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Moving one goose ahead:
Catch-up strategies of the German system of innovation.
The case of biotechnology

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1. Summary

The accelerating pace of internationalization has increased industrial competition and the urge to innovate. Modern technological development has often been determined by nation states that were identified as technological „leaders“. Other nations have sought catch-up strategies to imitate the success of the role model. Catch-up strategies, however, have often turned out differently than intended. This is due to national specific institutional arrangements that are historically grown. Institutional arrangements cannot be imitated or changed easily because they usually support traditional innovation and production systems that are dominant in a particular nation. An attempt to rearrange this innovation and productions system would endanger the dominant mode of economic institutional organizations.

This paper is a brief overview on a 30-year effort to rearrange the dominant German innovation and production process in such way that it would support the emerging biotech industry. In doing so, German actors have looked to the U.S. model of biotech development and have tried to imitate its prevailing features. This, however, cannot be interpreted as a sign of international convergence toward one best-practice model. Rather, all these new strategies are German by origin because, to a high degree, they are rooted in the German institutional arrangements and have not called the dominant pattern of innovation and production into question.

2. Introduction: The limits of catch-up strategies

Two major events have inspired a renaissance of the debate on innovation and growth the in 1980’s. One event was the macro economic transformation and replacement of international leadership in several high-growth sectors (Nelson & Winter 1982, Freeman 1987, etc.). Take, for example, the sector of semiconductors and electronics, where Japan, a former NIC, rose from the ashes to challenge US dominance on the international markets. A plethora of studies have been published to describe and explain this and other similar phenomena. New theoretical approaches and „schools“ were nurtured by the new organization of capitalism. The second event was the end of communism paralleled by the reclaimation of US leadership on the international market. This was interpreted by many as the overall victory of Anglo-American style capitalism. On the theoretical level, this event has nurtured the discussion on national path dependencies versus international convergence. The issue of whether one style of capitalism has been dominant and could serve as a best-practice model to others or whether national paths in a globalizing world still matter remains open for debate.

According to the goose model applied in modernization theory, one of the geese in a swarm takes the lead and the others form a horizontal V following it. In order to reach their destination, they have to follow the path of the leader. This model is used to demonstrate catch-up strategies (Vernon 1963). This paper is going to argue that following the flight of the leading goose means that the others will come in second, third, or farther behind but will never be first.

Geese are not nation states, of course, and the imitation strategy of a best-practice model will in many cases not work with other nations, because they have a different institutional setup. This institutional arrangement has developed historically and is, therefore, path dependent and cannot be changed easily. Institutional inertia and thickness (Amin & Thrift 1994) block many efforts to modernize and adjust structures that would imitate the success model. Hollingsworth & Boyer et al. (1997) have discussed the path dependency of national and regional institutional dependencies in modern capitalism in great detail. Scholars of „National Systems of Innovation“ have argued similarly, concentrating on institutional arrangements that determine innovation processes. Streeck (1991) has pointed out that some national styles differ in such a way that one national institutional arrangement supports „diversified quality production“ (DQP) as in Germany whereas another institutional arrangement may support industries that are characterized by more flexible organizational forms serving short-term, high-risk market-based economies as in the U.S. This is not to say that other types of economic organization could not exist in a nation. Rather, the argument is that one type of institutional arrangement is dominant (Hollingsworth 1997) just as the metal-working, auto, engineering and chemical sectors have been dominant in Germany and the institutional arrangement to support these sectors still exist, even though information technology is overtaking these traditional sectors. The dominant structures, however, hamper the shift to a more flexible and volatile liberal market economy that would reward risk takers with high performance incentives upfront and punish inertia. These latter market patterns are more supportive of emerging high technology industries as they develop in the U.S. In comparison to the U.S., the German system’s high technologies such as biotechnology have been underperforming.

However, this paper will use the German case to demonstrate that, major actors - government, industry and academia - involved in the German system have undertaken several efforts to rearrange the institutional setup in order to facilitate biotech innovation and industrial development in the pharmaceutical sector. In doing so, they have chosen the U.S. model as a best-practice model. As will be shown, this model cannot easily be imitated, because dominant

institutional arrangements can be adjusted only over a long period of time and require a fair amount of institutional learning. Thus, the challenge is to find strategies that pose no threat to the dominant institutional arrangement and at the same time provide the necessary „economic ecology“ for the advancement of biotech industry and innovation.

Taking into consideration the already mentioned approach of „National Systems of Innovation“, one central argument is that nations differ in their institutional social and economic arrangements, and these arrangements affect their different innovative performance. The approach of ”National Innovation Systems” is used in order to define those variables (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997). These comprise a set of factors in any nation which generate, select and diffuse innovation. Depending on the nation and technology analyzed, this set of variables can be constituted as the various government actors and institutions involved in shaping and enacting technology or economic policy: academic research institutes, such as universities, the industry structure, the legal system and the system of academic education, and institutions that promote technology transfer from academic research to the market. Systems of innovations are not static. Even though every institution is inert to some extent, forces from outside and even from inside are constantly posing challenges. The dynamics of these challenges will be shown along with some major variables within the German system of biotech innovation: structure and goals of federal and state S&T policies, industry structure, the organization of research and development at universities and public research institutes, the organization of technology transfer, and finally the finance sector.

Empirical evidence for this paper was taken in large from expert interviews undertaken regularly over a period of three years, the last round was finished in April 1999. The experts include representatives and project managers of public and private banks, venture capitalists, CEO of biotechnology companies, and heads of regional biotechnology coordination offices in Germany. Since these interviewees preferred to remain anonymous their names or institutions are not mentioned in the references.

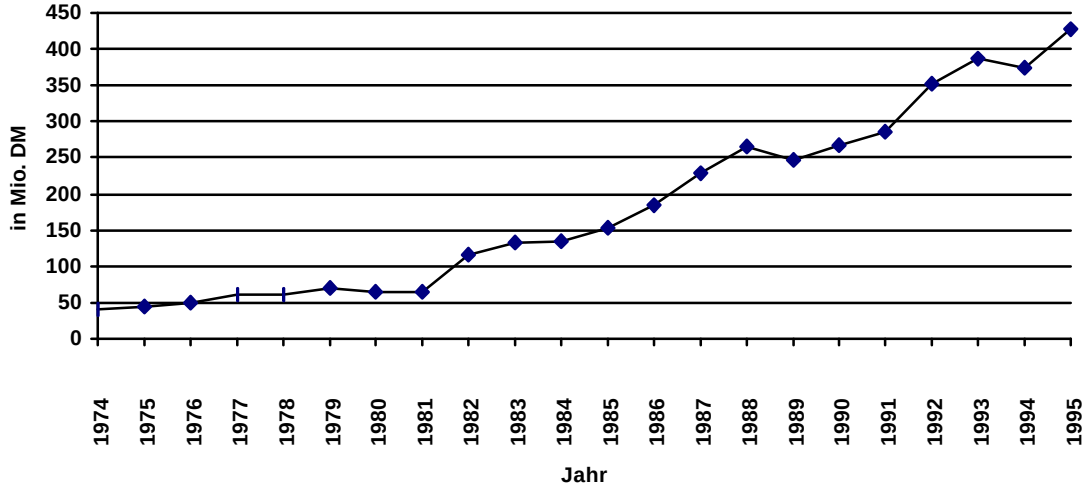
3. Innovation paradox of German biotechnology

The starting point of this paper is the government support for biotechnology development in Germany, beginning in the late 1960s, when an OECD report identified this technology – among others – as one that was expected to play a key role in future economic development (OECD, 1968; Buchholz, 1979). Thus, biotechnology became one of the technologies to be supported by public funds. Historically, the government promoted future technologies because

Germany was prosperous after the war, and it believed that the federal government was able to implement decisions for the achievement of intended outcomes that could continue this prosperity.

The so called Fordist crisis, starting in the early 1970s, however, put economic growth on hold. Political reaction to this crisis was an intensification of interventionist strategy. An active, direct and interventionist science and technology policy was regarded as a tool for developing a prosperous national economy (Hohn & Schimank, 1991, Hauff & Scharpf 1975). For this purpose, a federal Ministry of Science and Technology was founded in 1972, taking over and expanding the tasks that up to this date had been the responsibility of the Ministry of Economy and the Ministry for Scientific Research (BMBW, 1972). Various research priorities were identified for biotechnology, believing that biotechnology had future scientific and economic potential. With the inclusion of biotechnology into its funding programs for new technologies, the federal government - mostly through its Ministry of Science and Technology - has initiated several working groups, advisory boards, and funding program for the advancement of biotech research. Chart 1 indicates the rise of government funding for biotechnology over the last 30 years. From 1974 to 1995 federal R&D expenditures for biomedical and biotechnology in Germany rose from DM 48 million to over DM 430 million (BMFT, 1993; BMBF, 1996b).

Chart 1: German federal spending for biomedical and biotechnology research, 1974 - 1995, in million DM



Quelle: BMFT 1993; BMBF 1996: 208

Even though the German federal government was the first to directly support biotech R&D and several tools were put into place to fund biotech research in academic and industrial research labs, the outcome has been quite different from what was intended. Despite the solid basic research that has been established over the years at the various universities and publicly funded research institutes, major innovations that can be transformed into marketable products have not emerged on the German pharmaceutical market. As in other cases of high technology (e.g. for IT see Gebhardt 1997), Germany has fallen behind some of its major international competitors.

Taking last year's figures into account, Table 1 shows that the United States outperforms all other countries in the biotech sector in terms of its number of companies and employees as well as in terms of sales and R&D expenditures. Table 2 shows that American biotech companies are dominating the world market for products sold. In 1993 and 1995, all top ten products were developed in the U.S., and most of them sold by U.S. companies. Foreign companies could not compete unless they bought licenses of products developed by U.S. biotech companies. The enormous growth rate of European figures indicates a catch-up strategy, wherein European countries are striving to make biotechnology a recognizable industry in their own countries as it is in the U.S. The U.S. columns, on the other hand, show a consolidation of the national biotechnology industry. Net loss decreased and so did the number of companies. For the first time since the ups and downs the industry faced in 1993 and 1994, when a lot of new companies tried to enter the market and many, established ones faced losses of capital and trust caused by negative testing results, the U.S. biotech industry appears to be stable once again. The fact that no comparative German figures for the prior year exist, can be taken as an indicator of how little biotechnology is recognized as an industry in Germany and abroad.

Table 1: Biotech Industries Compared

	Germany	**Europe (incl. Germany)**		**USA**	
	1997	**1997**	**Percent change to prior year**	**1997**	**Percent change to prior year**
Financial data (in mill. DM)					
Revenues	577	5.369	58%	31.498	19%
R&D expense	282	3.764	27%	16.292	14%
Net loss	69	3.980	81%	7.423	-9%
Industry data					
Number of companies	173	1.036	45%	1.274	-1%
Employees	4.013	39.045	42%	140.000	19%

Ernst&Young 1998

Table 2: Top ten selling biotechnology products, 1993 and 1995, world wide sales

Product	developed by	produced by	Net revenues in mill. $	
			1993	1995
Neupogen	Amgen (USA)	Amgen (USA)	719	829
Epogen	Amgen (USA)	Amgen (USA)	587	721
Intron A	Biogen (USA)	Schering-Plough (USA)	572	426
Humulin	Genentech (USA)	Eli Lilly (USA)	560	665
Procrit	Amgen (USA)	Ortho Biotech/ J&J (USA)	500	600
Engerix	Genentech (USA)	SmithKline Beecham (USA/GB)	480	582
RecombiNAK HB	Chiron (USA)	Merck (USA)	245	-
Activase	Genentech (USA)	Genentech (USA)	236	280
Protropin	Genentech (USA)	Genentech (USA)	219	225
Roferon	Genentech (USA)	Hoffmann-LaRoche (CH)	172	-
Humatrope	Eli Lilly (USA)/ Genentech (USA)/ Novo Nordisk (DEN)/ BioTechnology General (USA)/ Pharmacia AB (S)	Eli Lilly (USA)/Genentech (USA)	-	226
Ceredase/Cerezyme	Genzyme (USA)	Genzyme (USA)	-	215

Ernst&Young 1994, 1997

The German biotech innovation system is hampered by the lack of innovative start-ups and by the dominance of big pharmaceutical companies with little innovative potential in modern biotechnology. Except for one medium-sized company, Boehringer Mannheim, which received approval for its genetically produced r-tpa factor Reteplase in 1996[1], the German pharmaceutical industry has no in-house biotech innovation on the market, neither in therapeutics, vaccines, or antibodies. Of the 31 genetically produced drugs admitted on the German pharmaceutical market, only nine were distributed, six produced, and one developed by German pharmaceutical companies; 14 were developed entirely by or in cooperation with U.S. companies, mostly start-ups. The rest were developed by different European companies. In contrast, U.S. companies are dominating their own domestic market: Of the 41 genetically produced drugs admitted in the U.S. 33 were developed, produced and distributed by U.S. companies, only one by a German company (BIO 1998; Dechema 1998; Giesecke 1998).

Another indicator reveals the unintended outcome of federal biotech policy: Even though German companies were dominant on the world pharmaceutical market during the post

[1] Boehringer Mannheim, however, could not maintain its independence on the market and was acquired by the Swiss corporation Hoffmann-LaRoche in 1997. Since Hoffmann-LaRoche owns most shares of the U.S. market for r-tpa through its 60% purchase of Genentech Boehringer Mannheim, for anti-trust reasons and by order of the Federal Trade Commission, the company is not allowed to sell Reteplase in the U.S. (Ernst&Young 1998).

war period, they have lost their share on the market during the last 20 years due to the lack of innovation e.g. in the biotech sector. While German pharmaceutical companies made 17% of their turnover on the world pharmaceutical market in 1973, this share decreased to 8% in 1993 (BVK, 1997). The German chemical and pharmaceutical company Hoechst, ranking on the very top of the international scale in 1976, declined to number 10 in 1994. Hoechst could reclaim its position among the top three but only as a result of its merger with Marion Merrel Dow and Rhone Poulenc Rorer in 1996 (Sharp & Patel, 1996; Handelsblatt, June 24, 1997).

The decline of the German pharmaceutical industry was due not only to the cut back of R&D expenditures (from a 13% share of OECD member budget for pharmaceutical R&D in 1973 to 7.7% in 1990, Sharp & Patel, 1996) but also due to the absence of investment in biotech R&D, especially in modern biotechnology, until the 1980s. Thus, the dominance of the U.S. companies' share on the world pharmaceutical market can in part be explained by the innovative biotech industry in the U.S.: The U.S. share of biotechnically produced drugs on the world market in 1995 was 70%; whereas, the German share was 4% (BMWi, n.a.). Even though they are no more innovative than German pharmaceutical companies[2], U.S. corporations in this sector have been able to use their regional advantage of shorter physical distance and common cultural background to outperform German and other foreign competitors. In addition, the U.S. pharmaceutical market is not only the biggest national market but also the fastest growing one[3].

During the start-up phase of biotech industry development U.S. biotech companies were more interested in forming strategic alliances with domestic pharmaceutical companies, because they wanted to conquer the U.S. market and needed strong partners with established distribution networks. Foreign companies became more of interest to U.S. start-ups during the expansion phase. Thus, some foreign companies such as Hoffmann-LaRoche of Switzerland or Kadi of Sweden were able to maintain their competitive position by licensing biotechnology innovations (McKelvey 1996). Both companies bought exclusive licensing rights for the European Market for Genentech's first two innovations: human insulin and human growth hormone (Swanson, 1996). Genentech was the first economically successful biotech start-up with major

[2] Only in 1997 have Merck and a few other pharmaceutical companies been able to bring in-house biotech innovation on the market. Merck has come up with Crixivan, a protease inhibitor fighting the expansion of HIV. Hoffmann-LaRoche has developed a similar product (Ernst & Young, 1996).

[3] In 1995 and 1996 the average growth rate of the world pharmaceutical market ranged between 7 and 8%. At this time, the growth rate of the domestic U.S. market was 11%, its volume $ 54.7 mill. (Sharp/Patel 1996; Handelsblatt July 15, 1996, March 3, 1997).

innovations on the therapeutic market and served as a role model to other start-ups for nearly 20 years.

Why now is the German biotech industry performing so poorly compared to other nations? As will be shown, this question touches on an "innovation paradox": Considering the extraordinary engagement of the German federal government in biotech research, the lack of innovation is even more striking. In contrast, the U.S. biotech industry is the strongest but has not relied on direct government support. The question arises as to whether the federal government has any impact on the innovative performance of biotechnology or if the government's capacity, in fact, is limited. I will return to this question later on.

4. Institutional learning and evolutionary change of German biotech policy

First, I want to examine the history of biotechnology in Germany. The history of German biotechnology can be divided into three phases:

1st phase, post war until 1980,

2nd phase, 1981 until 1990,

3rd phase, 1991 until today.

In the following paragraphs I will describe these phases along with the three major actors involved: government, industry and academia.

1st phase

Federal government

Government support for this high technology has already been pointed out in the last section. The federal government which had almost no competencies in this technology wanted to draft several programs that would support biotechnology in the sciences and industry. They asked an industry interest group, which ironically represented mainly those companies that had only little interest in biotechnology and a more profound background in synthetic chemistry, for help [4]. Several support programs were implemented but had no specific focus or any noticeable effect on either industry or academic research.

[4] This lobby group, called DECHEMA, represented the big corporations of the German pharmaceutical and chemical industry.

German S&T policy has two tools for pursuing their objectives in an interventionist policy style. Both are monetary. The first is earmarked funds for research institutes and organizations; the second is extramural funding for projects.

1. Except for universities, that are financed through a different arrangement, all publicly funded research institutes are entitled by law to a fair share of national and state R&D expenditures every year. In practice, they are not only guaranteed funding but receive an increase in funding every year.
2. In addition, there is a budget administered by the Science and Technology Ministry for extramural funding. Universities, publicly funded research institutes and industry may apply for a 50% coverage of their project's expenditures for a term of 3 to 5 years. The general research objectives have to match the priorities and guidelines of the national S&T programs.

Early public support for biotech in Germany funded research institutes as well as individual projects that focused on biotechnology.

Industry

The chemical and pharmaceutical industry traditionally has been very strong in Germany, and some companies became global players during the postwar area. Their success was built on synthetic chemistry. Even though management and researchers were confronted several times about whether or not to pursue traditional biotechnology as an alternative innovation strategy, the decision almost always was in favor of synthetic chemistry over biotechnology until the 1970s (Marschall 1997). Thus, most of the companies did not build up any capacities to deal with later scientific developments that were related to genetic engineering. Both industry and science experts, however, did not consider genetic engineering as a major source of product or process innovation in the early 1970s. Instead, they opted to continue research on traditional fields of biotechnology (Buchholz, 1979; Jasanoff, 1985; Marschall 1997; BMFT, several years). The science and economic experts the government relied on were usually affiliated with those academic institutions and industrial companies that got extramural funds from the Ministry of Science and Industry. In this way, new incentives from outside the "inner circle" of government R&D funding were excluded. Instead, this structure perpetuated the same research directions that had been established over the years, resulting in lock-ins (Gebhardt/Giesecke, 1997; Giesecke, 1998).

Academia

We have discussed so far why the government could not find much support for its idea to expand biotech research in the pharmaceutical industry. In the sciences and academia, these programs did not inspire new lines of technology either. This has structural reasons: There is a division of labor between publicly funded research institutes and universities with their main focus on basic research and industry R&D with its main focus on application and commercialization. The earmarked funding mentioned above supplies universities and research institutes with guaranteed autonomy on issues of research topics, money and personnel. Universities and federally funded research institutes show a high degree of resistance against attempts of intervention whether on the part of the government or industry.

As with the pharmaceutical industry in Germany, most research institutes and universities did not change their priorities as a result of these new government programs. This in part explains why there was no noticeable perception of or even reaction to the Cohen and Boyer gene splicing event that occurred in California in 1973, and to the subsequent scientific and economic developments started by this discovery.

2nd phase

In 1981, the actors suddenly realized that German biotech industry had fallen behind the U.S. development of modern biotechnology. One event in particular symbolized the beginning of a slight change in German biotech activities: The biggest German chemical and pharmaceutical company Hoechst signed a research contract with Massachusetts General Hospital for over $ 70 million (Culliton 1982). This move to off-shore R&D in the U.S. was interpreted as going against the quality of German industrial and academic research in this field and is responsible for some - at least minor - reactions of government, academia and industry.

These actors discerned the U.S. strategy of technology transfer as a best-practice model and tried to imitate some of its features. The core of the American model is the biotech start-up - a symbiosis of academic knowledge and venture capital - that serves as a catalyst to bring both incremental and radical innovation from the research lab to the market. The start-up nurtures the new technology until big pharmaceutical corporations become interested in forming a strategic alliance and undertaking all subsequent steps of the product development process.

Federal government

In order to catch up, the German Ministry of Science and Technology in the 1980s and 1990s initiated several programs as part of the extramural funding measure to support more applied research with the intention of yielding products competitive on national and international markets. The focus changed from basic to more applied biotech research (BMFT/BMBF Bundesbericht Forschung, several years).

Industry

Industry at large remained apathetic to the genetic revolution that occurred over seas as well as to the government objectives until the 1980s. The largest pharmaceutical companies received the biggest share of the extramural industry funding from the Science & Technology Ministry. These companies were not used to trying out new directions of research. After the Hoechst shock, those companies that could afford to go off shore - to the U.S. - engaged in strategic alliances or mergers and acquisitions to catch up with the latest biotech development.

Only a few entrepreneurs were willing to take the risk of setting up a start-up company of their own in Germany. At that time, there was only little support from government resources, and the financial market was not yet willing to fund such a risky and costly high tech enterprise either. Big pharmaceutical companies neglected the emerging German start-ups because of their lack of quality.

Academia

Triggered by the Hoechst shock, a few changes occurred in academic research organizations as well. Centers of excellence, called Gene centers, were introduced in four locations that had some tradition in medical, biomedical and genetic research: Heidelberg, Munich, Cologne and Berlin. These gene centers had two prevailing tasks: to consolidate all existing resources for biotechnology and to cooperate closely with industry in order to move from basic research to applied research. This program was supported by the national and the state (länder) governments as well as some big pharmaceutical and chemical corporations. At the gene centers as well as at the universities and other public research institutes, there were attempts to redefine research objectives to include more genetic engineering, that would generate marketable innovations.

Most of the researchers in publicly supported labs and at the universities, however, viewed themselves as dedicated to basic research and resisted all efforts by the Ministry of Science and Technology to turn to applied, industry-related research.

3rd phase

Thus, even though many actors and institutions were urged to reevaluate their traditional way of thinking and even though a few changes were started to move closer to the U.S. ideal type of biotech industry and research organization, it took more than a decade to see some early success and initiate some institutional learning on the government, industry and academic level. Further, a few institutional changes in the financial markets helped support a more preferable „economic ecology“ for biotech development in Germany during the third phase.

Federal government

There is some evidence that the Science and Technology Ministry looked very carefully at the determinants for success in the US and tried to imitate some of those by designing programs that were quite innovative for German policy standards. Traditional earmarked and project funding was continued. As a consequence, the federal budget for biotech and biomedical R&D rose considerably (chart 1). Additionally, not only monetary instruments were designed to promote biotechnology. I will choose only four programs to demonstrate the various characteristics and the broad range of resources the government tried to mobilize.

Under the Biotechnologie 2000 program, all financial resources of extramural funding for biotechnology were orchestrated and new research directions defined in order to push academic and industry research toward more marketable products. An additional program was the BioRegio-contest, It awarded the top three of 17 applicant regions with federal money of DM 50 million each over five years[5]. The winners were Munich, Heidelberg and the wider Cologne-Rhineland area. These funds are administered to each by a central coordination office. An independent board of advisors is in charge of approving the regional applications for these grants. This means that the funds are administered on the regional level instead of the federal or state level. Applicants usually are small biotech companies that are in a start-up or expansion phase. Similar to applying directly for project funds at the BMBF, applicants must provide

[5] plus an additional smaller grant for one of the East German regions, Jena

for 50% of the sum themselves. The central coordination office provides help in finding additional sources, e.g. from banks or VC (venture capital) companies. They also assist in drawing up the applications and gathering information e.g. on patents.

It is striking that the selection criteria are similar to the characteristics of U.S. biotech innovation clusters as they can be found in Silicon Valley, San Diego or the Cambridge area: Among these were scientific expertise in biotechnology, existing services offered for database and patent research, existing small biotech companies as well as pharmaceutical companies, a network of banks, venture capitalists and other finance providers (Warmuth 1996/7, 14 ff.).

All 17 regions applying for a BioRegio grant tried to orchestrate existing resources and build a network that would support biotech research, innovation, and the founding and expansion of start-ups in the area. Thus, even those 13 regions that did not receive any additional funding gained from this competition, because for the first time, all actors involved were integrated into a regional network. Today, almost all the networks still exist. The regional coordination offices provide help for (potential) entrepreneurs. Technology transfer and patent offices as well as venture capital pools are operating to promote biotech innovation. They are an important link between academic research at universities and public research institutes and the industry. All companies and research institutes may still apply for BMBF project funding through Biotechnology 2000, of course.

This initiative also changed the attitude of many academics who are traditionally very reluctant to think about entrepreneurship. Today, a lot of them are inspired by the business plan competitions that are carried out regularly in some of these regions and by the help of the new networks. These contests have also changed the attitude of investors and big corporations towards biotech entrepreneurship. Banks have become more open minded towards the needs and difficulties of young entrepreneurs who want to start a business in a science-based industry. This is not to say that they give credits more easily; however, German venture capitalists who try to be on the safe side and traditionally invest in low risk technologies and services also want to get a piece of the biotech pie as well.

Additional programs were started by the government not only to help promote biotech innovation but high-tech development and entrepreneurship in general. Academic researchers in Germany never had any significant incentives to file patents. According to German law, employees of public universities fully own their intellectual property. They don't have to share it with their employing institutions. This rule has turned out to be an obstacle to the overall innovative performance of German universities. Academics have to bear the cost of filing and sus-

taining patents all by themselves, and this can be very costly. In contrast, in the U.S. the university's technology transfer offices pay for the fees and in return get a share of the royalties. Technology transfer offices at German universities and at most public research institutes, however, are not run as for-profit enterprises.

Another disincentive for filing patents is the German and European patent law. Unlike the U.S. rule „first to invent", in Germany and at the European Patent Office the rule is „first to file". An invention that has already been published, e.g. in a journal, cannot be patented afterwards in Europe. For academics, it is more important to publish than to patent. Subsequently, the possibility to file a patent is missed.

The German government is aware of these problems, but it will still take some time to amend the laws. In the meantime, the Science and Technology Ministry has started a „patent initiative". This is a program that hopes to encourage public research institutes, universities, entrepreneurs and inventors to invent marketable products. It is firstly a free information service; secondly, it subsidizes a share of the cost for patenting if necessary (BMBF 1996).

An additional BMBF initiative reflects the success of the U.S. model and the German imitation strategy. German policy makers realized that high tech start-ups are a crucial technology transfer mechanism that bring new results of academic research from the lab into the market place. Naturally this is an ideal scenario. Important, however, is the awareness of the entrepreneur's new role. The intention behind this thinking is to stimulate Germany's innovative performance and make its economy competitive on the global scale.

With the Exist-contest, the Science and Technology Ministry invited science and technology dominated regions organized as networks to encourage entrepreneurs and start-ups to participate in a competition for a total of DM 45 million federal subsidies for three years. More than 200 universities and 100 regions submitted proposals; five of those were selected winners. Of these five, three were networks in the western part of Germany (Wuppertal-Hagen, Karlsruhe, Stuttgart) and two in the east (Jena and Dresden). The funding is supposed to establish a „culture of entrepreneurship" by supporting and strengthening information services at the universities, hiring lecturers with industry experience, establishing a curriculum for entrepreneurship at the universities, establishing a virtual university on the internet, providing contacts for investors, integrating international experience and raising public awareness for the prospects of entrepreneurship.

Similar to the BioRegio-contest, Exist was an incentive for many regions to consolidate existing resources and to integrate them into a network. Even though only five networks re-

ceive funding, many others have started operating on their own. They want to help academics market their research results and start their own businesses. One popular instrument for this is the business plan contest organized in several regions through a tightly cooperating network almost every semester.

State governments: the example of Bavaria

Paralleling science and technology policy efforts to support biotech development on the federal level, some länder (states) in Germany have initiated support programs as well. I want to introduce the Bavarian model as the most successful one to date.

It is not by chance that the greater Munich region in the heartland of Bavaria won one of the three BioRegio-contest prizes. Not only does this region have one gene center and three Max-Planck-Institutes operating in scientific fields that are relevant for modern biotechnology. The Bavarian government has been very supportive of emerging high technologies. By privatizing parts of its shares in power companies during the 1990s, it has created a pool of investment for subsidizing applied technology developments in Bavaria worth several billion DM (Focus 1998, FAZ, June 17, 1998). Because of the optimism toward biotechnology as a future technology for Bavaria, permission for biotech production plants was issued with less delay and less obstacles than in most other federal states of Germany[6].

Most initiative in Bavaria came from the Economics Ministry. It commissioned a study[7] to find out how biotechnology could best be promoted in Bavaria. The results are similar to the determinants of success of the bio valleys in the US: venture capital as well as management support had to be provided for small start-ups and the transfer of research results from the academic lab to the market had to be facilitated (Koschatzky et al. 1995). Different from the U.S., however, these objectives had to be part of an interventionist biotech policy. Accordingly, the Bavarian Economics Ministry financed an institute called Innovationszentrum Biotechnologie (IZB, innovation center for biotechnology) which has structures and objectives that are similar to incubator labs and technology parks. This office is located next to the Munich gene center and within reach of two of the Max-Planck-Institutes that focus on biotech research. At this location, which is on the outskirts of Munich, a lot of property is still available

[6] Permission for biotech productions plants are issued by the länder administrations not by federal administration.
[7] from the Fraunhofer Institute for Innovation Research

for companies that decide to leave the IZB so that they may expand without losing the close connection to the scientific infrastructure.

To solve the bottleneck of venture capital the Economics Ministry setup a venture capital fund, Bayernkapital, with its office at the IZB. A triple multiplication effect is very attractive for start-up companies that chose to locate in Bavaria, especially in the Munich area: If a company can raise venture capital from a private source, e.g. a bank or a VC company, Bayernkapital will supply the same amount as well as will tbg, a federally owned investment bank that I will introduce in more detail in the next chapter.

Now that Munich receives additional funding through the BioRegio program, a coordinating office, BioM, is located at the IZB as well. BioM was set up as a corporation (Aktiengesellschaft) in order to make investments with its shareholder's money. Most of the shares are held by banks which did not only want to loan money but also earn high returns. Their motivation was also to learn more about biotechnology, its risks and prospects, and to be part of a broader network that generates and exchanges crucial expertise on promising investments. BioM has become a company that is owned equally by three categories of stock holders: the state of Bavaria, banks and VC companies, and pharmaceutical and chemical companies. BioM holds a central position over all biotech development in Bavaria: Not only does the company provide and generate venture capital, it also provides information services to investors, entrepreneurs, businesses etc. for free and is the nexus of the Munich biotech network. If additional expert advice is needed, e.g. by lawyers, BioM makes contacts and provides subsidies.

Finance

TBG

The German system of corporate finance is dominated by bank loans and existing company profits. Venture capital was almost non-existent until the late 1980s and is still a rarity today. In the 1980s, federal government realized that venture capital is necessary to finance entrepreneurs and „Mittelstand" (family owned medium-sized firms), because venture capital was one of the most important mechanisms that gave birth to the U.S. biotech industry (Kenney 1986). This realization, again, demonstrates the learning process that was going on within German state institutions). Under the auspices of the federal Economics Ministry, the Deutsche Ausgleichsbank (DtA), a state-owned investment bank, founded a subsidiary, the Technologiebeteiligungsgesellschaft (tbg), in 1989.

Tbg programs generally are based around equity participation in exchange for funding; however due to the public status of the bank and, in particular, the provision of substantial loan guarantees by the German government[8], the tbg is able to provide highly favorable provisions to most clients.

The tbg has three main programs.

- "Futour" – a smallish program designed primarily to aid high tech development of East German start-ups.
- BTU programs (Beteiligungskapital fü kleine Technologieunternehmen, venture capital for small technology enterprises) provide loans that are underwritten by the German government (Economics Ministry, BMWi) in order to promote the foundation and expansion of new German technology programs. These loans account for about 80% of all tbg lending.
- DtA–Technologiebeteiligungs-programs are developed by the tbg itself without external guarantees. These programs comprise only a small part of tbg venture funding now but could expand in the future, esp. if the tbg takes a role in the secondary and further funding of client firms.

In general, virtually all tbg funding is in the form of matching grants or "silent partnerships". The tbg demands that each client be served by a lead-investor; if the partnership fails within five years (during the quasi-lending period), then the tbg takes responsibility for 50% of the liabilities. In return for funding, the tbg also takes an equity stake in the firm. However, these stakes are generally structured in a way that is advantageous to the investor. The tbg charges a 5-6% interest rate for its investment, and, in addition, if profits are generated, it asks for a percentage, generally 30%. However, the client firm is free to pay back the loan and, by doing so, buy back its stake at any time during the course of the loan (usually up to 10 years). As a result, most firms that are expected to be profitable will buy back their stake before profitability is reached; this limits the tbg's potential upside gain but exposes the tbg fully to downside risks. The tbg is willing to incur such risks primarily because most loans are currently under the BTU program. Thus, the risk is substantially born by the government. In addition, most BTU loans are given for early phase financing of start-ups (usually after seed financing for business plan development, but before secondary or further expansion).

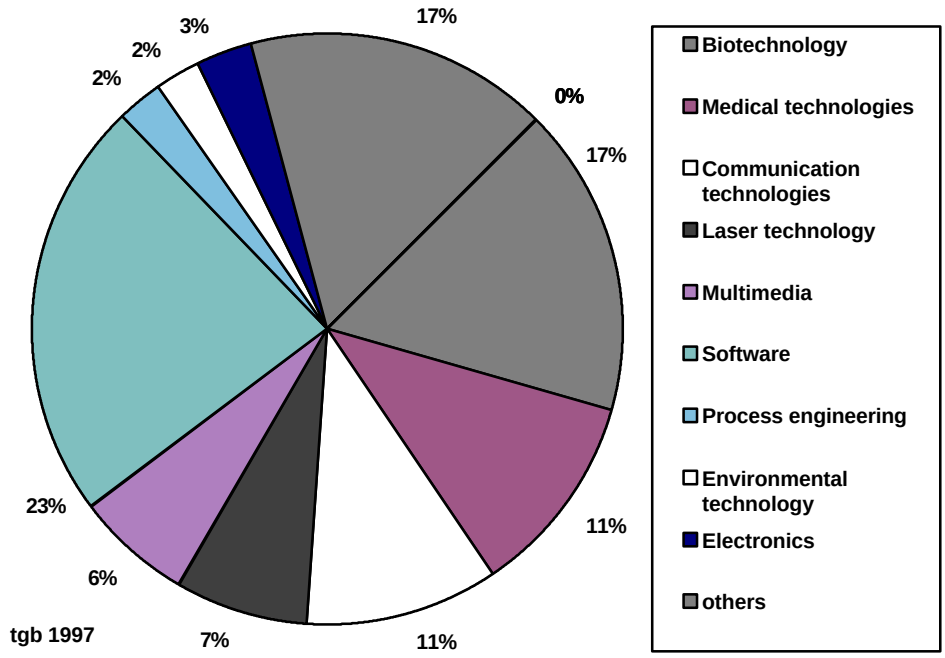
[8] This program used to be supervised and financed by the Science & Technology Ministry, BMBF, until 1998. After the last elections all programs focusing on technology were transferred to the Economics Ministry, BMWi.

Investments made for secondary or bridge financing, which generally cannot be covered under BTU programs (but by DtA), will have different terms that reflect the differing risk structure; the tbg generally wants to generate a profit on these loans. Though no loans of this size have thus far been given, the bank conceivably could lend up to DM 10 million in bridge financing for an IPO (initial public offering).

In general, the client firms also ask tbg to make contact with potential lead investors because tbg is part of a good network. Thus, tbg's role is much broader than just providing for cheap loans. The mandating of lead investors is crucial. By doing so, market judgments and risks are incorporated into every deal. The tbg does perform some analysis on potential deals, but usually based on due diligence prepared by the lead investor to the loan. In addition, the tbg does not take on all applicants; it rejects many deals that it feels are too risky and do not have important criteria, especially knowledgeable and experienced management and a clear plan to commercialize products. The reputation of the lead financier is especially important. Tbg leaves the selection of viable companies and technologies to the market, that is to say to the lead investors. Though not a requirement, the tbg generally favors the inclusion of a venture capitalist as the lead investor. 48% of lead investors are venture capitalists. Other sources are private investors, banks, insurance companies, corporations and funds. Monetary limits are also placed on deals. In general, DM 3 million is the maximum lent on BTU projects for all normal start-up financing deals; much smaller sums are sometimes available for seed financing. Over its first eight years of operation, tbg has participated in 535 projects, lending a total of DM 426.9 million (tbg 1998). It is still too early to assess the success of the funded projects because for most companies, the 10-year-period is not yet over.

Chart 2 gives an overview on loans provided by tbg, breaking down the investments by sectors. Next to software (23%) which is a very broad category, biotech (17%) is the sector most invested in, while process technologies are underrepresented. In contrast, German venture capital investors from the privately financed market give only 2,6% of their investments to biotech companies but 60% to process technologies and 20% to services (BVK 1997). Further, tbg focuses on early stage (seed and start-up) funding (67.7%), whereas the average VC investment in this phase is no more than 7% but for the expansion phase it is 65% (tbg 1998, BVK 1997). Interestingly, 36% of all tbg investments are in the Bavarian area; about 80% of those in Munich.

Chart 2: Tbg funding breakdown for sectors 1997



The tbg also actively monitors its investments. This is generally through yearly visits to each client. This is mainly to insure that the "real" business meshes with that envisioned within the business plan; i.e. to check that milestones are being met.

Whether the tbg will continue these programs in the future or if it will have to change its policy is at the moment undecided. Some policy makers would like to see the bank privatized, although this will depend strongly on the political atmosphere. At the moment, tbg has a central role in providing seed capital in Germany for high tech start-ups even though it does not want to be in that position. Regular banks will never play an important role in this game because for them - besides regulatory rules - the cost of evaluating the technological feasibility of projects is too high.

Neuer Markt

Other institutional changes in the German financial market during the last few years have facilitated biotech investments and expansion as well. Those were not necessarily pushed for by the government but by market forces. In 1997, a NASDAQ-modeled stock exchange for technology firms, the Neue Markt, was created. It has become a critical institution for technology firms, as it provides a legitimate exit strategy. Presently, three out of 86 companies listed

(April 1999) are biotech companies. One of them, Qiagen, a platform technology and utility company, has a second listing at the Neue Markt and is very successful; the others are Morphosys and Rhein Biotech, both started as platform technology companies but have the potential of becoming therapeutic companies. Morhosys was listed in March 1999 with moderate success; and Rhein Biotech's bid was very successful, but since they started selling stocks in April 1999, it is too early for an assessment.

Thus, the Neue Markt has not yet become a stock market for biotech shares but is successfully supporting equity listings of German and foreign firms in other technology sectors, such as software and information technology, and in other services. Finance experts in Germany think the Neue Markt rather than the Easdaq in Brussels could become the European Nasdaq because it is currently the most liquid high-tech centered stock market in Europe. Neue Markt is popular with investors in retail trading and, thus, generates more volatility than Easdaq, that has more institutional investors. Investors have become hesitant to invest in London stock markets that used to hold the central position for European high tech investments until 1997. The scandal caused by negative testing results of British Biotech, a promising company that was listed there, has caused the loss of confidence of many investors in these stock markets. The Neue Markt could not absorb a high cost failure like British Biotech. Thus, the quality of projects has to be evaluated very carefully.

Venture Capital

Unlike the U.S. and the UK corporate finance systems, where industrial expansion has been mostly financed through stock markets, the German system is bank-based (Zysman 1983). The growing awareness that the stock market and venture capital represent an alternative to conservative bank loans has become very attractive for high tech enterprises, whose funding is dependent upon intangible rather than tangible assets.

In the U.S., venture funds pool money from a variety of institutional and individual investors. The venture capitalists make profits as the value of their shares rise assuming, of course, that the small company's products perform successfully on the market or that an IPO provides a profitable exit by selling shares on the public market. This money is invested into small start-ups which usually need a long period of time and several rounds of finance before becoming competitive on the market. So, investors may not readily see profitable returns, which may vary of course. Kleiner-Perkins, the investors of Genentech, the first successful biotech company in the U.S., earned 500 times their initial investments. The rate of companies

that fail, however, is very high; estimates of successes range between one to 10 out of 100. Accordingly, venture capital companies are obliged to spread the risk. They don't put all of their money in one or two companies but invest in a wide range of firms. Further, they form investment syndicates with other VC companies, one of them being the lead investor overlooking how the small firm performs. Their task is not only to provide money but also to offer managerial advice to the start-up firms which usually have no experience in business planning, product management etc. They are also part of an investment network, generating and providing information on prospects and promising investments, preparing IPOs and evaluating the due diligence and feasibility of the projects.

The number of VC companies with interest in German biotech, has risen from only two - Atlas Venture and Techno Venture Management - at the first half of the 1980s to more than 70 that are now engaged with biotechnology. Some of those are owned by banks; some are public or semi-public. Only recently have they discovered biotechnology as a profitable investment, after public participation programs stepped in to cover some of the financial risks involved in this high technology (see chapter on tbg). As mentioned before, however, only a small portion of venture capital in Germany is invested in high technology. Of the total DM 6.6. billion venture capital in Germany in 1996, only DM 177 million were invested into biotechnology. Compare this to the US: Of the total DM 50 billion venture capital, DM 1.3 billion were invested into biotechnology (Handelsblatt Feb. 10, 1998, 6).

Start-ups and platform technologies

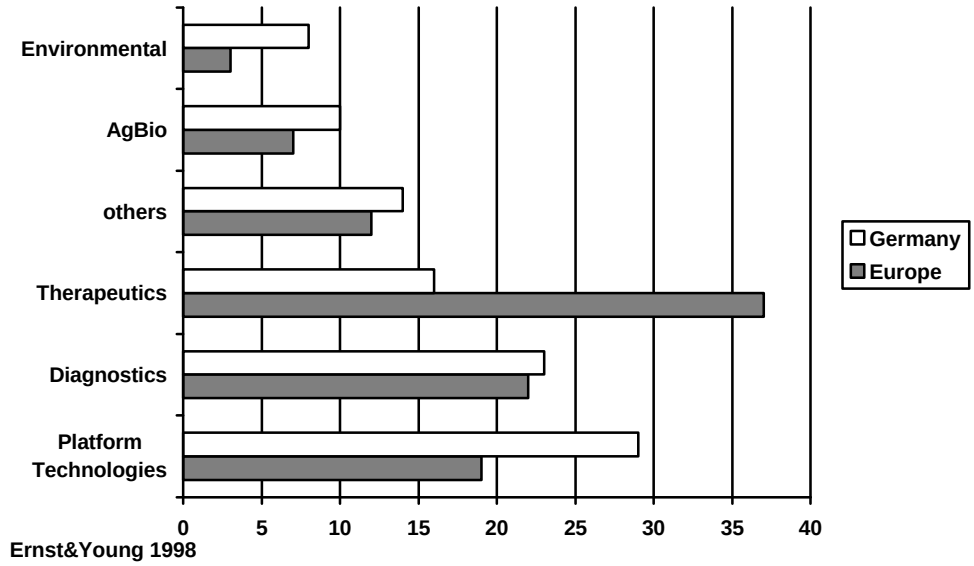
Despite the dominance of big corporations in the German pharmaceutical sector, almost two hundred biotech start-ups[9] have managed to set foot into the German market - with substantial federal and state support. The majority of them are indeed very small. They have an average turnover of only DM 100.000 and generally no profits. Only a few have a research staff of more than 15.

The latest boom has been started by the BioRegio-contest of 1995/96. Until then, only a few dozens firms existed in Germany. Today, all of them are trying very hard to find and defend their technological niches. Characteristic of German biotech start-ups today is their specialization in one of the so called platform technologies, which are defined as instruments that

[9] Ernst&Young biotech report on Germany in 1998 counted 171. These figures are hard to assess, however, since they comprise so called Life Science companies which are not necessarily the same as biotech companies and include a wide range of companies specialized in platform technologies. Some of those are not research oriented companies. Thus, it is most likely that the actual number of companies is below 171.

have become crucial for further development of biotechnology. In Germany, this specialization is more prevalent than in any other European country or in the U.S. as chart 3 demonstrates. According to the Ernst&Young statistics, almost one third of German biotech companies concentrates on this segment and only 15 % on therapeutics. In contrast, therapeutics is the dominant sector for all other European countries, comprising some 40% of biotech companies whereas platform technologies comprise roughly 20% (Ernst&Young 1998).

Chart 3: Product development specialization in German and European biotechnology, in %



Platform technologies include combinatorial chemistry and combinatorial biology as well as genomics and others. Specialization in one of the new platform technologies is the result of two specific features of biotechnology that only became visible along its path of development: First, the difficulties of the first generation of biotech companies in the U.S. to develop new drugs and to attain the capital, time, and knowledge needed for innovative products caused a severe crises in the U.S. biotech industry in 1993 and 1994, which made clear the incapacity of most companies to become a diversified or integrated pharmaceutical company comprising the total process of developing a new drug. The need for capital, for know-how concerning clinical testing and upscaling, for distribution networks, etc. led to a disintegration of the development process. Instead, many companies started to specialize on certain technological or service units as part of the whole innovation and production process. Second, the diversity of biotechnology, the manifold possibilities of its integration with other technologies

into new hybrid technologies, and the standardization of some of the underlying processes (polymerase chain reaction, high throughput screening) for biotech research offered new market niches and, thus, possibilities for new specializations. The companies have learned from these developments. For German companies, a possible path to overcoming the blockages in the national system of innovation and to containing technological and financial risks is to become a supplier of a technology or service component at the upstream or downstream end of the innovation and production process.

Thus, some biotech companies in Germany have managed to conquer profitable niches despite the blockages. Success cannot be measured in terms of market innovations or sales. Rather, some German biotech companies have come up with promising business partners that invest in start-up developments and new ideas. Some of them were able to attract big German and international pharmaceutical companies. As these corporations are experiencing a lot of restructuring in order to be more competitive and innovative, small start-ups are becoming outsourcing partners, thus, filling in niches that may give them a chance to survive in the long run.

5. The future of German biotech industry

For the last five to ten years, German biotech industry has been experiencing an evolutionary change. Actors and institutions involved have engaged in a process to mobilize and orchestrate resources. In doing so a lot of institutional learning was required. Some new strategies involve trying to imitate the U.S. success model, e.g. the government's BioRegio- and Exist-contests to create networks at promising locations; the financial market structure has moved in a similar direction by providing more venture capital and introducing the Neue Markt. However, all these new strategies are to a high degree rooted on the German institutional arrangements and cannot be interpreted as a sign of international convergence.

Though the federal government has been aware of biotechnology as a future strategy for German industry that needs to be supported early on, it has taken almost 30 years for a learning process that orchestrates all necessary resources and shows some positive results, to develop. This learning process has often been a trial and error process.

This paper has presented some evidence that despite the pattern of diversified quality production that is still dominating German industry, some institutional arrangements could be reconfigured to accommodate biotechnology as a future sector in this country. Due to limited

space, some evidence had to be left out of this paper, e.g. further technology transfer measures, new incubators, the role of scientific advisory boards at start-ups etc.

In conclusion, I very briefly want to assess the new strategies pointed out in the third phase for German biotech development and comment on some future prospects of the industry. The government funding programs for start-up companies have born a major part of the financial risk involved. As a consequence, venture capital companies have been more likely than usual to provide seed capital. More companies and projects have been started than will be able to survive in the long run or even remain financed through a second and third round. Platform technologies cannot be a long-term strategy for German biotech companies. The international market is so competitive that only a few of them could survive on the single-product strategy. The others will have to use platform technologies to get started in this sector and then develop therapeutics on their own. This will be very cost intensive. If only 50 of those almost 200 firms in Germany have a therapeutic product in their pipeline, between DM 12.5 to 350 billion will be required to develop marketable products[10]. Venture capitalists estimate, however, that the funds available can only provide DM 1 billion for further biotech development. The question arises as to whether the rest could be financed through stock markets and strategic alliances with pharmaceutical corporations. It is more likely, and we can learn this from the U.S. and UK experiences in 1993/94 and 1997/98 respectively, that the German biotech industry sooner or later will experience a very painful consolidation process, either through mergers and acquisitions or through company close-outs. Analysts expect that in the long run only four to six German biotech companies may survive.

Returning to the goose model mentioned at the beginning of this paper, it can be concluded that the German actors made a concerted effort to keep their goose stay in line with the others and to follow the leader. The German goose might even have gained enough strength to overtake one or two in front, but it is unlikely that it will get much closer to the leader. Whether the public and private money spent on biotech investments has been worth the outcome and whether the rearrangement of the German institutional set-up has been worthwhile can only be assessed after the consolidation process.

[10] These figures are calculated on the assumption that the development of one therapeutic product costs between DM 250 and 700 million (Handelsblatt, Sept. 19.1999).

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