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Future employment in biotechnology in Germany

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Abstract

This paper quantitatively analyses the employment effects of biotechnology in Germany. In 2000, a total of 614,000 employees were influenced by this technology of which biotechnology was highly relevant for maintaining the competitiveness of around 220,000 jobs. In this high-impact cluster the number of jobs increases to a range of 330,000 to 677,000 jobs in the year 2010 which equals a maximum of approximately 1.7 per cent of all employees in Germany. Additional spill-over effects of biotechnology will range between 657,000 and more than 1 million jobs in the year 2010, depending mainly on diffusion rates of biotechnology.

FUTURE EMPLOYMENT IN BIOTECHNOLOGY IN GERMANY

Specific interest is attributed to modern biotechnology owing to its key technology character, significant importance in the innovation process and ability to maintain the competitiveness of German companies in different economic fields.[1,2] In addition to the pharmaceutical and chemical industry, biotechnology influences in particular agriculture, food processing, environmental technologies as well as manufacturers of laboratory equipment. Important arguments for public financial support for research and development activities in the biotech field are the impact of this technology on the development and competitiveness of existing jobs as well as the creation of new employment possibilities via founding of new high-tech biotech firms.[3] However, existing studies aiming to analyse the employment effects of this technology in Germany are mainly based on company surveys (in particular in high-tech biotech enterprises[4–17]) or expert estimations[18] but lack a systematic approach in order to quantitatively analyse the impacts of biotechnology on the current and future development of the employment in all industrial sectors in Germany. Therefore the German Ministry of Economic Affairs and Technology initiated and financially supported a study analysing this issue which was carried out by the Fraunhofer Institute for Systems and Innovation Research (ISI), located in Karlsruhe (Germany) and finished in 2003.[19] The future employment effects of modern biotechnology are outlined in this paper, thereby widening the time period of analysis until 2010.

METHODOLOGY OF THE ANALYSIS

For analysing the impacts of biotechnology on the employment in Germany a basic concept has been developed which differentiates the following effects (Figure 1):

- 'Direct effects' are based on substantial research and development activities in the biotechnology field and result in the development of new biotech-related knowledge, methods, technologies and products. Such activities are carried out in universities and other public research institutions, high-tech biotech firms, mainly small and medium-sized enterprises (SMEs), the manufacturers of biotech instruments and supplies as well as in plant breeding companies.

- 'Indirect' employment effects of biotechnology can be observed when

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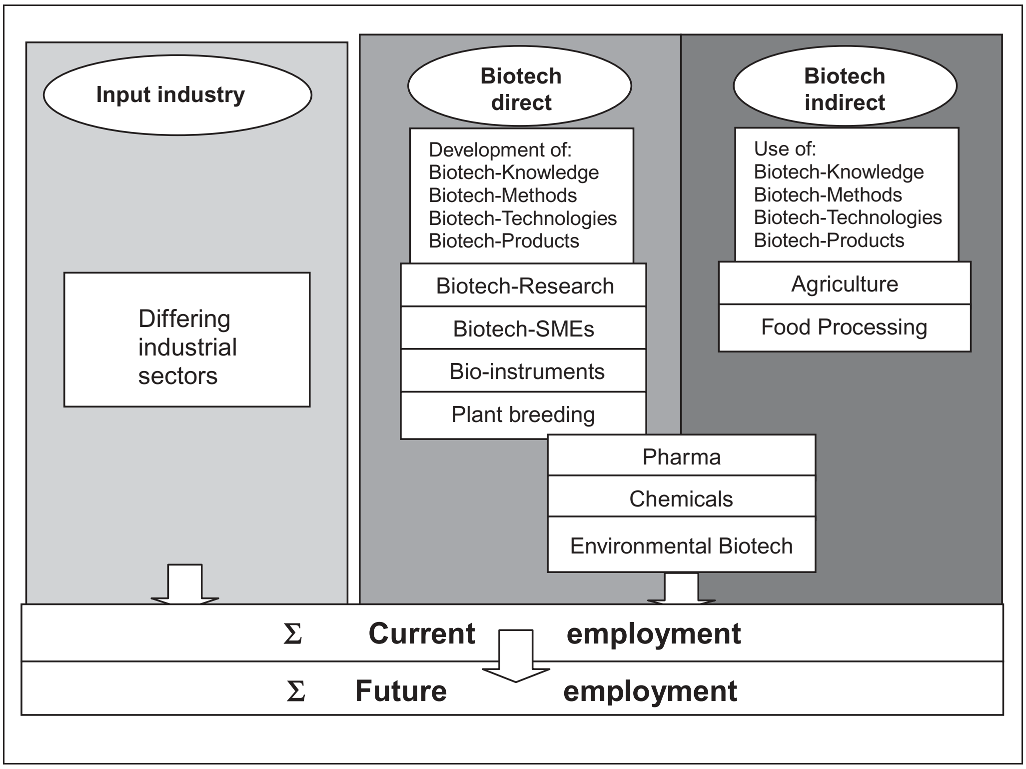

Figure 1: Basic concept of analysing the employment effects of biotechnology
Source: Menrad *et al.*[19]

A mix of different methods was applied to analyse employment effects

biotechnological methods, approaches, technologies or products are used in traditional industries in order to improve efficiency. In particular this is the case in the food processing industry and agriculture, partly as well in the pharmaceutical, fine chemicals and environmental technology industry. (Owing to the lack of data in order to differentiate between direct and indirect employment effects in the pharmaceutical, chemical and environmental technology industry, all effects are calculated to the indirect category in this analysis.)

- Additional employment effects occur in differing industrial sectors due to the purchase of goods and services of those parts of the Germany industry and public institutions that are directly or indirectly influenced by biotechnology. These effects are summarised as employment effects in the input industries.

To analyse the employment effects of biotechnology in Germany a mix of different methods was applied. The present employment effects of biotechnology in industry were investigated by identifying those groups in the production statistics that are influenced by biotechnology and by relating production volumes to the number of jobs.[19] In addition, available studies, in particular dealing with employment in research organisations and biotech firms,[4–18,20–22] as well as information from industrial associations were evaluated.[23] Expert interviews were used in order to obtain information on the relevance and role of modern biotechnology on the competitiveness of jobs and companies. Employment induced by biotechnology in upstream industries was assessed using an existing input–output model of the Fraunhofer Institute ISI.[19]

For analysing future employment effects of biotechnology until 2010 a simulation model based on a systems dynamics approach was developed that allows the job situation to be calculated for the various segments (used for those parts of the industry that are affected by biotechnology as well as public research institutions in this field) affected by biotechnology and also to obtain information on new employment generated and retirement (Figure 2). A systems dynamics approach was used to simulate the job situation and development in biotechnology since this represents a system that is influenced by a variety of factors which are changing over time. It is fairly common to use a systems dynamics approach to model this type of systems. The mathematical simulation model consists of a system of differential equations that cannot be reduced to a few mathematical formulae. Therefore a graphical presentation is the common way to present the general form of the model and interactions between the different factors (Figure 2).

Three different diffusion scenarios were simulated

Three different scenarios of the diffusion of biotechnology were calculated.[19] In a first trend scenario it was assumed that diffusion (in this context, the adoption of biotechnological technologies, methods and products in the different application fields of biotechnology) of biotechnology proceeded at the same speed as during the past years. In this scenario an average adoption period of 25 years (an average 4 per cent of the respective biotechnological methods, technologies or products each year) was calculated for the chemical and pharmaceutical industry, while the respective figures for environmental biotechnology, the food industry and agriculture were assumed to be on average 15 years.[19] In addition, a fast diffusion scenario (assuming that adoption of biotechnology takes place in half of the adoption period compared with the trend scenario) and a retarded diffusion scenario reflected different adoption rates of modern biotechnology by the various sectors. In the retarded diffusion scenario it was assumed that the adoption period of biotechnology in the various sectors are doubled compared with the trend scenario.

Specific macro-economic elements influencing biotechnology adoption and diffusion (such as financial investments in biotech SMEs, legal regulations, general acceptance of biotechnology in the public, benefits and costs of biotechnological methods, technologies or products) are not directly used in the calculation of the scenarios partly because of lack of data and in particular because of lack of knowledge of the exact functioning and interactions of the various influencing factors.

In all three scenarios two versions of supply of university graduates were employed: a restricted version and an open approach. In the restricted version the supply of university graduates is limited to the proportion of academics who are currently employed in the

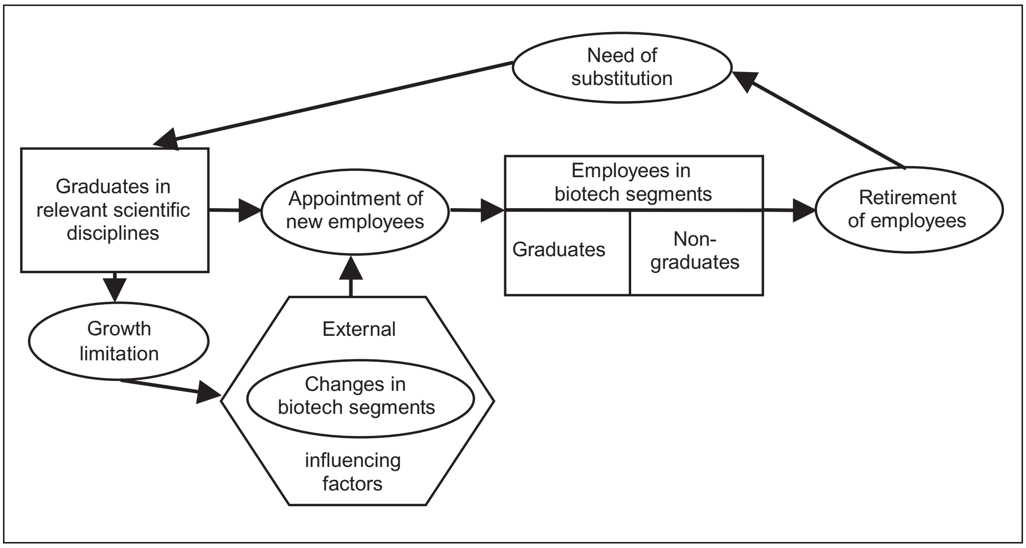

Figure 2: Simulation model of future employment effects of biotechnology in Germany
Source: Menrad *et al.*[19]

In 2000 a total of 614,000 employees were influenced by biotechnology in Germany

different segments that are influenced by modern biotechnology, ie if one sector employs 5 per cent of all natural scientists in Germany, a maximum of 5 per cent of all graduates in natural sciences will be devoted to this sector. This restriction is released in the 'open approach', which means that the simulations are calculated without any limitations in the supply of university graduates. In a final step the results of the three scenarios are combined in two clusters which take the differing degree of the impacts of modern biotechnology on the competitiveness of the affected jobs into account.[19]

EMPLOYMENT EFFECT OF BIOTECHNOLOGY IN 2000

In a first step the employment effects of biotechnology were analysed for the year 2000 since this year represented the most recent year with a complete data set. In 2000 around 69,500 employees in Germany were directly affected by modern biotechnology (Table 1). Of these, around a half (almost 36,000 employees) were located at universities or non-university research institutions. Around 33,500 employees were influenced by modern biotechnology in industrial companies of which almost 20,500 were situated in bio-instruments and bio-supplies companies. In contrast, the direct employment impacts in small and medium-sized biotechnology companies were rather limited, with around 10,100 employees. In plant breeding companies around 2,900 employees were influenced by modern biotechnology.

In upstream industries around 36,000 employees were depending on research institutions and those parts of the industry that are directly influenced by modern biotechnology (Table 1). With 18,200 employees, around half of these employees was related to bio-instruments and bio-supplies manufacturers. In contrast, university institutes and non-university research institutions, which are influenced by modern biotechnology, as well as small and medium-sized biotechnology companies did not induce high employment effects in the input industries, with together around 15,000 employees, which is caused by the high value-added intensity in these two fields.

In the year 2000 an additional 167,000 employees were indirectly influenced by the use of modern biotechnological methods, technologies and products in Germany (Table 1). More than three-quarters of these employees were working in the food-processing industry in which the proportion of the total costs or the total value-added which is influenced by modern biotechnology, is often relatively limited. In this sense it can be assumed

Table 1: Employment effects of biotechnology in Germany in 2000

Segment	Number of employees		
	In segment	In input industries	Total number
Universities/research institutions	35,979	11,700	47,679
Biotech SMEs	10,103	3,300	13,403
Bio-instrument/bio-suppliers	20,470	18,200	38,670
Plant breeding companies	2,964	2,900	5,864
Total sum direct effects	**69,516**	**36,100**	**105,616**
Pharmaceuticals	13,046	11,300	24,346
Fine chemicals	11,274	18,800	30,074
Environmental biotech	11,189	9,900	21,089
Food processing	131,375	301,500	432,875
Total sum indirect effects	**166,884**	**341,500**	**508,384**
Total effects	**236,400**	**377,600**	**614,000**
High relevance of bio-technology for maintaining competitiveness			**220,682**

Source: Menrad *et al.*[19]

Number of employees in input industries is significantly higher than in segments which are directly or indirectly influenced by biotechnology

that a high proportion of these jobs are currently only partly affected by modern biotechnology methods, technologies or products. Owing to a lack of differentiated statistical data it is not feasible to identify and segregate those jobs in the food industry in which application of modern biotechnology already plays a substantial role. In the other economic fields indirectly influenced by modern biotechnology, the number of affected employees was around one-tenth of those in the food-processing industry. In 2000 the respective figures of the pharmaceutical industry were around 13,000 employees followed by the (fine) chemical industry with almost 11,300 employees and environmental biotechnology with almost 11,200 employees. Owing to the de facto moratorium, which prevents market approval of genetically modified organisms in the EU, it is assumed that agriculture in Germany is currently not concerned with biotechnological methods, techniques or products.

The employment effects in the upstream industries of those economic sectors that are indirectly influenced by modern biotechnology are significantly higher than those of the sectors directly influenced by this technology. Within the four indirectly influenced application fields, around 341,000 employees could be connected to the use of modern biotechnological methods, techniques and products in the input industries in 2000 (Table 1). This figure was also strongly shaped by the food-processing industry which contributed around 301,000 employees in its input industries. So the number of affected employees in the upstream industries was significantly higher than the employment effects induced by modern biotechnology in the food-processing industry itself, which can be explained by the high input intensity of the food-processing industry as well as the above average labour intensity in the upstream industries of food-processing (eg in agriculture). With around 18,800 employees in its upstream industries the chemical industry showed a high-input intensity in 2000 as well. In contrast, the employment effects induced by the pharmaceutical industry and environmental biotechnology in its upstream industries were smaller than the number of employees influenced by modern biotechnology in these two economic fields.

Including the employment effects on the upstream industries the total employment potential of biotechnology in the year 2000 can be estimated to be about 614,000 jobs (Table 1).

With the exception of the food-processing industries all economic fields that are influenced by modern biotechnology can be regarded as very knowledge-intensive. This is clearly shown by the high percentages of employees with an academic degree or a master craftsman certificate. In addition, more than 6 per cent of all employees are entrusted with R&D activities, which again indicates a high research intensity.[19] This is in particularly true for bio-instruments and bio-supplies manufacturers as well as the pharmaceutical industry.

In addition to analysing the gross effects of biotechnology in the various sectors, the extent competitiveness of the different sectors was influenced by biotechnology and whether biotechnology created new jobs or rather contributed to the substitution of existing traditional jobs were also investigated. In the pharmaceutical industry there is a strong effect of biotechnology on competitiveness. Biotechnology leads mainly to new products; its contribution to substitution of traditional products is rather low.[24] Also in the chemical industry a strong competitive effect of biotechnology could be detected. In this sector biotechnology is mainly used in the context of the introduction of new products or processes. In environmental biotechnology the competitiveness of about two-thirds of all jobs is affected by biotechnology, in particular in waste-water treatment.[25,26] In the food industry

In directly influenced sectors significant growth can be expected in employment in Biotech SMEs and manufacturers of bio-instruments until 2010

the influence of biotechnology on the competitiveness of the sector has been rather limited so far. The main contribution of biotechnology has been in the substitution of traditional products.[27] Altogether, modern biotechnological methods, approaches and products had a high relevance for maintaining competitiveness of around 220,000 jobs in Germany in 2000 (Table 1).

EMPLYMENT EFFECTS OF BIOTECHNOLOGY UNTIL 2010

To estimate the future employment effects of modern biotechnology in Germany, three different scenarios were calculated which simulated differing diffusion rates of biotechnology in application industries. In the 'trend scenario' it was assumed that diffusion of biotechnology proceeded at the same speed as during the past ten years. In such a scenario the number of employees directly influenced by modern biotechnology increased to around 136,500 persons (including the input industries) until 2010 (Figure 3). In comparison with the year 2000 the number of employees increases in particular in small and medium-sized specialised biotech companies as well as bio-instruments and bio-supplies manufacturers while in contrast the number of jobs related to universities and other research institutions shrinks slightly (Table 1, Figure 3).

It can be expected that the number of jobs that are indirectly influenced by modern biotechnology in application industries will significantly increase between 2000 and 2010 (Figure 4). This relates in particular to the pharmaceutical industry in which the number of employees affected by this technology will more than double to around 63,600 people by 2010. The figure will grow in the food processing industry as well, which is highly influenced by the effects in food processing input industries (Figure 4). In contrast, only a very moderate job growth induced by the use of modern biotechnology can be expected in the (fine) chemicals industry and in environmental biotechnology until 2010. When simulating the employment effects of biotechnology in Germany, it was assumed that the existing de facto moratorium for genetically modified plants in the EU will be lifted from 2005 so that the cultivation of such plants will be allowed in the EU member states in subsequent years. Assuming the adoption rate of genetically modified plants in

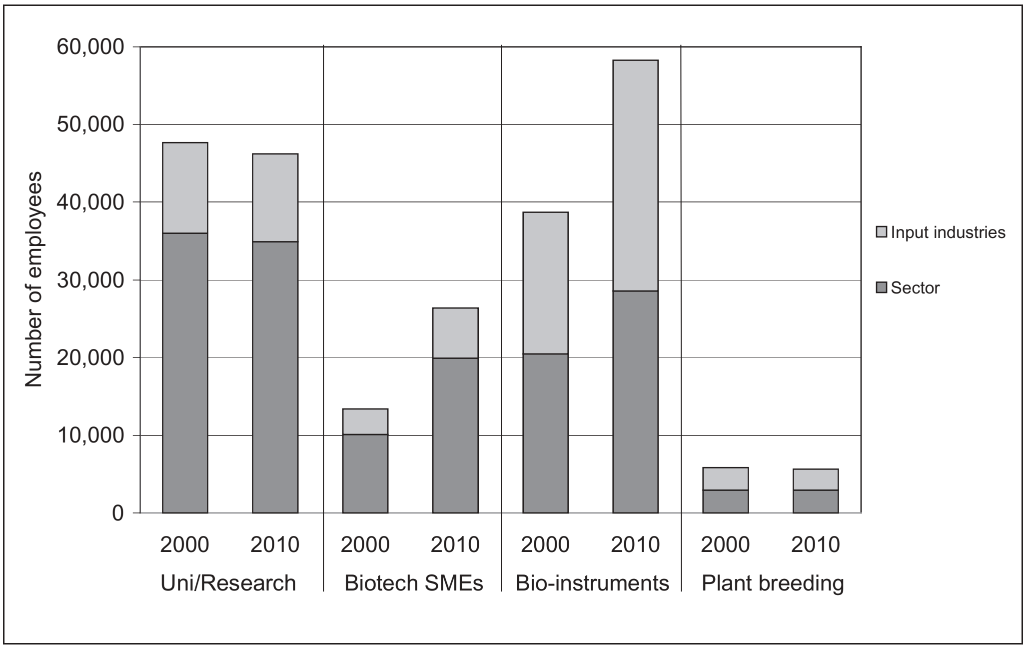

Figure 3: Development of number of employees in directly influenced sectors until 2010 in the 'trend scenario'

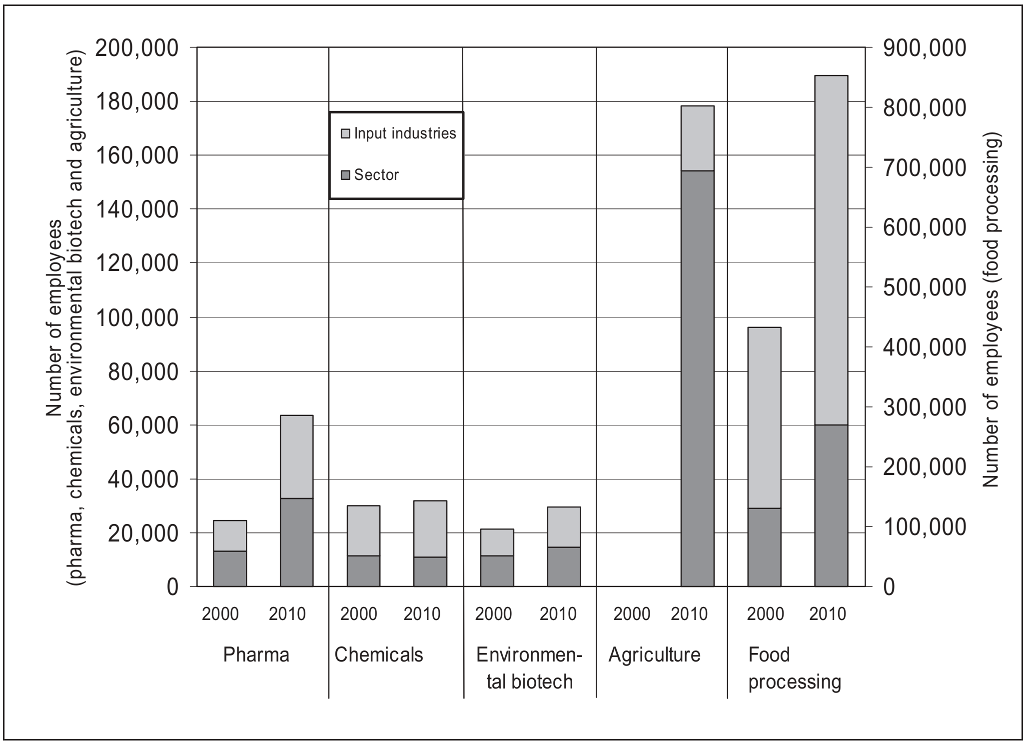

Figure 4: Development of number of employees in indirectly influenced sectors until 2010 in the 'trend scenario'

Employment effects in biotechnology until 2010 are highly influenced by the speed of diffusion of this technology in additional application fields

Germany which was observed in the USA and Canada in recent years this could lead to around 178,000 persons which might be influenced in the agricultural field by modern biotechnology in 2010 in Germany (Figure 4). (The figure of 178,000 people includes family workers as well as hired employees in agriculture in Germany. There might be some overlap of jobs influenced by modern biotechnology in the agricultural field and the estimated number of jobs in the input industries of the food processing industry. However, owing to a lack of statistical data, this overlap cannot be quantified within the scope of the project.)

The extent of employment effects of biotechnology until 2010 is highly influenced by the speed of diffusion of this technology in additional application fields. This is illustrated in Figure 5, which shows that around 990,000 jobs will be affected by modern biotechnology in Germany in 2010, assuming a retarded diffusion of this technology (ie assuming half of the diffusion rate of modern biotechnology, which was observed in its application industries in recent years). Taking into account a rapid diffusion of biotechnological products, methods and approaches (ie doubling the diffusion rate of modern biotechnology, which was observed in its application industries in recent years), more than 1.7 million employees will be concerned with this technology in 2010. Very differing employment effects of biotechnology can be observed in the food processing and pharmaceutical industry as well as the agricultural sector (Figure 4). In this sense the adoption capabilities of the concerned companies form a key factor for the further diffusion of new biotechnological methods, approaches and products and hence for its future employment effects. On the other hand, the influence of biotechnology that already exists on very differing industrial branches indicates that this technology can be regarded as one of the future key technologies with significant cross-sectional characteristics.

Simulations for assessing the future development of the biotechnology employment potential reveal that the supply of university graduates until 2010 does not limit the development of those parts of the pharmaceutical and chemical industry, the environmental industry, the

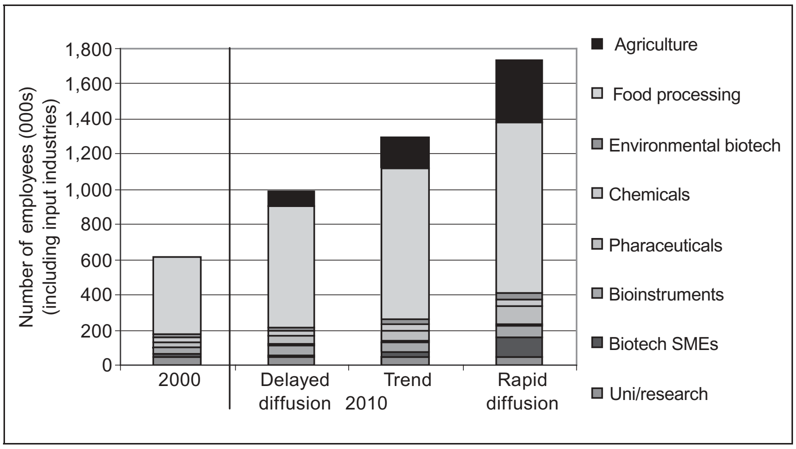

Figure 5: Influence of a differing speed of biotechnology diffusion on its employment effects until 2010

In high-impact cluster the number of jobs will increase from 220,000 in 2000 to a range of 330,000 to 677,000 jobs in 2010

food industry and agriculture that are affected by biotechnology. In contrast, the development of those sectors that are directly influenced by biotechnology depends considerably on the supply of university graduates. This holds true in particular for specialised biotech firms and equipment and supplies companies (Figure 6).

When assessing the overall effect of biotechnology on future employment, it is important to consider that the various jobs are influenced to different degrees by biotechnology. In order to take this aspect into account, the total set of jobs affected by biotechnology was classified into two clusters: a first cluster where biotechnology exerts a strong influence and a second where the influence of biotechnology is restricted. In the first, high-impact, cluster the number of jobs increases from about 220,000 in the year 2000 up to a range of 330,000 to 677,000 jobs in the year 2010, depending on diffusion rates and supply of university graduates (Figure 7). Hence, in the year 2010 a maximum of approximately 1.7 per cent of all employees in Germany will depend on biotechnology. In addition, spill-over effects of biotechnology on further jobs need to be considered. The upper limit of these jobs is given by the low-impact biotechnology cluster. In particular the food industry and related upstream industries contribute a large share to these jobs. The total number of jobs in this cluster increases from about 393,000 in the year 2000 to between 657,000 and more than 1 million people in the year 2010, depending on diffusion rates.

CONCLUSIONS

In all three scenarios the extent of the future employment effects of biotechnology depends crucially on the adoption rates of biotechnology in additional application areas. Therefore, the absorption capabilities of the affected

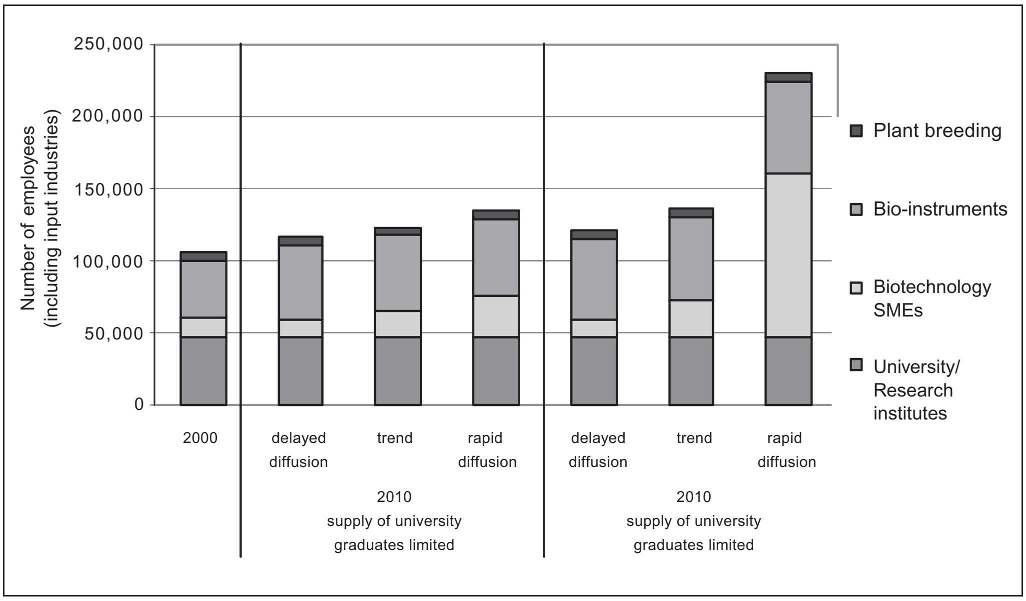

Figure 6: Influence of differing supply of university graduates on direct employment effects of biotechnology

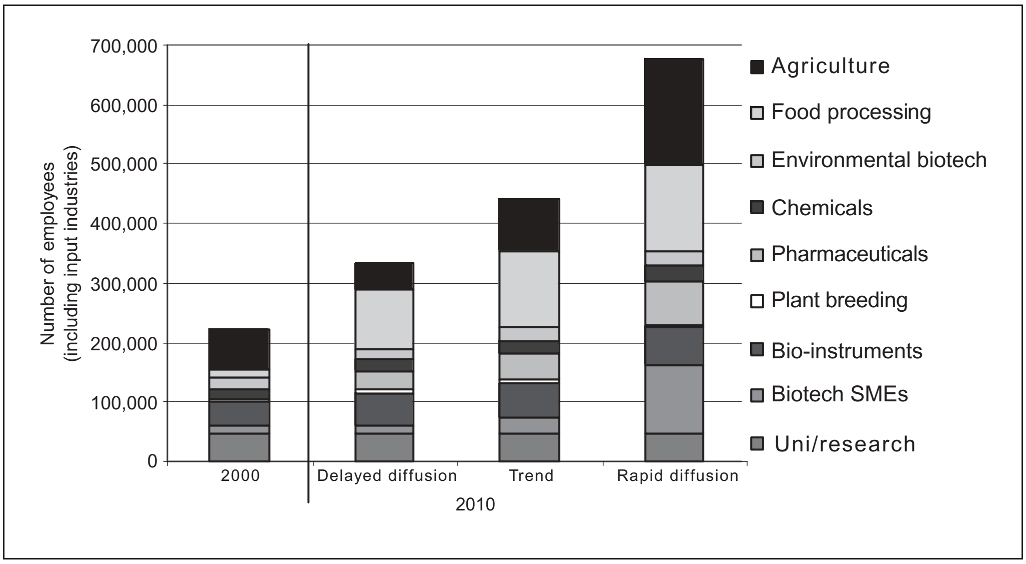

Figure 7: Development of employment until 2010 in those sectors in which biotechnology has high relevance for maintaining competitiveness

Absorption capabilities of traditional industries are a crucial factor for future employment effects of biotechnology

industries can be considered as a crucial factor for the further diffusion of biotechnology. In addition, the present and future impacts of biotechnology on various different industrial sectors indicate that biotechnology has taken root as an important key technology with a pronounced cross-sector character.

Future employment effects of biotechnology will be high in traditional industrial sectors such as the food processing industry, agriculture or the chemical industry. Quite frequently only a limited number of large firms in these industrial sectors have at their command the required preconditions to integrate complex technologies such as biotechnology into existing processes or to develop new products and services based on biotechnology. However, most SMEs in these industries do not possess the required skills. Since these SMEs provide an important contribution to the overall employment, it becomes crucial to develop the required interface competencies in these companies. This includes the creation of external knowledge and competence networks as well as entering strategic partnerships. So far this has been mainly discussed and realised in biotech SMEs but not in SMEs in traditional industrial sectors.

While no general lack of university graduates will limit the growth of industrial branches influenced by modern biotechnology until the year 2010, the facts that currently there are already some bottlenecks in specific niches (eg in bioinformatics) and that there will be increasing shortage, in particular of specialised natural scientists and engineers, cannot be ignored. In addition, industry complains about the low availability of experienced managers for biotechnology companies. A further restriction might arise in the future in technical personnel for biotechnology whose labour market has not been analysed in detail in this study.

The supply of university graduates can be extended only by increasing the transition rates to universities and technical colleges or by shortening the length of the studies. Since these activities will meet their limitations relatively quickly, more emphasis has to be put on re-educating employees in those fields that will be penetrated by modern biotechnology in the future. For this purpose, corresponding opportunities for further training have to be established in order to maintain competitiveness and employment possibilities in the companies and industrial branches affected.

Based on the results of this study the need for additional investigations could be identified. The expected results would also contribute to the fine adjustment of the research design used for this project:

- Identification of constraints for the diffusion of biotechnology in further application sectors.
- Development of strategies to remove those obstacles.
- Improvement of the little knowledge on those factors that determine decisions about human resources at a company level and the effect of those decisions on company development.
- Analysis of the present and future demand and supply of professions with a technical qualification for biotechnology.
- Enhancement of the quality and availability of statistical data on biotechnology: in order to monitor the further development of this area and to be able to shape the future evolution, it seems advisable to implement a continuous reporting scheme.
- Analysis of the relation between increased productivity due to biotechnology and possible job reductions.

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