Between the ivory tower and the industrial laboratory: universities in the West German innovation system, 1945-1990

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Manuel Schramm & Uwe Fraunholz [*]

Abstract: *»Zwischen Elfenbeinturm und Industrielabor: Universitäten im westdeutschen Innovationssystem, 1945-1990«*. The article provides an evaluation of the role of universities for the West German innovation system. It considers both research and education. On the whole, the balance is mixed. The higher education system, although in principle clinging to the ideals of Humboldt, was flexible enough to accommodate rapidly growing student numbers in the 1960s and 70s. Research was not driven out of universities, but universities lost ground in the competition with extra-mural research institutes. The links between universities and industry were stronger in the 1950s and 1960s than in the 1970s and 1980s. Efforts at improving knowledge transfer since the 1970s can be seen as attempts to make up for loosening informal ties. An assessment of the contribution of universities to labour productivity casts doubt on the assumption that a shortage of human capital acted as a break on economic development.

Keywords: universities, innovation system, Federal Republic of Germany.

1. Introduction

Internationally, German universities are mainly known for their orientation toward the humanistic educational ideal, an ideal which Humboldt tried to translate into reality with the founding of the University of Berlin at the beginning of the 19th century. What the reformer had in mind was the realisation of a *Volluniversität*, i.e. a university including the four then known faculties (theology, medicine, law and philosophy), where the much-praised "unity of research and teaching" could be realised. Professors were not only supposed to be university teachers but also active researchers. Within the framework of their teaching, they were to convey the latest research results to their students. Professors were also seen as free to choose their research themes and were only to submit to an internal scientific rationality. During the next few years, the entire German higher education system oriented itself toward the Berlin model,

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even though, by 1900, it had already crystallised into an ideology and reality had long lost touch with the former ideal (vom Bruch 1997).

After World War II, this avowed orientation toward a Humboldtian ideal underwent a surprising renaissance. The three western occupation forces, as opposed to developments in the GDR, did not pursue a unified concept as far as university policies were concerned. The university officers and university commissioners enjoyed relative freedom: as a rule, they based their decisions on pre-existing structures and transferred operative aspects to the new regional governments. Thus, the extent and the consequences of denazification also diverged (Ellwein 1992, 239-49). From 1945 onwards, too great a proximity to the industry became suspect, since this type of relation seemed to have been delegitimised through national socialist attempts to make science totally subservient to the needs of industry. The professoriate therefore rhetorically clung to older traditions and extolled the humanistic educational ideal in their discourse. Thus the main concern of universities was not to provide a curriculum focused on the acquisition of professional skills but the formation of an individual personality which should have been guided by scientific criteria (Jarausch 1997).

Today there is little left of these noble ideals, ideals which never really materialised. In times of tight public budgets, university education having always been mainly considered as a public task, universities also have to prove their societal usefulness. They must provide diplomas which give access to professional qualification and the research that is conducted there should, if possible, be exploitable on the market. Universities are understood as important pillars of the national innovation system. As pillars, they are supposed to, on the one hand, provide the national economy with scientifically educated personnel and on the other, produce innovations themselves, in order to maintain international competitiveness. In this context, cooperative relationships between universities and businesses become crucial, that is especially the transfer of scientific knowledge from academia to the economy.

Were these links between the universities and the industry successful in the old Federal Republic or were there specific hindrances and barriers rooted in the organisation of the German innovation system, or perhaps even in the long-term characteristics of a German innovation culture (Wengenroth 2001)? Based on a historical review, can a change in these links and their appraisal within the West German higher education system be observed, a change that might stem from a growing orientation toward the American model?

The general research and discussion status on these questions could be sketched as follows. Recent theories and insights from the sociology of science, such as “mode 2” (Gibbons et al 1994; Nowotny et al. 2001) or “triple helix” (Etzkowitz and Leydesdorff 1997), take it for granted that the linkage between universities (or research institutions in general) and companies is getting closer. The “mode 2” of knowledge production involves the dissolution of boundaries, between science and society, between research and teaching, and the de-institutionalization of knowledge production which becomes reflexive, eclectic, contextualized and transdisciplinary (Nowotny et al. 2001, 89-91).

Peter Weingart (2001, 175) talks about an increasingly "tight coupling" between the societal subsystems of economy and science. But he emphasises that the differences between the subsystems remain, because actors can only co-operate synergically if boundaries are clearly defined. For Rudolf Stichweh universities are the "core institution of the knowledge society" (Stichweh 2001, 352). These insights reflect international trends, but as far as Germany and Europe are concerned, the assessment is usually different. The European Commission (1995) mentions a "European paradox", referring to the relatively weak innovation performance of the European economy as opposed to its outstanding research achievements. The efficiency of knowledge transfer between universities and the industry is also specifically questioned in the German case (Keck 1993, 141). Most authors actually see the failing links between these two domains as the "core problem of the German innovation system" (Krücken 2001, 338). The inflexible rules of the federal university legal system, as well as the limited competitiveness incentives provided by the higher education system, are seen as the main causes of this state of affairs. A number of researchers and politicians hold the view that German universities have been undergoing a crisis since the 1980s. This implies that it is not only the actual knowledge transfer that is at stake but also the quality of research itself which is questioned (Stölting and Schimank 2001; Ash 1997).

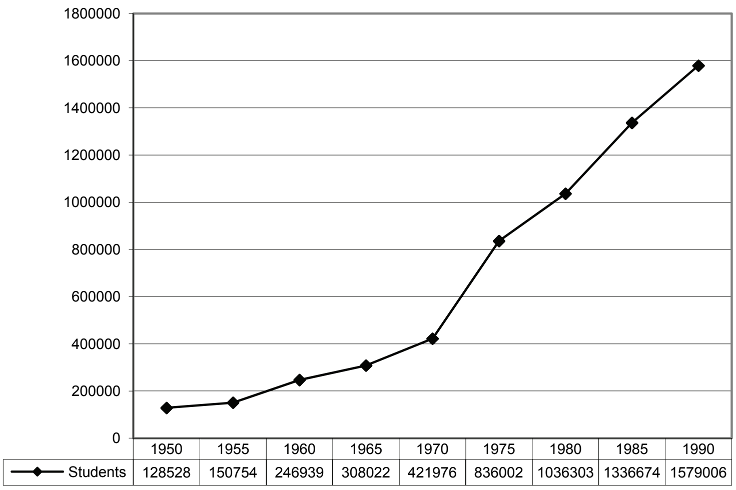
In the following we attempt to sketch the development of universities within the West German innovation system. Our description focuses on the double function of universities: the creation of a human capital that is capable of innovation and the conducting of research that is useful for innovation. Section 2 of this contribution describes the link between education in universities and the German innovation system. Additionally, we provide a short overview of the quantitative development of student numbers. This should enable us to show that technical and commercial colleges (Fachhochschulen) are institutions that provide a scientific education with a strong orientation toward practice and the needs of industry. Finally, linked to the pressure of increasing student numbers, we will examine attempts to reform the higher education system to see how they addressed the apparently incompatible interests of innovation and democratisation. In Section 3, we attempt to sketch the influence of university research on innovation in the Federal Republic between 1945 and 1990. Both basic research, which is primarily conducted in an academic environment, and applied research are considered. Subsection 3.1 provides an overview of how transfer activities are organised in universities and linked to this, discusses the development of third-party funding. Subsection 3.2. looks into the connection between universities and the economy, based on the analysis of the doctorates honoris causa awarded by certain universities. This analysis should shed light on existing networks between universities and other societal subsystems. The final section provides an evaluation of the contribution of universities, both through teaching and research, to the growth of labour productivity.

2. "Non scholae sed vitae": From General Education to Professional Training in Academia

2.1. The Development of Technical and Scientific Human Capital

Traditionally, in the innovation system, the main function of universities is seen as the generation of human capital. The education of highly qualified engineers and natural scientists who are familiar with the newest technologies is usually seen as a precondition for the development of a strongly innovative economy (Abramson et al 1997, 11). From a quantitative point of view, federal universities successfully upheld this function, since, in the Federal Republic, the number of students rose sharply until 1990.

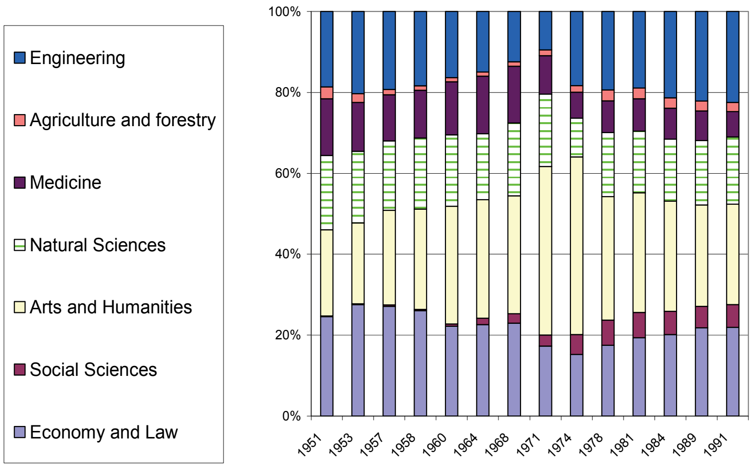
Figure 1: Students in the Federal Republic of Germany, 1950-1990[1]



1 Student enrolment in winter semesters, (Führ and Furck 1998, 652).

In the early post-war years, growth was moderate and contained within the old structures. However, in the second half of the 1950s it rapidly increased. During this half decade, as in the first half of the 1970s, the increase in the number of students was well above the long-term average of approximately 6.5%. After 1975, the yearly growth dropped clearly to the level it had attained 40 years before and at the end of the period considered it represented only 3.4%. Depending on the academic subject, the development was irregular: whilst the number of students in the humanities and social sciences rose by 217 percent between 1960 and 1971, the number of engineering students only increased by 55 percent. In the 1970s again, the highest growth rates could be found within the humanities and social sciences. The overall expansion of the higher education system was thus mainly fostered by academic subjects in these two fields.

Figure 2: Fields of Study at West German Universities and Technical Colleges, 1951-1991[2]



The number of engineering students, whose education is believed to have a major impact on the development of the innovation system, rose more slowly than the overall number of students. Their participation in the total increase sank continuously from approximately 20 percent in the 1950s to 15 percent in the 1960s and to under 10 percent around 1970. In the 1970s and 80s, the percentage of engineering students as opposed to university students in general stabilised, oscillating between 11 and 12 percent. The growth of the engineer-

[2] Statistisches Jahrbuch für die Bundesrepublik Deutschland, various years.

ing domain in the 1970s and 80s (see figure 2) is mainly due to the development of professional engineering schools. Thus, when considering all the student figures, one notices that, in the 1980s, technical or scientific fields represented the same proportions as in the late 1950s.

While the share of students in electrical and mechanical engineering rose within the total number of engineering students, architecture, civil engineering, infrastructural planning, mining and metallurgy statistically lost ground, thus reflecting the general structural changes in the economy of the Federal Republic. In the mathematical and natural sciences fields, the shares of physics and mathematics sank proportionally to the increase witnessed in the new computer science domain. Whilst the relative number of chemistry students was halved, the proportion of students in biology and earth sciences significantly rose. In the 1970s, the share of students in the medical domain dropped to just below 10 percent and then stabilised. (Statistisches Bundesamt, various volumes). In general, traditional universities and Technische Hochschulen were to bear the burden of increasing student numbers, since only a few universities such as Mainz (1946), Saarbrücken (1947) and Berlin (Freie Universität, 1948) had been founded after the war.

2.2. Engineer Shortage and Practical Orientation: The Genesis of Universities of Applied Science (Fachhochschulen)

The beginning of the 1950s witnessed a vivid discussion about an impending shortage of engineers. It was framed within the Cold War systems rivalry. The worries of those who had been warning against Soviet supremacy seemed to find a confirmation in 1957 with the successful launch of Sputnik that came as a shock to the West. The Soviet Union and its Eastern European allies, especially the GDR, seemed to have internalised the postulate whereby a high-tech society needs an increasingly high proportion of engineers among its active population and they renewed their investment in engineering education (Schairer 1956). The GDR could in fact rejoice in the success of its engineering curricula. Amongst its active population in 1960-61, it boasted twice as many graduate engineers as in the Federal Republic. The shortening of engineering studies down to four years fostered another augmentation in the number of engineering graduates: in 1974, 13% of the young people belonging to the same age cohort became engineers as opposed to 2.6% in the Federal Republic (Wolter 1990, 86-90).

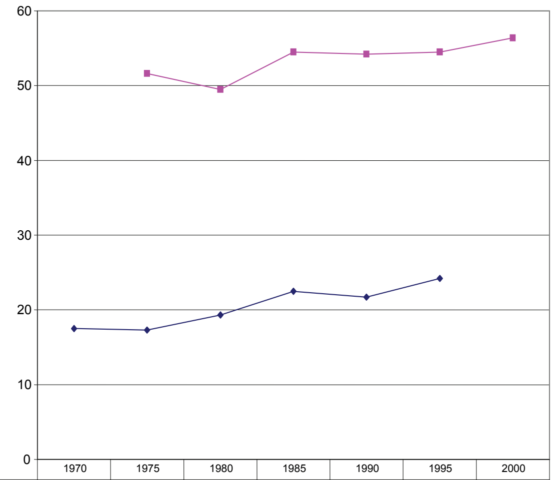
In the 1950s, even though engineering schools were also further expanding in the Federal Republic and the number of students in engineering curricula at technical universities also increased by 50 percent, this sector remained below the average growth rate of student numbers. Thus the absolute number of engineering students only greatly increased because the overall number of students also rose sharply. This was due to the fact that, at that point in time, technical colleges (Ingenieurschulen) were transformed into universities of applied science (Fachhochschulen) in order to compensate for the absence of a shorter and more attractive academic engineering curriculum. Protests and demonstrations, linked to the unclear international recognition of diplomas, were orchestrated by the ever increasing group of engineering school students. From 1968 onwards, they were also supported by professors. This tense political climate induced the governments of the Länder (the German states) to quickly introduce a reform. Because the rapid change in professional standards required a stronger theoretical foundation in education, the prime ministers of the Länder agreed to establish universities of applied science (Fachhochschulen), establishments which would mainly stem from existing engineering schools.

The aim of these colleges was defined as providing teaching related to practice. This education was seen as based on scientific principles and was supposed to be geared toward independent activity in a professional environment. In the context of this educational mission, universities of applied science could conduct their own research and could take on R&D tasks (Lundgreen 1994, 44-50). This organisation matched that of the Technische Hochschulen in many respects, so the recommendation made by the academic council to introduce shorter engineering studies in Technische Hochschulen became obsolete. Thus, in striking contrast with the original plans, the Technische Hochschulen emphasised theoretical aspects and strengthened their scientific orientation, a move which lengthened the engineering curriculum and reinforced the distinction between Technische Hochschulen and universities of applied science.

From the 1970s, the proportion of students attending universities of applied science within the total number of students rose slowly and almost reached one quarter by 1995. Approximately half of the entire university of applied science population study engineering, but these students represent more than half of all engineering students (fig. 3). Economics and social sciences are also strongly represented in universities of applied science. However, mathematics and natural sciences are mostly represented through computer engineering.

Linked to the growing quantitative significance of the universities of applied science, there arises a demand for full academic recognition as epitomised by efforts to obtain the right to award doctorates. This striving toward proximity with universities initiated by the newcomers, also described as "academic drift", represents a trend that has long been present internationally. However, in this field, German universities of applied science only started meeting with substantial success in the course of the 1990s. In the 1980s, the German Science Council (Wissenschaftsrat) had still vehemently voted against a convergence with universities and Technische Hochschulen and had emphasised the orientation toward application in both teaching and research as a characteristic of universities of applied science (Oehler and Bradatsch 1998, 435).

Figure 3: Share of Students at Universities of Applied Science Among all Students and Share of Engineering Students at Universities of Applied Science Among all Engineering Students, 1970-2000[3]



	1970	1975	1980	1985	1990	1995	2000
Share of students at universities of applied science as % of all students	18	17	19	23	22	24	
Share of engineering students at universities of applied science as % of all engineering students		52	50	55	54	55	56

2.3. Incipient Reforms Under the Sign of Mass Universities

The German Science Council was founded in 1957 as a consulting and coordinating institution and was composed of researchers and politicians from both the federal and the Länder levels. In 1960, the Council's first sizable study heralded a new era in university policy. Even if the recommendations therein were not legally binding, they still proved influential (Benz 1998; Bartz 2007). Amongst the politicians entrusted with the education question on the federal level, it enabled the breakthrough of the view that considerable investments would be needed in the new universities born of the reform. These investments would be necessary to ensure a continuous development of the national innovation system and to maintain international competitiveness. Specific recommendations about the number, the structure and location of new universities as well as about the expansion of existing universities led to above average investments and a number of new establishments. Between 1965 and 1975 alone, 24 new universities were founded. Along with their traditional mission of provid-

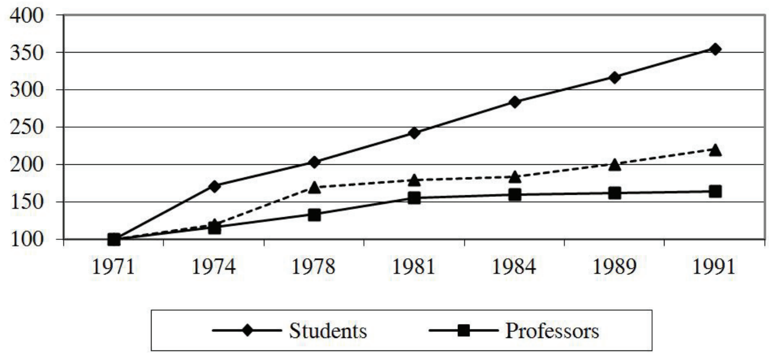
[3] Oehler/Bradatsch 1998, 417. Verein Deutscher Ingenieure: Studierende und Studienanfänger-/innen – Fächergruppe Ingenieurwissenschaften, <http://194.245.72.99/ index4.php> (accessed 08. 01.04), Before 1990 West Germany, thereafter all Germany.

ing "research and teaching", they were also to offer new curricula. From that point onwards, experimenting with reform concepts was on the agenda and "interdisciplinarity" as well as "application-orientation" became the contemporary buzzwords (Handel 2001, 279-99; Schimank 1995, 62).

However, it was the debate on the so-called "education emergency" in the mid-1960s which first enabled the discussions on the inadequacies of the higher education system to reach a broader audience, debates which until then had been conducted in professional circles only. The need for specialisation increasingly questioned the former highly praised "unity of the sciences" and the growing number of students enrolled threatened the "unity of research and teaching". The old education model apparently contradicted the mission of educating a professional elite for the modern industrial society. It was claimed that the small number of high school graduates led to a lack of highly qualified professionals (Picht 1964).

In 1977, linked to the heightened demand for student places in the wake of the baby-boomers' coming of age, the federal and Länder governments declared that universities should expand and that barriers to access should be reduced. They had counted on a limited overload, a temporary excess of students. In any event, the number of students grew continuously until the German unification process of 1989-90 and the imperative to expand was not linked to additional financing. Instead, from the beginning of the 1980s, higher education expenditures stagnated. The financial crisis of the Länder was drastically reflected in the basic funding of universities. These financial difficulties were partially overcome by means of third-party funding. Thus, in the 1980s, third-party funds almost doubled, while state funding froze at the previous level, despite the further student increase. A decade earlier, under the pressure of massively increasing student numbers, the financial and personnel resources available were mainly concentrated on the teaching dispensed in extremely popular fields. Linked to this, it was feared that basic research at universities could be increasingly limited. In other words, the talk was often about a suppressive pressure of teaching upon research (Schimank 1995, 40-96). In fact, however, individual time budgets did not shrink. But the growth in scientific personnel could obviously not match the startling escalation of student numbers, which entailed a deterioration of supervision. Research capacities were not curbed but the time available for teaching and supervising was spread between more and more students. The supervision relationship between professors and students steadily worsened and the quality and intensity of this supervision declined. Thus, the lengthening of studies beyond what was originally foreseen became the inevitable consequence of this situation.

Figure 4: Development of Numbers of Students, Professors, and Academic Staff, 1971-1991 (1971=100)[4]



Whilst capacity in terms of scientific personnel only grew very slowly from the 1970s, student numbers shot up during this period. Nevertheless, as a result of university expansion in the 1960s and 1970s, the number of research positions grew more rapidly than that of students so that in 1990 the relation between the two was approximately the same as it had been in 1960 (Schimank 1995, 62, 64, 76). The main feature of this development was a conversion to an "assistant-university", in which the main teaching burden is shouldered by the "Mittelbau", i.e. the non-professorial teaching staff. Hence university teaching conditions, as opposed to research conditions, continuously deteriorated from the 1960s onwards. Additional research capacities were built in settings outside of the universities, such as the Max Planck Society, the Fraunhofer-Gesellschaft or in national research centers (Szöllösi-Janze and Trischler 1990; Ritter et al. 1999). Between 1963 and 1987, the share of the industry in domestic R&D expenditures increased from 59 to 73%, and the rest was evenly distributed between universities and extra-university institutions (Hohn and Schimank 1990, 50). But it should be noted that approximately 90% of researchers in the industry are responsible for development activities (Schimank 1995, 18-9.). This implies that universities still hold the high ground in terms of basic research, even if they often co-operate with other research institutes.

Thus, one can hardly talk about a relocation of research out of universities. However, from the 1980s on, university professors were increasingly encouraged to look for additional funding for their research. A frequently propounded argument was that this move would run counter to the apparent transformation of universities into "purely teaching" establishments. The ensuing orientation

[4] Statistisches Bundesamt: Statistisches Jahrbuch der Bundesrepublik Deutschland, various years, Personal an Hochschulen: wissenschaftliches Personal ohne Verwaltungskräfte.

toward third-party funding strengthened the universities' submission to the goals of the industry, even if the largest part of this third-party funding was provided by public agencies such as the German Research Foundation (Deutsche Forschungsgemeinschaft). The proportion of "indirect" funding stemming from public sources varied between 70 to 80% between 1970 and 1990, before dropping to about two thirds in the 1990s (Wissenschaftsrat 1993, 55; Wissenschaftsrat 2000, 57). These additional means were needed to maintain both teaching and research activities.

In sum, the West German higher education system could be praised for a certain democratisation of access to studies and a differentiation within the curricular offer, a development that was translated into the university of applied science system. As to the quality of the education provided however, the assessment is mixed. If some of the reformed curricula really did justice to the needs of the innovation system, the miserable supervision relations characteristic of the mass university contradicted the aim of a rapid and high-quality education.

3. Universities as Motors of Innovation?

Whereas the role of universities in innovation systems is an established research field (e.g. Noble 1977; Rosenberg/Frischtak 1985; Shapin 2008), it is only recently that historians of science and technology especially have systematically explored the question of technology transfer in post-war Germany (Lieske 2000; vom Bruch and Trischler 1999). It is difficult to come up with general conclusions about the Federal Republic's higher education system, since the connection between university research and innovations varies from branch to branch as well as from discipline to discipline. As a rule, the link between Technische Hochschulen and the industry is closer than the one between the latter and "classical" universities (see König 1990). There have traditionally been connections with science-based industries such as chemistry, electrical engineering, and to some extent precision mechanics and optics. However, in Germany, biology, for example, had little contact with the industry until well into the 1980s.

3.1. Third-Party Funding, Associated Institutes, and Technology Transfer

Third-party funding has been playing an increasingly important role for the financing of universities during the last two decades. The proportion of this type of funding effectively increased by 40% between 1980 and 1990, whilst basic funds nominally increased during this period, but, due to inflation, actually stagnated (Wissenschaftsrat 1993). However an overwhelming proportion of this third-party funding's origin is public. Even in 1993, funds by the industry only amounted to 1.4% of universities' entire expenditures (Wissenschaftsrat 2000). Reliable statistics on third-party funding have only been available for the past few years, which means that, when considering long periods, no definite conclusions can be formulated. However, information is available about the proportion of the industry's external (outsourced) R&D expenditures which universities have benefited from. This figure dropped from 20.9% in 1964 to 12% in 1971, 9.5% in 1977 and 8.2% in 1991. It then only slightly grew, reaching 10% in 1997 (Stifterverband 1964; Wissenschaftsrat 1975, 136; 2000; Häusler 1989). Despite the absolute increase in third-party funding, universities have thus effectively lost market shares from the 1960s onwards. Therefore, universities' third-party funding in absolute figures proves rather misleading as an indicator, since it does not take into account the increase in the industry's external R&D expenditures.

So-called "An-Institute" (associated institutes) represent an institutionalised form of collaboration between universities and industry. They are scientific institutes that are not part of the university. They are often legally organised as registered associations and have a contractual relationship with a particular university (Wissenschaftsrat 1987, 98-9.). Their financing consists entirely or mainly of third-party funding, i.e. it is not drawn from the university budget. As a rule, the statutes stipulate that the independence of the institute is guaranteed by the main investor. The institute director is generally a professor at the relevant university. And the institutes are mainly devoted to either basic or applied research that is relevant for specific branches of the industry, but hardly or not sufficiently represented in the universities. An example is the "Kautschuk Institut" (Rubber Institute) founded as early as 1943 at the Technische Hochschule Hannover. In 1951, it was transformed into a foundation of the "German rubber industry" business association. Another example is the Deutsche Kunststoff-Institut (German Institute for Synthetic Materials) founded at the RWTH Aachen in 1950 (Unternehmensarchiv Bayer 151-20, 302-909). In 1989, 1930 workers were employed in these associated institutes of the Federal Republic. 1774 of the 1930 employees were active in R&D. Their expenditures amounted to DM 249 million. However, this figure is relatively modest since it represents 1.8% of the university's total expenditures, or 2.5% in terms of R&D personnel (BMBF Forschungsbericht 2000, 492, 500, 520, 538). Nevertheless, the "An-Institute" were generally perceived positively because they displayed a greater flexibility than university institutes (Wissenschaftsrat 1987).

Since the 1970s and 80s, a number of Länder governments and universities have made attempts to support technology transfer through the establishment of transfer or contact bureaus, in a much more goal-oriented way than previously. The main focus was a collaboration between universities and small and medium-sized enterprises (SMEs). But these steps should be read more as a political strategy toward small business rather than as a new measure within research and university policy. Nowadays, almost all German universities have a technology transfer or contact bureau.

The main task of these bureaus is to process external inquiries and to provide the mediation necessary to make relevant contacts (Mittag and Stracke 1987; Stracke 1990; Weitkamp 1992, 250). SMEs in particular lack the overview needed to be able to assess which contact might prove the most relevant for their concrete problems. Thus the transfer bureaus contribute to the development of research contracts, hence also to the securing of third-party funding through this mediation activity. But since the main aim of these organisations is not the raising of funds but the facilitation of technology and science transfer, assessing them solely on the grounds of the funding they have been able to secure is a problematic venture. The concrete activity of the transfer bureaus lies more in the middle ground between establishing contacts and actively seeking third-party funding. Another important task is supporting the establishment of technology-oriented university spin-offs.

The origins of these contact bureaus go back to the 1970s, even if their wider dissemination is more of a 1980s phenomenon (Weitkamp 1992; Buchholz 1990, 194f.). At the beginning of the 1970s, the first generation of these institutions was located in technical colleges. In 1969 already, the Baden-Wurttemberg Ministry of Commerce and Industry launched a first attempt in the field. SMEs could obtain advice about technical questions by engineering school professors against payment. The ministry first shouldered the costs entailed by these advice bureaus (HSTAD NW 502, 748). Then, the Steinbeis Foundation, supported by the Länder government, the universities and large research institutions, was created in 1971 (Weitkamp 1992, 251). Today, this foundation still provides technical guidance.

"Unikontakt", the first university-based contact bureau, was created at the Ruhr-Universität-Bochum in 1976. 60% of the projects mediated during the first phase, i.e. until 1979, were carried out with partners from the Ruhr region. However, only 23% led to collaborations with SMEs (Meyer-Dohm 1980, 16-18). The model experiment attempted in Tuebingen between 1980 and 1986 proved more successful in that it mainly supported local SMEs. During this time span, out of the approximately 600 requests, two thirds stemmed from outside academia, and from this proportion, 80% out of the industry. 73% of the companies were based in Baden-Wurttemberg and 70% belonged to the SME category. The main fields were microelectronics, materials and analytical chemistry. Within the community of university researchers, it was chemists and physicists who proved particularly open to contacts with the industry (HSTAS EA 3/906, 676a Bd. 5). The Tuebingen model experiment was further pursued since it was eventually transformed into a research contacts department within the central administration of the university. In the 1980s, contact bureaus also spread to other regions.

Despite this seemingly successful history, transfer and contact bureaus remain disputed. Whilst many researchers recommend an extensive transfer bureau coverage in order to cater to the needs of SMEs (Weitkamp 1992, 186), quantitative studies are more critical, arguing that only a limited amount of the contacts between companies and universities are mediated through the transfer bureaus (Elle 1998; Wilhelm 2000). The participation of the bureaus in the securing of third-party funding is similarly rather modest. Therefore, the significance of transfer bureaus should not be overestimated. It should be emphasised that they do not signal a fundamental transformation of universities into a service industry, as it has been assumed until recently (Bultmann and Weitkamp 1999, 38-40). Nevertheless, it seems plausible that, for regional SMEs, they meaningfully supplement universities' transfer potential (Allesch 1988, 107).

3.2. From Basic to Applied Research? Networks between Universities and Companies

The institutionalised transfer activities described above only cover one dimension of technology transfer. Another dimension, which is more difficult to assess, it that of informal networks between university researchers and industry representatives – either researchers and developers or general managers. Obviously, it cannot be contested that this type of informal relation dates back to the 19th century, but it proves methodologically quite a challenge to map out the varying intensity of these relations. A recent study of university-industry linkages in Germany uses co-publications as indicator (Krücken et al. 2005). It covers the period 1980 to 2005 and finds that publications with at least one author from a university and another from a business enterprise have significantly increased over time. However, there are several problems with this approach: First, only data from the Science Citation Index, which underrepresents German journals, are easily available. It is not clear how this affects the measurement of co-publications. Second, co-publications are a special form of cooperation and probably not the most common one. They do not cover informal connections like consultation, information exchange etc. Third, co-publication is notoriously open to strategic manipulation. Bibliometrical studies have shown that authors choose their co-authors not according to competence but according to prestige (Wagner and Leydesdorff 2005). This is especially salient since the German government has started to finance university-industry networks in fields such as biotechnology since the 1980s (Fier and Harhoff 2002, 290). University researchers might therefore list more co-authors from business enterprises than there have actually been in order to demonstrate the existence of networks and attract funding.

We suggest, a useful indicator of the links between universities and other realms of society are honorary titles. Basically, there are three reasons for this:

first, the data are readily available. Second, universities usually limit the number of honorary titles they award each year (UAS 65/193) which means that there have to be good reasons for awarding a title. Third, the titles have so far not been used by universities to demonstrate close links to industry. That means they are not open to strategic manipulation in the same way as co-publications are.

In the following, we will attempt to sketch the development of informal networks using the example of honoris causa doctorates awarded by four Technische Hochschulen of the Federal Republic. The lists of honorary doctorates consulted include those of the Technische Hochschulen of Aachen, Braunschweig, Darmstadt and Munich, towns which are located in four different Länder (North Rhine Westfalia, Lower Saxony, Hesse and Bavaria).[5] The total of 677 recipients of honorary doctorates between 1946 and 2002 was divided into three categories: researchers affiliated with universities or other state research institutions; politicians, employees of the administration or the military; and finally, representatives of companies and trade associations. In most cases, it proved easy to assign individuals to one of these three categories.[6] We assume that a higher proportion of doctoral awards conferred upon the members of one domain (e.g. business) indicates intensified relations between universities and the corresponding sector of society during a particular time span. Technische Hochschulen were chosen because of their more obvious orientation toward practice and applications in the fields they represent, thus entailing a particular potential for technology transfer.

Fig. 5 shows the result of the statistical evaluation of all honorary doctorates awarded by the above-mentioned Technische Hochschulen. The proportion of individuals honoured stemming from the political/administrative sphere remained small, with figures ranging between 2 and 8%. The ratio of researchers increased continuously from 36% between 1946 and 1959 to 68% (i.e. more than two thirds) between 1990 and 2002. In contrast, the share of business representatives decreased from 54% between 1946 and 1959 to 26% between 1990 and 2002.

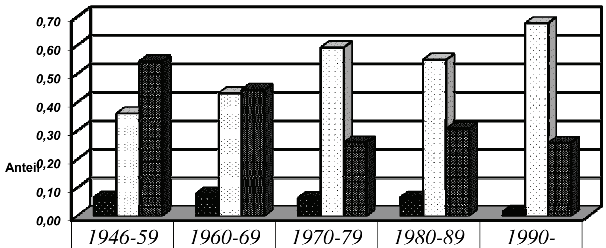
In the period of the 1950s and 1960s, the connections between Technische Hochschulen and companies were stronger than during the last period considered. However, the growth of the humanities faculties at the Technische Hochschulen should also be taken into account. It can be supposed that an

[5] The lists were compiled from the following sources: Hochschularchiv Aachen; Archives of the Technische Universität Braunschweig and Darmstadt; Habetha 1995; Dienel/Hilz 1993. We would like to thank the archivists for their friendly collaboration as well as the student-assistants Susanne Fragel and Stefanie Knebelspiess for their support with the data entry.

[6] What remained unclear though was the distinction between graduate engineers and doctors in engineering, whom we both assigned to the economic sector in our analysis. Otherwise, the downtrend in business representatives would have been even more marked whithin the period considered.

altered spectrum of subjects leads to a different distribution of honorary doctorates, since, as a rule, this type of title is awarded upon the recommendation of a faculty and that traditionally, humanists have less close links with the industry. This is the reason why fig. 6 only takes the titles awarded at the request of engineering faculties into account. These make up more than half of all titles in the sample. In fact, in these cases, scientists are slightly less strongly represented and representatives from the industry slightly more than in the entire sample. But the trend remains the same: the proportion of scientists grew from 29% between 1946 and 1959 to 52% between 1980 and 2002, whereas during the same period the percentage of industry representatives dropped from 59 to 35%.

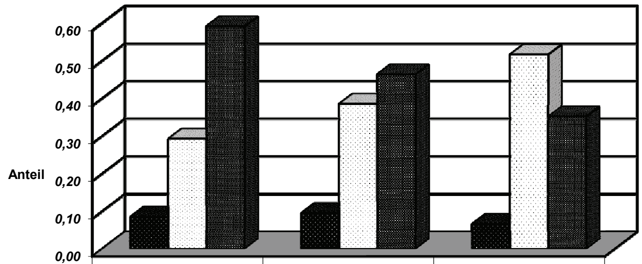
Figure 5: Honorary Doctorates at Technische Hochschulen, 1946-2002
(N = 642)



	1946-59	*1960-69*	*1970-79*	*1980-89*	*1990-2002*
Politics/Administration	*0,07*	*0,08*	*0,06*	*0,07*	*0,02*
Science	*0,36*	*0,43*	*0,59*	*0,55*	*0,68*
Economy	*0,54*	*0,44*	*0,26*	*0,31*	*0,26*

Thus, at least for the Technische Hochschulen, the trend is unmistakable. Despite all attempts to encourage contacts with the industry in order to facilitate technology transfer, and to anchor these contacts institutionally with e.g. transfer bureaus, the German academic system is characterised by a growing self-referentiality on the level of networks. Closer links with other societal domains or the blurring of boundaries between subsystems, as postulated by new premises developed by the sociology of science (especially “mode 2”), cannot be confirmed on the basis of the available data. These figures therefore confirm the trend which was also recognisable since the 1960s, whereby a diminishing proportion of universities took part in the externalised research and development activities of the industry.

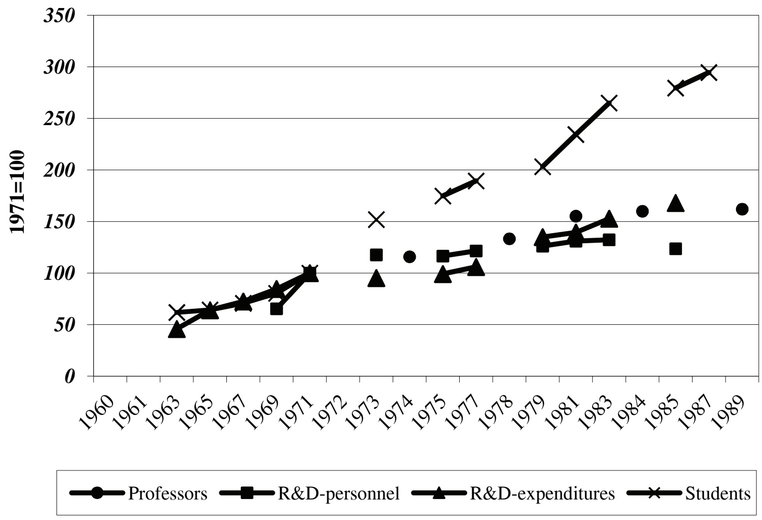
Figure 6: Honorary Doctorates at Engineering Faculties of Technische Hochschulen: 1946-2002 (N = 434)



	1946-59	*1960-79*	*1980-2002*
■ *Politics/Administration*	*0,09*	*0,09*	*0,07*
□ *Science*	*0,29*	*0,39*	*0,52*
■ *Economy*	*0,59*	*0,46*	*0,35*

This decrease in density of cooperations between Technische Hochschulen and the industry could hypothetically be explained by the expansion of the former. In this perspective, an increasing number of new professors would not have found a correspondingly expanding market for industrial research. Thus, the increase in the numbers of students and lecturers would have led to a “dilution” of a persistent academic culture. Hence, the decrease in cooperation density would not represent a change in actors’ preferences but simply a consequence of sheer quantity coupled with an asynchronous development. Fig. 7 shows that this potential objection, whereby the mass of academics might have overwhelmed the absorptive capacity of the R&D market, is only accurate to a small extent. In the 1960s, the growth rates of inflation-adjusted inland R&D activities of the industry approximately corresponded to the increased intake of students. It was only in the 1970s that student numbers really exploded, whilst R&D activities continued to increase regularly. However, the increase in the number of professors who would have been decisive for the securing of third-party funding did not keep up with the growing number of students. In the 1970s and 80s, the increase of professors never reached a level that would have justified reducing the above results to a consequence of sheer quantity. Rather, R&D activities in the industry grew only slightly more slowly in the 1970s, before catching up with the increase of professors in the 1980s. As far as the R&D personnel at the universities is concerned, the same is valid: in the 1970s the growth in this domain was greater than the increase in industry-based R&D activities, but in the 1980s, it was below this rate.

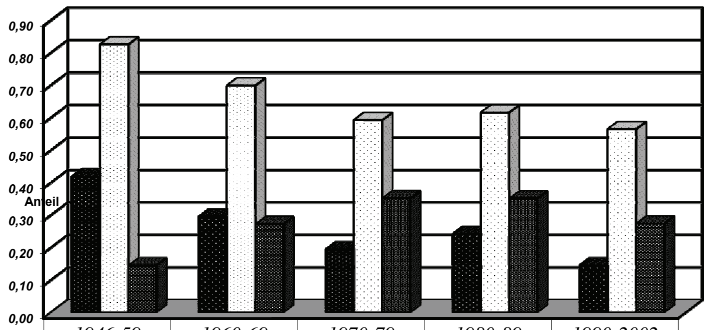
Figure 7: Development of Real Private Domestic R&D Expenditures, of R&D Personnel at Universities and Technische Hochschulen and of Students and Professors, 1960-1989[7]



The lists of honorary doctorates allow us not only to draw conclusions about the awarding of titles across societal categories but also provide insights into their geographical distribution. The decisive factor in this respect is not the place of birth but the place of residence or work. The analysis of changes in this distribution can help us to answer the question whether the main characteristics of the networks of the Technische Hochschulen are regional, national or international. A clear trend can be discerned for the entire sample: that of the internationalisation of corresponding networks (Fig. 8). The proportion of foreign honorary doctors (i.e. in this case of individuals working in foreign countries) grew from 15% between 1946 and 1959 to 35% between the 1970s and 80s. The 1960s seem to represent a clear break since during that period, the proportion of honorary titles awarded to "foreigners" reached 27%. Conversely, the proportion of "domestic" titles dropped from 83% between 1946 and 1959 to 56% between 1990 and 2002. The proportion of honorary doctorates awarded within regions (i.e. states in our case) fell from 42 to 15% during the same time span.

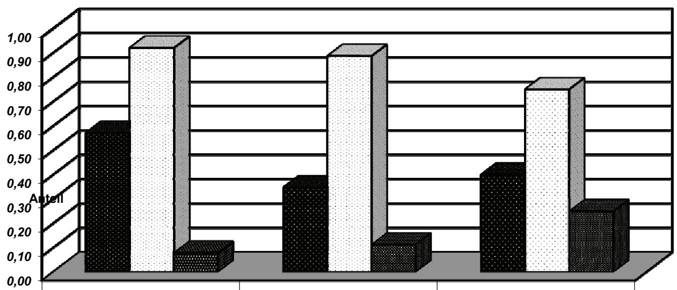
[7] Hohn/Schimank 1990, 51-2; Statistisches Bundesamt: Professors, see Fig. 3.

Figure 8: Honorary Doctorates at Technische Hochschulen, 1946-2002
(n: 677)[8]



	1946-59	*1960-69*	*1970-79*	*1980-89*	*1990-2002*
■ *Region*	*0,42*	*0,30*	*0,19*	*0,24*	*0,15*
□ *Germany*	*0,83*	*0,70*	*0,59*	*0,62*	*0,56*
▪ *Abroad*	*0,15*	*0,27*	*0,35*	*0,35*	*0,27*

Figure 9: Honorary Doctorates to Business at Technische Hochschulen,
1946-2002 (n: 281)



	1946-59	*1960-79*	*1980-2002*
■ *Region*	*0,57*	*0,35*	*0,40*
□ *Germany*	*0,92*	*0,89*	*0,75*
▪ *Abroad*	*0,08*	*0,11*	*0,25*

These figures thus provide us with an overall trend but could be distorted due to the varying distribution of honorary titles across time. Thus the internationalisation observed could be attributed to an increasing proportion of foreign researchers. Nevertheless, for the investigation of universities' place within the

[8] Note that figures add up to more than 100% because "region" is a subset of "Germany".

innovation system, the links between universities and the industry are particularly interesting. Fig. 9 therefore shows the spatial distribution of honorary doctorates in the economic realm across time. The internationalisation trend discovered above can also be found here but with a time lag and weaker. In the economic realm, internationalisation only developed in the 1980s, when the proportion of "foreign" titles reached 25% (compared to 11% in the 1960s and 70s). The share of honorary doctorates bestowed regionally was still 40% between 1980 and 2002, i.e. a proportion similar to that between 1900 and 1945. It was only between 1946 and 1959 that it reached a higher level, that is 56%. In sum, networks between Technische Hochschulen and companies are characterised by an increasing internationalisation (in recent years) as well as by a persistent regional anchorage of universities.

4. The Contribution of Higher Education to Labour Productivity

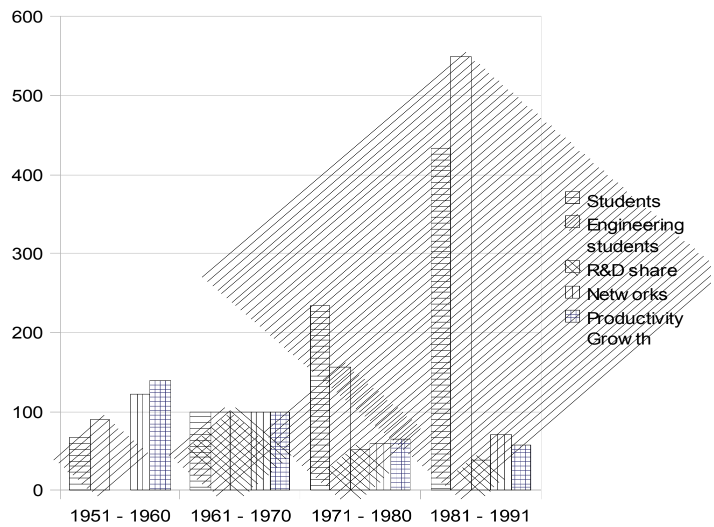
To evaluate the contribution of universities to innovations, it is necessary to put the preceding figures into perspective. The best quantitative evaluation would be to test a comprehensive model that contains the contribution of universities in terms of human capital formation and research results as input variables and the number of innovations as output variable. However, it is difficult to measure innovative activity directly.[9] Moreover, innovative activity depends on a number of variables, not all of which are known. So it is difficult to control for other factors like government policy, business size, the development of markets, globalization etc.

Therefore, we take labour productivity as a proxy for innovative activity. The basic assumption is that an innovation is not an end in itself, but (if successful) contributes to productivity growth. In the following figure, we contrast the average yearly productivity growth in the Federal Republic of Germany between 1951 and 1991 with four variables. For the contribution of universities to human capital formation, the share of students in the population is taken, both all students and only the engineering students. For the contribution of universities to research (with regard to innovations, not research as a whole), two variables are chosen: first the share of universities in the external R&D expenditure of industry; second, the university-industry networks as measured by the honorary doctorates explained in section 3.2. For each variable, an average for a decade is taken. To make the figures comparable, we take the decade 1961-70 as 100 instead of giving absolute figures, so the relative development comes out more clearly. However, we assume that there is a time lag between

9 For diverse strategies to measure innovation see e.g.: Spoerer, Baten, Streb 2007; Moser 2011.

the input of human capital formation and research and the output of productivity growth. Therefore, we compare the four input variables with the productivity figures for the next decade. The results are presented in figure 10.

Figure 10: Student Numbers, University-Industry Networks and Labour Productivity Growth, 1951-91 (1961-70=100)[10]



It shows clearly that the rates of productivity growth have declined markedly since the 1950s, whereas the share of students in population (both in general and engineering students in particular) has increased by a factor of 6 or more. Of course, this does not mean that rising student numbers are the cause for a slowdown in productivity growth. However, the figures cast doubt on the assumption that a shortage of human capital was a bottleneck in the economic development of West Germany, as has been claimed repeatedly, e.g. in the 1950s or 1960s as well as more recently.

The other two variables show a different pattern, one that is roughly in line with the development of labour productivity which means they show a downward trend. Again, this need not be a causal relationship. However, it seems

10 Sources: Labour Productivity: <http://www.bundesbank.de/statistik/statistik_wirtschaftsdaten_tabellen.php#wirtschaftsentwicklung> (02.02.2012); Student numbers: Statistisches Bundesamt: Statistisches Jahrbuch der Bundesrepublik Deutschland, various years; Share of R&D: Stifterverband 1964; Wissenschaftsrat 1975, 136; 2000; Häusler 1989; networks: see footnote 5.

plausible that the weakened links between universities and industry contributed to a slowdown in productivity growth. Even if the high growth rates in the 1950s are excluded because of the reconstruction effect after World War II[11], there is still a considerable decline since the 1960s which has to be explained. Probably several factors were at work here, but the weakening research and development cooperation between universities and industry is one factor which has been overlooked so far.

Abbreviations

HSTAD	Hauptstaatsarchiv Düsseldorf
HSTAS	Hauptstaatsarchiv Stuttgart
SMEs	Small and medium-sized enterprises
RWTH	Rheinisch-Westfälische Technische Hochschule
UAS	Universitätsarchiv Stuttgart

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[11] There is still a considerable divergence of views among economic historians over the causes of the German "economic miracle". However, reconstruction effects certainly played a role. Abelshauser 2004: 275-284; Temin 2002; Eichengreen/Ritschl 2008.

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