandsen (Oslo, Norway) compares in his contribution competitive advantages in relation to university environments between Cambridge (UK), Grenoble, and four Scandinavian universities. The competitive advantage model (Porter 1990) is further distinguished from the Triple Helix model. In a contribution with a focus on Japan, Morris Low (Australian National University, Canberra) completes this analysis by discussing strategic options for the further development of the knowledge infrastructure from the Japanese perspective. Henry Etzkowitz in a third contribution to this part focusses on the emergence of the entrepreneurial university in the US and its consequences for the self-understanding of the political system.

As noted, we return to the specification of the Triple Helix model in a concluding chapter. Our claims are far reaching: the Triple Helix combines

the notion of `duality of structure' (Giddens 1979) with the evolutionary models that have become available from complexity theory. The system proliferates communications within and across institutional boundaries (`variation'). Niche formation in co-evolutions is selective, and integration in social structure is achieved through adaptive reproduction of the institutional differentiation (cf. Tong 1996). While co-evolution in a double helix may lead to provisional stabilizations (e.g., in a biological system), the third helix allows all partners involved a reflexive turn, and thereby a transition from the present state. The present institutions carry over the evolutionary history of the system as enabling and constraining conditions on future communications.

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