ACADEMICS AND ENTREPRENEURS

Developing University-Industry Relations

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Foreword

Academia as a source of innovation and university-industry linkages have become a topic of increasing attention and even concern. Large sums are spent on universities and on the research carried out within them. On the one hand there is a continuing demand for yet more expenditure, and on the other hand the recession in Europe is linked to a lower level of technological innovation relative to the U.S. and Japan. These pressures are leading governments to look for a quicker return on their expenditure and to seek a more direct route from academic knowledge to economic application than is provided through the educational process and the graduate who eventually applies the knowledge.

This concern led the Six Countries Programme in May 1982 to hold a Workshop on University-Industry relations. Dr. Stankiewicz presented one of the papers and was subsequently commissioned to write a report which took in not only the other papers and discussions at the Workshop but also the state of the art of this rapidly developing area. That report is this book.

Dr. Rikard Stankiewicz was born in Warsaw but undertook his higher level education in Sweden. He is an Assistant Professor at the University of Lund and a programme director in the Research Policy Institute. He has carried out several studies of the communication processes in research and of the effectiveness of academic research teams. He is currently working on two inter-related projects — firstly, a comparative study of the organisation of R & D in selected strategic technology fields in Sweden, Germany and Japan, and secondly an analysis of what he terms the "competence network" of high technology companies with an inevitable and particular emphasis on the university-industry links.

Many mechanisms are being used to encourage academic entrepreneurs and foster direct links between universities and industry. The claims as to the success of one or another vary widely.

Dr. Stankiewicz gives here a broad review in an objective manner useful to the many who are interested in this topic and concerned that the always limited resources might be directed in the most effective manner.

G. P. Sweeney,
Chairman, Six Countries Programme.

November 1985.

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CHAPTER I.

Introduction

1. Background

It is widely recognized today that universities play a crucial role in promoting technical change. For the most part, they make their contributions *indirectly* by advancing the frontiers of science, by critically reviewing and systematizing the accumulated technical knowledge, and, especially, through the training of students and researchers. Generous investment in education and basic science is viewed as a necessity by every nation with industrial ambitions.

Along with such general and indirect links between universities and industry there exist others of a more immediate and specific character. Universities can be viewed as pools of technical expertise and creativity to be tapped *directly* through the involvement of academic scientists and engineers in the process of industrial innovation. Although by no means new, the emphasis on such direct links has intensified in recent years. Governments, universities, as well as industry have engaged in a wide spectrum of organizational experiments aiming at strengthening the links between the academic and industrial environment. These developments were accompanied by intensive public debates on the effectiveness of the various measures proposed, as well as on the potential threats which such measures pose to the health of the academic system.

What are the reasons for this intensified interest in university-industry relations? Are we dealing with an ephemeral phenomenon caused by some purely conjunctural factors or with more fundamental changes in the ways in which the R&D systems in the industrialized countries operate?

The importance of the short-term economic considerations is quite evident. Industry-university relations have been influenced by the recent worldwide economic slow-down. In order to *improve their* *competitive position* on stagnating or even contracting markets, nations have to mobilize all their scientific and technological resources. In most countries academic R&D constitutes a very large part of the national research effort. There is a general feeling that universities are an underutilized resource and that this situation can be changed by adopting appropriate policies.

The current stress on technology in industrial policies also reflects the belief that the present economic crisis is largely structural in character. It is felt that universities could contribute to the revitalization of national economies by *assisting small and medium enterprises* as well as by *generating entirely new high-technology businesses*. The regional importance of universities is often stressed in this respect. The belief in the possibility of reaping relatively rapid returns from increased university-industry interactions is by no means limited to the governmental policy-makers. Similar opinions are frequently expressed by representatives of industry, as well as by the academics themselves. There is in fact a new willingness on the part of academics to engage in various forms of service to industry, a willingness which — at least partially — can be attributed to the increasingly uncomfortable budgetary constraints imposed on the universities by hard pressed governments.

Granted that the present concern with university-industry interactions is strongly affected by the current economic difficulties, would it be justifiable to regard it as a purely transitory phenomenon? Will it fade out when the economies regain their equilibrium and reassume a steady growth rate?

Although there does exist a risk that such "fading-out" may actually occur, it should not be exaggerated. Indeed, it is argued that the reasons for the current interest in university-industry relations transcend the merely conjunctural considerations, and may be linked to certain major changes in the nature of the innovation process itself. These changes may have started a long time ago but their full impact only began to be felt recently.

Despite all the talk on both sides of the Atlantic about the alleged decline in technological innovation it is hard to point to a period in history when technology was undergoing as rapid and as many changes as it is today. What is particularly striking is the confluence and synergistic interaction of many new basic technologies in fields as diverse as electronics, computer science, materials sciences, energy research, biotechnology, medical technology and many others. Another conspicuous characteristic of these technologies is their "scientification" which manifests itself in:

- the sensitivity to the events taking place at the frontiers of fundamental research;
- a high degree of intellectual codification and "academization" (as opposed to the unsystematic empirical character of many traditional techniques); and
- the growing intellectual complexity calling for the cooperation of people with highly specialized scientific and technological backgrounds.

These trends have certain long-term implications for the academic systems. The nature of "transactions" in which the universities engage with society at large is undergoing change. Whether they like it or not, the universities find themselves playing the role of important economic actors not only in some diffuse long-term perspective but also in a much more tangible everyday manner. Knowledge has become a commodity.

The trend towards the "scientification" of technology calls furthermore for a readjustment of the role played by universities within the large national R&D systems. Due to their interdisciplinarity, their networks of contacts with the international scientific community, their capabilities in fundamental science, and permanent access to the flow of young scientific and technological talent, the universities are increasingly looked at as a natural integrator of the multifaceted and rapidly growing knowledge industry.

It is difficult to see how the trends described above could be reversed in the near future. Instead we would expect their further acceleration. It seems therefore inevitable that the university will undergo a variety of institutional adjustments. Indeed, many of the organizational experiments now taking place at the university-industry interface can be viewed as harbingers of more fundamental changes.

The concern with the long-term adjustment of the academic system to the requirements of the emerging information-economy should not however detract from an analysis of more immediate policy concerns. An attempt is made in these pages to balance these two perspectives.

2. Structure of the book

Chapters II and III provide the background against which the recent policies designed to stimulate university-industry interaction are presented in subsequent sections of the report. Chapter II focuses on what is known about the process of university-industry interaction with special emphasis on the science-technology links. Questions are posed about the importance of university-industry interactions in the past and an attempt is made to resolve some of the conceptual hurdles which are likely to make the discussion of these issues difficult. Chapter III addresses the institutional aspects of the university-industry interaction. The organizational difficulties connected with such interactions are identified and the major approaches are presented.

Chapters IV and V are devoted to the various practical mechanisms of improving university-industry relations which have been introduced in recent decades. Two modes of interaction are identified and discussed separately: (a) the technical assistance mode in which universities do not themselves assume the entrepreneurial role, and (b) the entrepreneurial mode in which the academics carry the responsibility for the commercialization of technical innovations. In this context special attention is paid to the firms formed as a spin-off from academic research.

Chapters IV and V also consider various specific policy and organizational mechanisms. The concluding chapter, Chapter VI, returns to the broader issues. It discusses the compatibility between institutional features of the traditional university system and the various university-industry interaction mechanisms described in Chapter IV and V. Major policy problems are identified and ways of dealing with them are suggested.

CHAPTER II:

University-Industry Interactions — The Process

1. The contribution by universities to the development of technology — evidence and counter-evidence

The belief that universities constitute a significant *underutilized* source of technological innovation can and has been challenged. It is often argued that the indirect knowledge transfers between universities and industry (those mediated by the process of education, and the open communication system of science) are quite effective and do not need to be supplemented by more direct relationships to any significant extent. The universities — it is asserted — should concentrate on their primary goal, which is the expanding of our common knowledge pool, and leave the transfer and application of knowledge to other systems more suited for that purpose.

These views can be supported by various *quantitative* indicators which show the apparent unimportance of direct university-industry links. For example: in a recent study by NSF (1982) it is stated that ''Direct links between universities and corporations currently constitute only a miniscule portion (less than one-half of one percent) of the national R&D effort''. Figures of this sort can make it appear that the great concern with university-industry interactions is somewhat misguided, at least in the light of historical experience. This scepticism is reinforced by several other studies of the innovation processes. Here is a sample.

Project HINDSIGHT was one of the pioneering efforts to assess quantitatively the importance of various types of R&D inputs to technical innovation. Its empirical base was a sample of American weapon systems. Reporting on the results of the project Isenson (1967) concluded that basic science contributed only marginally to the development of the systems. Furthermore, only 9 percent of all the ''critical R&D events'', i.e. those necessary for the development of the system, took place in universities.

Townsend et.al. (1981), having analysed over 2,000 important innovations in British industry, found that universities supplied important knowledge inputs to less than 2 percent of the innovations studied. Similar results were obtained in a Canadian study by de Melto et.al. (1980).

The belief in the ability of universities to spin-off new high-technology industries has also been challenged. This belief is largely based on the highly publicized success of two industrial academic complexes in the United States: route 128 and the Standford area. A study by Sibru et.al. (1976) suggested that these two examples were quite unique, and that the participation of universities in the other industrial high-technology agglomerates has been quite marginal. Recent studies in West Germany (see Allesch, 1982) and Sweden (Utterback et al, 1982), tend to confirm such views: new enterprises started by academics are quite rare.

Yet the statistical evidence is by no means straightforward and a number of studies exist which attribute to universities a truly significant role in technical innovation.

The NSF sponsored project TRACES (1968) and its follow-up study (1973) (which constituted a kind of "answer to HINDSIGHT") analysed a number of major civilian technological innovations. One of the conclusions reached was that as many as 60% of the critical R&D events, necessary for the conception and development of the innovations studied, had taken place in universities. The contrast with the findings of HINDSIGHT is glaring. Some critics attributed it to the bias the institutional sponsorship of the two studies (HINDSIGHT — by the Dept of Defence and TRACES — by the National Science Foundation). The divergence of conclusions can, however, be explained in terms of the different time perspectives in which the two analyses have been made. TRACES indicates that in order fully to appreciate the impact of science on technology, a time perspective of 30 or more years is necessary. In the present context this is an ambiguous finding. It may be interpreted to mean either that the transfer of knowledge from basic science to technology is intrinsically very slow or that it tends to be greatly delayed due to poor interaction between universities and industry.

Several other recent studies emphasize the importance of these interactions. Gibbons and Johnston (1972), for instance, estimated that when the sources of inputs from outside the innovating firm are looked at, the contributions of universities may be more than 33 percent. Similar conclusions have been drawn by Pavitt and Walker (1976) in their review of relevant British studies.

The above sample of the literature on university-industry relations leaves us with a somewhat confused picture. Many of the findings do not only run counter to the intuitive judgement of knowledgeable people in both academia and industry but also contradict one another. Why should this be the case?

This is not the place to subject the above mentioned studies to detailed review and methodological criticism. Both HINDSIGHT and TRACES, as well as the other analyses cited, have been debated and criticized in the literature. Many of the authors cited (for instance Townsend et.al.) are well aware of the methodological pitfalls in their approaches. I shall therefore only point to a few general issues which are directly relevant to the subject matter of the present report.

Firstly, most of the studies reviewed above have been based on the assumption that the links between science and technology could be adequately measured by studying certain types of "critical events" in science and technology ("discoveries", "breakthroughs", "communication of crucial ideas", etc). This kind of "atomistic" view is debatable. Both science and technology are intellectual systems which interact fairly continuously. The impact which they have on one another is often the result of small and subtle influences which, nevertheless, tend to accumulate over time. Consequently, the isolation of "critical events" or the identification of supposedly crucial "information sources" tend to be methodologically dubious.

Secondly there is a tendency in the studies referred to above to lump together all sorts of technical innovations. This has two consequences: (i) technologically trivial innovations are not distinguished from significant ones, and/or (ii) few efforts are made to differentiate between various types of innovation processes. There is too much concern with producing some overall measure of the impact of basic science/universities on the aggregate called "industrial innovations" and too little concern with the definition of the unique role that the universities and fundamental science have to play in technological change.

Thirdly, the studies cited earlier in this chapter lack a historical perspective. They tell us very little about whether or not and how the relationship between science and technology has changed over time.

Finally, but perhaps most importantly, these studies tell us extremely little about the actual *mechanisms of interaction* between science and technology. Consequently the correlations that are reported are difficult to interpret.

Let us disregard for the moment the question of the reliability and validity of the measures used in the studies and ask: are the low levels of interaction between the universities and industry reported by several authors a result of the weakness of cognitive links between science and technology, or a consequence of the organizational mismatch between universities and industry? Or, to be even more provocative: is the 30-year gap between a scientific discovery and its technical application, a result of the operation of some natural law, or a consequence of the way in which our R&D system is organized?

From the policy point of view these are crucial questions. Is the scarcity of university-industry interactions an argument for doing nothing, or for redoubling our efforts?

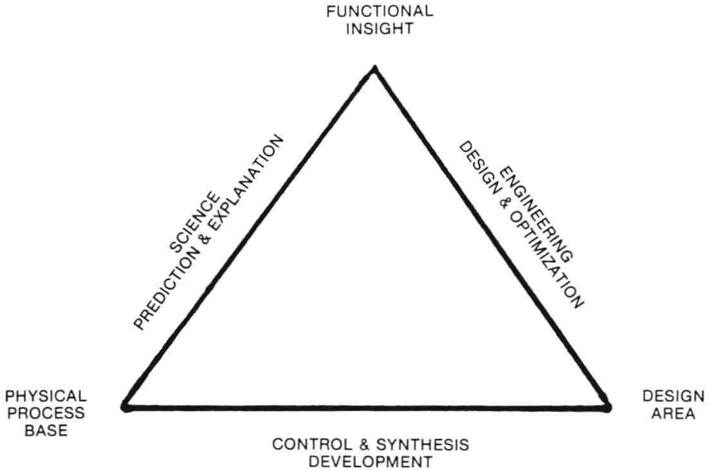
It appears that the studies of the kind reviewed above offer little guidance in these matters. We must instead turn to another type of approach, one which relies more on qualitative historical analysis. In pursuing this approach we should make a distinction between two interrelated but distinct issues: (a) that of the intellectual links between science and technology and (b) the organizational mechanisms mediating these links.

2. The cognitive links between science and technology

In what follows I shall discuss a few historical examples of the interaction between science and technology. Before doing so, however, let me clarify some of the issues by considering the intellectual structure of technology and thus defining the kinds of knowledge inputs which are important in the process of technological innovation.

Every technology may be described in three dimensions: (1) the *function* it performs, (2) the *physical process(es)* which are used to perform the function, and (3) the *design,* i.e. the specific way in which the processes are arranged into a functional whole. This general structure of technology is illustrated by diagram 1.

DIAGRAM 1: The Dimensions of Technological Change



The process leading to a specific innovation can be triggered by an insight corresponding to any of the three dimensions mentioned above, or to a combination of them. It is often argued that the most successful innovations are triggered off by functional insight i.e. the identification of some need combined with a perception of the technical means for satisfying that need. For example, an engineer studying some industrial process may become aware of a source of inefficiency which he feels can be eliminated through the introduction of a new device. The device itself may be technologically quite unsophisticated but functionally/economically highly significant. The functional insight, which is the ability to identify the requirements for the effective operation of some specific system, usually presupposes extensive knowledge of the systems concerned combined with a good measure of creativity.

The innovation process can also be triggered off by a creative design idea. In that case the need may have been well formulated and widely known for a long time. The idea may require no new physical insights whatsoever. What happens is simply that a genuinely new way of putting things together suddenly emerges. Many innovations in such areas as the combustion engine, or computer design are of this kind.

Finally, an innovation may be triggered off by the perception that some property of matter or a physical process (here the term "physical" also includes chemical and biological phenomena), not previously used in that manner, can be harnessed to perform some specified function. The invention of penicillin, radar, radio, nuclear energy are instances of this kind of technical change.

The diagram identifies three distinct activities which tend to be implicated in the technical innovation process. *Engineering* is defined here as the link between "functional requirements" and design ideas. It consists in creating and optimizing designs. The majority of innovations are typically triggered off by functional or design insights and depend chiefly on engineering inputs. If one were to give a more literary definition of what the engineering aspect of innovation is one could say that it is the type of work described in Tracy Kidder's book "The Soul of a New Machine".

By *development* I mean here the activity required to master certain physical processes so that they can be harnessed through design to perform some functions. Development often involves some elements of research. It can be started off by the discovery of new processes or by the recognition of the functional relevance of some earlier known but unexplored processes. It may, however, also be triggered by new design ideas which, even if not based on previously unknown processes, often require improvement and extension of the relevant physical insights. Hugh G. A. Aitken's book about the origin of radio, "Syntony and Spark", illustrates development rather well.

Science, which involves analysis and explanation, can play an important role not only as the source of physical insights underlying developmental work; it can be also very important as the basis of functional insights. In order to elicit effective technological responses our needs must not only be felt but also understood, i.e. linked to physical, chemical, biological, psychological or social insights.

It would be useful to have a history of technology which systematically assesses the relative importance of the intellectual processes described above. So far only fragments of such a history are available. It seems possible, however, to make a few tentative statements about the course of development.

Until the middle of the 19th century technology — or, more correctly, technologies — was largely constituted of self-contained intellectual systems. The practitioners of various arts (techniques) have been relatively self-sufficient in terms of functional insights, design ideas and the knowledge of relevant properties of matter. The interactions with science, in so far as they occurred at all, were relatively sporadic although the two compartments of knowledge were by no means hermetically separated from one another. However, it is a matter of general agreement that from the middle of the 19th century the situation started changing at an accelerating pace. Particularly important in that context was the emergence of the first two science based industries: the chemical and the electrical industry. Both these industries were based on physical insights which emerged from the laboratories of chemists and physicists rather than as the accidental results of tinkering in workshops and factories. These insights were intimately linked to scientific experimental work and were expressed in terms of theoretical concepts quite different from those used in everyday life. From then on "product and process improvement and innovation in some industries have evolved to levels of complexity that demand understanding of fundamental physical and biological phenomena and thus require much higher levels of training in and