

VITALISATION OF INDUSTRY THROUGH THE REGIONAL PROMOTION OF KNOWLEDGE INTENSIVE NEW FIRMS – THE CASE OF GERMAN BIOTECHNOLOGY

Nils Omland and Holger Ernst

INTRODUCTION

As a consequence of falling transportation costs, free capital flows and the elimination of trade barriers, competition becomes global in many markets and companies are enabled to dynamically choose their locations on a global scale. Given that high labour costs, high environmental standards and low raw material endowments are common among the currently leading countries, there are important reasons for many companies to shift their business away. Policy makers first reacted to this challenge by trying to retain companies that could operate more efficient elsewhere with government subsidies. As an example, the German government covers the economic loss of companies from mining in Germany, spending Euro 4,76 billion or Euro 33,000 per employee per year in 1998 (BMWA, 1999). An economically better alternative to inefficiency-compensating subsidies is the attraction of new, promising companies commercializing new technologies. These can compensate for companies active in industries at the end of the technology life cycle that leave the region. This (re)vitalization of regions can be initiated by creating superior business environments.

THE IMPORTANCE OF THE REGIONAL BUSINESS ENVIRONMENT

In today's economy, competitive advantages are generated mainly from knowledge, human relationships and management systems (intellectual capital). Most other input factors have become ubiquitous. Intangible assets constitute a major share of the market value of publicly traded companies (Boulton et. al., 2000; Lev, 2001). Consequently, the most value creating companies are knowledge-intensive companies and can be attracted by environments in which intellectual capital can be acquired, employed and increased easily.

While there certainly is a tendency towards the creation of global innovation networks, technology-orientated companies also tend to cluster in regions. In Germany, one can easily observe this by looking at patent data. Figure 1 shows the spatial distribution of patent applications in Germany and figure 2 the patent density, measured as the number of patent applications per inhabitant of the pre-defined regions. The main regions of knowledge creation in Germany are Stuttgart, Munich, the Rhineland, Berlin, Hamburg, the Rhine-Neckar-Triangle, Frankfurt, Nuremberg and Wolfsburg. Considering patent applications per inhabitant, Berlin and Hamburg are not very innovative regions (see figure 2).

Many aspects of a business environment that stimulates the creation of intellectual capital depend on the spatial dimension: The pooling of specialized factor markets, especially skilled labour and specific business-oriented services (Krugmann, 1991). The lower transaction cost and risk of cooperation and information exchange, especially when tacit knowledge is involved (Lundvall, 1988, Howells, 1999). Tacit knowledge cannot be codified and needs practice and direct social contact to be transferred. The cost of transferring tacit knowledge is thus dependent on distance (Audretsch and Stephan, 1996 and 1999). It has empirically been shown that most knowledge spillovers that result in new patents occur at the regional level

(Jaffe et. al., 1993). The impact of universities and research institutions is also largely of regional scope (Feldman and Florida, 1994): They enhance the local market for specialized labour, provide possibilities for knowledge exchange and research alliances and act as a source of entrepreneurial activity.

Figure 1: Spatial Distribution of Patent Applications

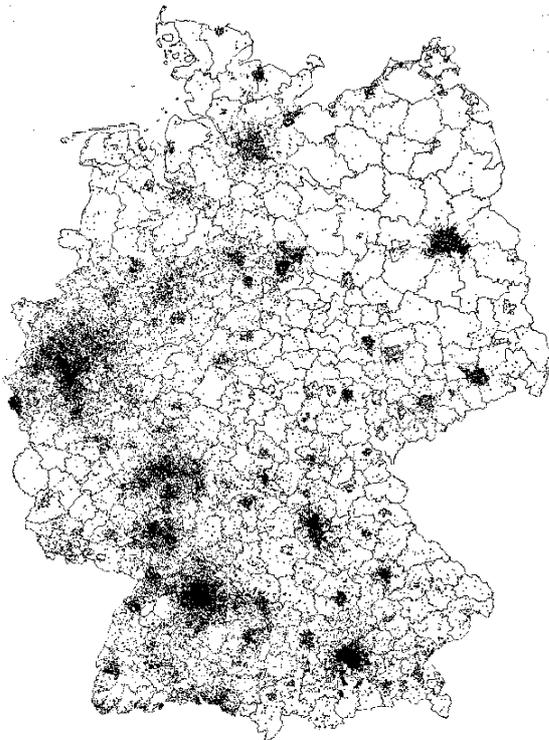
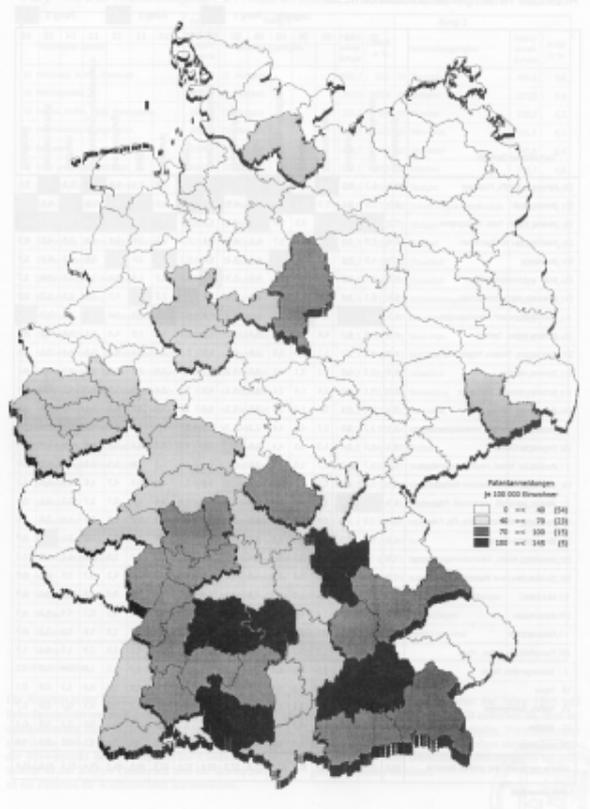


Figure 2: Patent Applications per Inhabitant



Source: Greif and Schmiedl, 2002

A NEW POLICY FOR THE DEVELOPMENT OF GERMAN BIOTECHNOLOGY

Most of the arguments given for the importance of regional business environments have direct policy implications. In this paper, we report on the results of the BioRegio competition, a biotechnology promotion policy based on the new concept of innovative regions, that has been implemented by the German Federal Government since 1995. The success of this policy gave rise to a sequence of similar regional promotion concepts in other fields of technology. It thus represents a new “universal” technology policy instrument.

Biotechnological companies are well suited to observe the effects of promotion policies in knowledge-intensive industries: They are not only extremely knowledge-intensive and research-oriented, but they also need comparatively strong funding, since often significant research investments must be made before any cash-flows can be generated. Additionally, as most companies in this industry are relatively new, their original location decision reflects contemporary properties of their regions. Finally, biotechnology is a ‘strategic’ technology for Germany and other developed nations. The most important inputs to biotech firms are very skilled labour and specialized knowledge. Therefore, they are likely to locate close to leading research institutions (Zucker et. al., 1997).

The BioRegio Competition

Although Germany had important research institutions in the field of biotechnology, before 1996 the economic exploitation of the research results took place in other countries, mainly the U.S.A. and the U.K.. Recognizing the importance of this ‘strategic’ technology, the German government decided to encourage the formation of new biotechnology companies, stimulate the growth of existing enterprises and increase the availability of venture capital. The long run aim was to make Germany the number one in European Biotechnology and to vitalize the biotechnology regions. To achieve this, the Government developed a new policy characterized by the promotion of designated biotech regions as centers of growth and by the stimulation of interregional competition (Dohse, 2000). This policy was first implemented with the BioRegio contest in which the winning regions got access to special federal funding for a period of five years. For any project in these regions to receive funding, at least half of the necessary investment had to come from private sources. In fact, federal government largely relied on the judgement of the private investors to distribute the public funds within the regions (Milmo, 1999). The regions participating in the competition were evaluated along 9 criteria by an independent jury of scientists and industry representatives (see table 1).

Table 1: Evaluation criteria of the BioRegio contest

1	Number and scale of existing biotechnology companies in the region
2	Number, profile and productivity of biotech research facilities and universities in the region
3	Interaction of different branches of biotechnology in the region
4	Supporting service facilities (patent attorneys, information networks, consulting)
5	Strategies to convert biotechnology know-how into new products, processes or services
6	Regional concept to help start-up biotech companies
7	Provision of resources (private and public) to finance biotech companies
8	Cooperation among regional biotech research institutes and clinical hospitals in the region
9	Local authorities approval practice concerning new biotech facilities and field experiments

Source: BMBF, 1996

In late 1996, three winners were chosen among the 17 participating regions. The winners were the regions Munich, Rhineland, and the Rhine-Neckar-Triangle. These are located in traditional industrial clusters of Germany. They were chosen for their superior scientific base, existing entrepreneurial activity and regional development concept. Apart from the three main winners, the small region of Jena in Eastern Germany was given a ‘special vote’ for their ambitious and focused re-orientation towards biotechnology after the re-unification of Germany. Funds of Euro 75 million were reserved for biotechnology projects and regional promotion activities in the winning regions from 1997 to 2005. Jena received a special fund of Euro 15 million. Apart from that, companies from these regions were granted preferential access to the funds of the general federal ‘Biotechnology 2000’ program that was endowed with Euro 750 million for the period from 1997 to 2001 (Dohse, 2000).¹ These numbers do not include the funds for biotechnology research in public universities or public research facilities.

As a consequence of the BioRegio contest, the four winning regions received funds to implement their regional development concepts and the firms located in these regions

¹ As it was a requirement that at least 50% of the funds for a project must come from private investors, a total of more than Euro 1.5 billion was made available to biotechnology companies.

received the main share of Biotechnology funding from 1997 to 2003. Table 2 shows the disparity of investments in biotechnology projects among the 17 regions of the BioRegio contest in the first 23 months. The stated investment volume is the investment in industrial biotechnological R&D projects and new firms that received partial funding from the government. On average, 40% to 50% of the total volume come from federal funds.

Table 2: Biotech Investments (January 1997 – November 1998)

Name of Region	Absolute Investment Volume (Million Euro)	Share of Investment into all 17 regions
Rhineland	47.6	24.4%
Rhine-Neckar-Triangle	42.2	21.6%
Munich	25.2	12.9%
Jena	14.5	7.4%
All other 13 regions combined	66.1	33.8%

Data Source: Dohse, 2000

CHARACTERISTICS OF THE BIOREGIO WINNER REGIONS

The regions of Rhineland, Munich and the Rhine-Neckar-Triangle all have strong biotechnology science institutions. The promotion of biotechnology in Germany effectively began between 1984 and 1989 with the establishment of the German gene centers in Cologne (Rhineland), Heidelberg (Rhine-Neckar-Triangle), Munich and Berlin. The regions are similar in important characteristics and pursue comparable regional development concepts in biotechnology. However, each region also has unique characteristics that demand a closer look. The four BioRegio winner regions will be described in more detail

Munich

Apart from its gene center Munich has many other biotechnology research facilities: There are two universities, the Technical University of Munich and the Ludwig-Maximilians-University that perform research and educate scientists, two colleges that educate laboratory personnel, three large renowned research institutes and two university clinics. In total, there are more than 60 institutes and professorships in the life sciences in the Munich region, many of them located near Martinsried. Martinsried is home to most of the biotech companies in the Munich area. The public life science research spending is estimated to be Euro 125 million in the Munich region (Bio-M AG). Many of the new biotechnology companies are spin-offs of local research institutes.

An important role for biotechnology in Munich played the pharmaceutical company Boehringer Mannheim, that established biotechnology production sites near Munich as soon as 1946. By 1997 the production facilities had been modernized with an investment of Euro 750 million and had more than 2000 employees. When the company was acquired by Hoffman LaRoche in 1997, these biotechnology facilities were reinforced and integrated into the global research network of the company. The Hoffmann LaRoche facilities continue to have a big impact on the local labour market and the company is actively seeking contacts and cooperations with local research institutions and small biotech companies (Zeller, 2001).

As the German Patent Office is located in Munich and the European Patent Office also has important office there, one can expect that the competence in intellectual property available through patent attorneys and consultants is especially strong in the region. Intellectual property is of paramount importance for the successful foundation of new biotech firms.

In Munich, the promotion of biotechnology already began before the BioRegio competition, as a part of the Bavarian “Future Offensive Bavaria” financed by the privatization of public assets. In 1994, two years before Munich emerged as a winner of the BioRegio competition, the Start-Up-Center in Martinsried was founded. This center is a building complex designed to meet the needs of biotech companies. It offers certified laboratory space and other infrastructure to new firms. Due to the proximity to major research centers and the extreme concentration of biotech start-up firms, it facilitates formal and informal exchange of information and tacit knowledge (Zeller, 2001).

As a result of the BioRegio competition, the Bio-M AG has been founded in 1997. The Bio-M AG helps biotech companies in a variety of ways: It assists in obtaining public and private funding; it even has its own fund to offer seed or venture capital. Bio-M also offers advice in the process of new firm formation, patenting and licensing and assists in finding appropriate facilities. It coordinates and stimulates the networking of the local biotech scene, and establishes contacts to founders, research institutions and investors. Bio-M offers seminars aimed at employees and founders, covering technical and economical topics. Finally, it is the institution that promotes the region throughout the worldwide biotechnology community (Bio-M AG, 2002).

Rhine-Neckar Triangle

The region around Heidelberg, Mannheim and Ludwigshafen has the University of Heidelberg, the German Cancer Research Center, the Max Planck Institute for Medical Research and the European Molecular Biology Laboratory. All of these institutions are internationally renowned for their research in the life sciences. Combined, these public research institutions have more than 55 institutes and research groups related to the life sciences. There are also two university clinics and several colleges educating laboratory personnel. The research infrastructure is less concentrated than in Munich.

Several important pharmaceutical companies are located in or nearby the region: BASF, Boehringer Mannheim (now Roche), Merck Darmstadt and Knoll (now Abbott). These companies have significant research capacities in the biotechnology field and are potential clients of new biotechnology firms.

The promotion concept of the region comprised the establishment of three entities:

- The BioRegion Rhine Neckar Triangle e.V. This organization helps the academic and private research institutions in obtaining public funding and offers advice for potential founders and start-up companies. It also arranges contacts between firms and investors. The organization also promotes the region in trade fairs, scientific conferences etc., and tries to improve the national regulatory environment. This entity is more concerned with basic research and what is called the “pre-competitive section”.
- Heidelberg Innovation which coordinated all aspects of the regional development that concerned the “competitive section”: It offered consulting and support services. The consulting services offered comprised many economic and strategic aspects and even

included help with writing the business plan. Many of the services offered could be paid in shares of the newly-founded company. Heidelberg Innovation also managed the local seed capital fund and has by now become a pure venture capital firm.

- The seed capital fund “Heidelberg Innovation BioScience Venture” was founded with a capital of Euro 12 million in 1997. This fund is financed by the local savings banks, the leading pharmaceutical companies of the region, and national credit institutes and works on a for-profit basis in financing very young firms. Since 2001, this fund has changed to a Euro 113 million venture capital fund operating internationally.

The region also has a technology park with a focus on the life sciences and in proximity of related research institutes. Similar to Munich, the technology park gives companies access to office and certified laboratory space.

Rhineland

Universities generating larger amounts of biotechnological knowledge in the Rhineland are located in Cologne, Düsseldorf, Aachen and Bonn. They are supplemented by the gene center in Cologne, the Max-Planck-Institute for Plant Breeding, the Center for Molecular Medicine in Cologne, the Jülich Research Center, the Fraunhofer Institute for Molecular Biotechnology and others. The Rhineland also has several university clinics. There are no numbers available for the quantity of institutes and research groups that exist in the life sciences field. The responsible biotech promotion agency emphasizes that the Rhineland is embedded in a wider region that has the highest density of universities and research institutes in Europe.

The Rhineland is home to a variety of pharmaceutical companies. The multinational chemical and pharmaceutical company Bayer and several mid-sized pharmaceutical companies like Schwarz Pharma have their headquarters in the heart of the Rhineland. Other multinationals such as Aventis have important facilities in the region.

Already in 1994, two years before winning the BioRegio contest, the BioGenTec NRW was founded to promote biotechnology in the Rhineland and the rest of the state Northrhine-Westphalia. This organization was developed from an initiative in Cologne that had been started in 1991. The BioGenTec was significantly strengthened in the BioRegio competition and coordinates biotechnology related networks in science, consulting and finance. It maintains close contacts to specialized regional biotech funds such as the Bayer Biotech Capital Fund. BioGenTec advises founders and young firms on their business plan and financing options, and offers practical help in new firm foundation. The agency helps researchers and companies in acquiring public and private funding for new firm foundation and research projects. It establishes contacts to consultants for many aspects such as market studies and intellectual property. The service of the consultants and other preparatory measures such as prototype development are partly supported with public funds granted through BioGenTec. The organization stimulates the knowledge transfer between research institutes and companies, establishes contacts on an international level and offers conferences and seminars to educate university researchers and employees of biotechnology firms. BioGenTec is also responsible for the promotion of the image of the region and biotech in general. BioGenTec NRW recently merged with the other regional life science promotion agencies (HealthCare NRW and MeTNet NRW) to form the Life Science Agency GmbH.

A particularity of the Rhineland is the distribution of biotechnological know-how and biotechnology parks across several cities. There are more than 10 technology parks with office and laboratory space for biotechnology companies.

Jena

The small innovative region around Jena has just around a hundred thousand inhabitants while the other regions have several million inhabitants. Consequently, there are less research facilities: Apart from the university of Jena and its clinic, there are 7 research institutions of which only three are directly related to biotechnology. Despite the comparably small size of the local scientific community, Jena is an internationally recognized research location since the breakthroughs of Carl Zeiss and Otto Schott in scientific instruments in the 19th century. The biotech-related R&D expenditures of the university and other public research institutions are estimated to be around Euro 100 million annually (BioRegio Jena e.V.).

In Jena, 53% of all employees work in companies active in optics, precision engineering or medical technology. There is one medium-sized pharmaceutical company, Jenapharm. With the special competence present in the region, Jena focuses its biotechnology efforts on the area of bioinstruments.

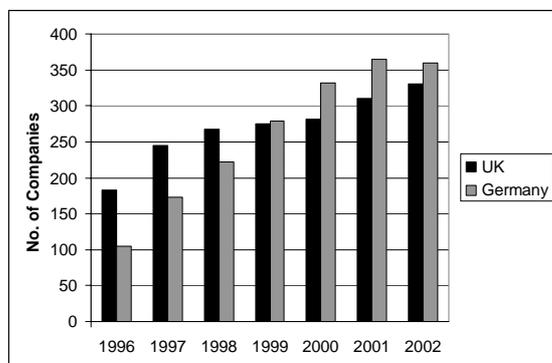
The promotion concept of Jena comprises three legal entities: The organization BioRegio Jena serves as the central agency to coordinate the region's companies, scientific institutions, investors and other stakeholders. BioCentiv operates the biotechnology park and offers consulting services in the process of the formation and growth of new firms. Finally, BioStart represents the region in the national and international community and tries to attract scientists, founders and investors.

The bioinstruments technology park at Beutenberg has been inaugurated only in 2000 and is already fully occupied. Another, more general technology park is also fully occupied. Compared to the other three regions, Jena thus does not offer so much central, easily accessible office and laboratory space for new firms.

RESULTS OF THE BIOREGIO PROMOTION

The BioRegio initiative and its successors have been very successful: While in 1996 the U.K. led the European Biotechnology scene by far, since 1999 Germany is the leading European country in terms of the number of companies (see figure 3; BMBF, 2000).²

Figure 3: Dedicated Biotechnology Companies in Germany and the UK



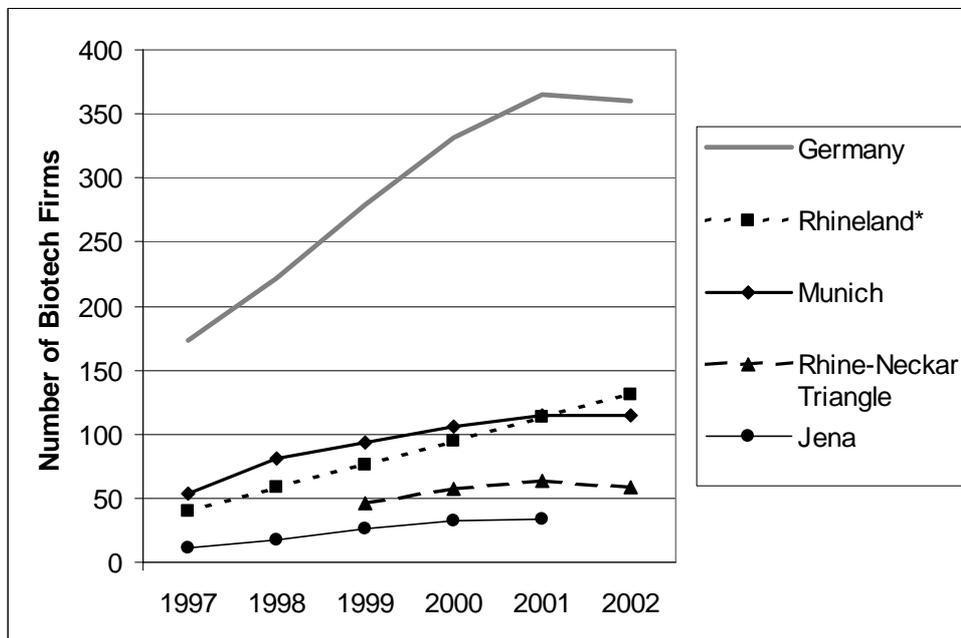
Data Source: Ernst&Young (2003a, 2003b)

² The turnover of the U.K.-based biotech companies, though, is still four times higher than that of the German firms.

The German venture capital firms have been able to attract large sums to their life science funds and Germany has become one of the prime targets for European life science investors (Milmo, 1999). After the start of the BioRegio promotion, the federal government started several other biotechnology initiatives, many of them with similar concepts: the BioProfile (from 1999, Euro 50 million for private R&D projects in three regions), BioChance (from 1999, Euro 50 million for high-risk private research projects in new firms), BioFuture (from 1998 to 2010, Euro 75 million for new star scientists) and ultimately the BioChancePlus (from 2004, Euro 100 million). Even though we are just observing the first effects of the promotion of biotechnology in Germany, we can already report the creation of more than 10000 jobs in dedicated biotechnology firms in Germany from 1996 to 2002 (Ernst&Young, 2003b).

When analyzing the performance of the individual regions, it is important to keep in mind that all 17 regions participating in the BioRegio contest developed regional biotech promotion concepts. Although special funds of Euro 90 million were reserved for the winners, the rest of the Euro 750 million biotechnology program was open to companies from any German region. Many of the regions that “lost” in the BioRegio competition nevertheless implemented their regional development plans and succeeded in attracting new companies. Therefore, by stimulating the regions to develop regional biotechnology concepts, the federal government effectively promoted biotech in all 17 participating regions. Consequently, the resulting difference between winner regions and other clusters cannot be automatically expected to be very high. Figure 4 shows the development of the number of biotechnology companies in the four BioRegio winner regions. The values for Rhineland have been linearly interpolated between the two known numbers for 1997 (start of the distribution of BioRegio funds) and 2002.

Figure 4: Number of Biotech Firms

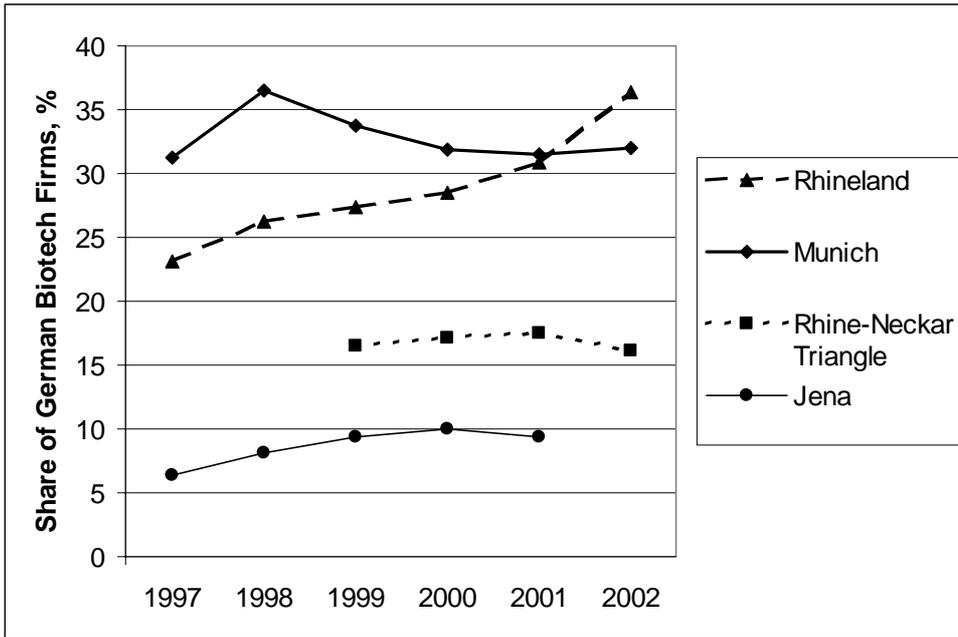


Data Source: Ernst&Young (2003b), Life Science Agency GmbH, Bio-M AG, BioRegion Rhein-Neckar-Dreieck e.V., BioRegio Jena e.V.

Figure 5 shows the number of companies in a region expressed as the fraction of all biotech companies active in Germany in a year.³

³ As the definition of a “biotech” company may differ between the regions and may also differ to the definition of Ernst&Young, the resulting figure should be interpreted concerning the dynamic development only.

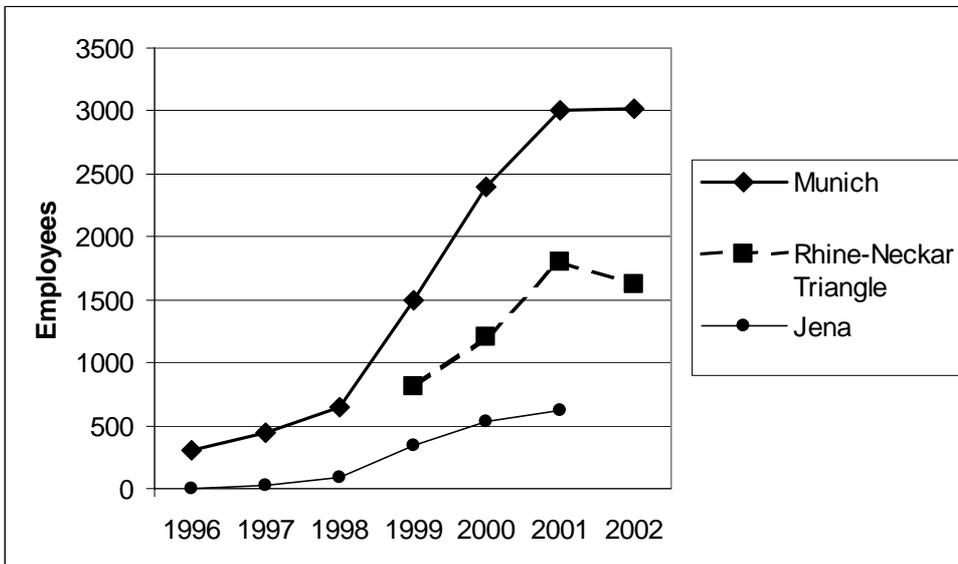
Figure 5: Regional Share of Total German Biotech Firms



Data Source: see Figure 4.

Rhineland was able to attract more new companies than any other of the four winner regions. Munich had the second largest increase in absolute terms. The major part of the growth, though, dates back to the period of 1997 to 1999. The Rhine-Neckar-Triangle attracted only few new companies during the period of 1999 to 2002. Jena very successfully improved the local biotech community from essentially nothing in 1996 to 29 companies in 2001. Concerning the relative increase from 1997 on, Jena clearly outperformed all other regions. Rhineland attracted more biotech companies than any other German region. As seen in figure 5, among the four winner regions only Jena and Rhineland significantly increased their share of German biotech firms. Rhineland significantly outperformed the promotion efforts of the Munich region and is now the biggest German biotech cluster. Concerning job creation, the situation is similar (see figure 6). Unfortunately, no statistics exist for the Rhineland.

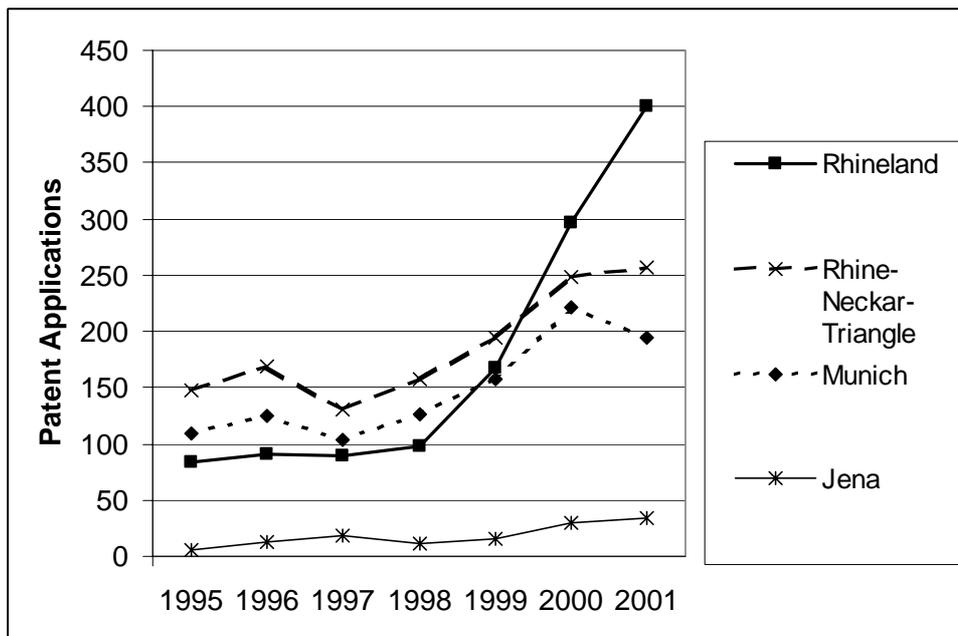
Figure 6: Job Creation in the BioRegion Winner Regions



Data Source: Bio-M AG, BioRegion Rhein-Neckar-Dreieck e.V., BioRegion Jena e.V.

Apart from the creation of new firms, an important policy aim is the creation of knowledge clusters. To analyze whether the regional promotion policy was successful in this respect, we examine patent data from the German and the European Patent Office. We searched for patent applications originating from Germany and classified into one of the main biotechnology IPC classes C07K, C12M and C12N. Between 1995 and 2001, 8888 patent applications match this criteria. Figure 7 shows the generation of biotechnological knowledge in the regions, as evidenced in patent data.

Figure 7: Patent Applications Per Year in Biotechnology



Data Source: Own Research.

All regions have accelerated their rate of knowledge creation from 1997 on, when the BioRegio promotion actively started. Rhineland has tremendously increased its patent output since 1998 and has by far surpassed Munich and the Rhine-Neckar-Triangle. The latter two regions are similar concerning their patent output. Jena, due to its small size, has a much smaller patent output compared to its big competitors. Figure 8 shows the relative development of patent applications indexed to the values of each region of 1995. Jena has accelerated its creation of patents more than any other region. However, the region of Jena started from a very low level of five biotechnology patent applications in 1995.⁴ While all other three regions increased their output of patent applications less than the German average until 1998, from 1998 on Rhineland seems to have massively improved its knowledge-creation process. Since 1999 Rhineland increases its patent output faster than the German average, while Munich and the Rhine-Neckar-Triangle continue to lag the development.⁵

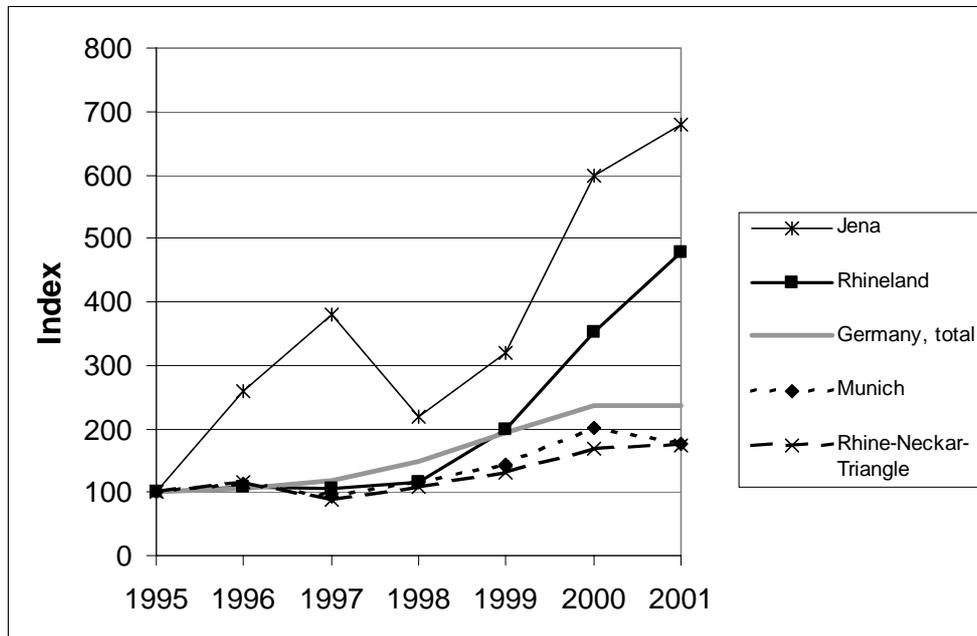
On average, about half of the patents originate from the industry and the other half from academic research. In the Rhine-Neckar-Triangle, the share of patents from the industry is

⁴ Many of the patents created in Jena that relate to Bioinstruments are not biotechnology patents in a narrow sense and are not counted.

⁵ There is the possibility that the disappointing development of Munich and the Rhine-Neckar-Triangle does not reflect their knowledge creation process, but a shift in patent application strategies. A shift away from European patents (e.g. to US patents only) or the usage of foreign subsidiaries to apply for patents could produce systematic distortions.

highest (67%) and in Munich it is lowest (41%). Removing the patents of the big pharmaceutical companies, the share of industry patents is more level among the regions.

Figure 8: Relative Development of Patent Applications.



Data Source: Own Research.

When counting only the patents from dedicated biotechnology firms, effectively excluding public research and big pharmaceutical companies⁶, the regional differences shown in figures 7 and 8 do not change much except for Munich. In Munich, patent creation is extremely dependent on the Fraunhofer and Max Planck research institutes. In 2001, just 56 patent applications in the investigated classes come from biotech companies. In Rhineland, the Rhine-Neckar-Triangle and Jena originate 235, 143 and 20 patent applications from biotech companies in 2001, respectively.⁷

Considering both the emergence of new companies and knowledge creation, Rhineland performed best in absolute terms. While Munich was leading the development until 1998, from that year on Rhineland's knowledge and company base grew faster and surpassed Munich by 2001. At present, however, the companies of Munich have a higher turnover than the firms of the Rhineland. If the development of the last years continues, however, it must be suspected that Rhineland will take over the lead of the Munich region in this respect, too.

The highest relative increase in biotechnology competence and companies was achieved by Jena. Starting essentially as a non-biotech region, Jena managed to leverage the existing competencies in related fields to enter the new business of biotechnology. It must be noted,

⁶ The analysis has been performed by including only patents from companies into the sample and then excluding patent applications from big pharmaceutical firms. Therefore, actually all small firms (not only biotechnology firms) are included into the statistics. We expect the majority of these firms, however, to be dedicated biotechnology firms.

⁷ As patents applied for by individuals cannot be attributed to a biotechnology firm the individual may have founded, it could be that actually more patents are the property of biotechnology firms. However, this systematic underestimation of patent applications is made in the other regions, too. It also does not concern the knowledge creation within industrial research. Given Jena's focus on Bioinstruments, we might miss some related patents that are not classified in the typical biotechnology classes.

though, that relative to its size Jena received a much stronger funding by the BioRegio contest.

CONCLUSIONS

The BioRegio contest was the manifestation of a new promotion policy by the federal government that implements the concept of innovative regions. It was a success for Germany as a whole and for all participating regions, especially the winners of the competition.

The job-creating effects of the government spending in regional biotechnology promotion are impressive. Even the region of Jena, which entered biotechnology only in 1997, created more than 600 jobs in new companies in this sector by 2001. In the long term, the initial public investment in new firms is expected to lead to the creation of many more jobs in Jena.

Despite the differences of the characteristics of the regions, all have successfully improved their regional biotechnology industry and the related specialized knowledge. It does not seem to matter if the promotional activities are performed by one or by several coordinated agencies. Furthermore, the presence of already existing biotechnology firms is not a prerequisite, as shown by Jena.

In a survey of German biotechnology firms in 1999, Dohse (2000) asked the companies for the advantages of the BioRegio instrument. The main advantages as seen by the firms were the strengthening of regional communication and cooperation, the evolution of a regional innovation-prone environment, regional research alliances and interregional competition for technology.

The success of the BioRegio competition is thus mainly dependent on the underlying concept, namely to promote the exploitation of research results in new companies. According to our analysis, the only prerequisite of this policy seem to be regions with a strong scientific base. But as shown by Jena, even related disciplines can serve as the starting point.

The regional promotion agencies made the process of new firm foundation much easier for scientists: They supplied crucial economic knowledge, contacts, seed capital and even office and laboratory spaces. This was complemented by the availability of federal funds for biotechnology projects. An important characteristic of the BioRegio policy was the requirement that any project funded with public money must have acquired at least half of the required funds from private investors. In this way, private investment in biotechnology was stimulated and public investment was directed into projects with high expected economic payoffs.

REFERENCES

- Audretsch, D. B., Stephan, P., 1996: Company-Scientist Locational Links: The Case of Biotechnology, *American Economic Review* 86 (3), pp. 641-652.
- Audretsch, D. B., Stephan, P., 1999: How and Why Does Knowledge Spill Over in Biotechnology?, in Audretsch, D. B., Thurik, R. (eds.), *Innovation, Industry Evolution, and Employment* Cambridge University Press, Cambridge, pp. 216-229.
- Bio-M AG, 2003: Annual Report 2002, Martinsried.
- BioRegio Jena e.V. (2001): *BioInstrumente Jena – die ersten Jahre*, Jena.
- Bundesministerium für Bildung und Forschung (BMBF), 1996: *BioRegio Wettbewerb – Entscheidung im November*. Press Release by the Federal Ministry for Education and Research, Bonn.
- Bundesministerium für Bildung und Forschung (BMBF), 2000: *Biotechnologie – Basis für Innovationen*, Federal Ministry for Education and Research, Office for Public Relations, Bonn.
- Bundesministerium für Wirtschaft und Arbeit (BMWA), 1999: *Der Bergbau in der Bundesrepublik Deutschland 1998*, Berlin.
- Boulton, R. E. et. al., 2000: *Cracking the Value Code: How Successful Businesses are Creating Wealth in the New Economy*, Harper Business.
- Dohse, D., 2000: Technology policy and the regions – the case of the BioRegio contest. *Research Policy* 29, pp. 1111-1133.
- Ernst&Young (2003a): *European Biotech Report 2003*, Stuttgart
- Ernst&Young (2003b): *Deutscher Biotechnologie Report 2003*, Stuttgart
- Feldman, M. P., Florida, R., 1994: The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States, *annals of the Association of American Geographers* 84 (2), pp. 210-229.
- Greif, S. and Schmiedl, D., 2002: *Patentatlas Deutschland, Ausgabe 2002*, Deutsches Patent- und Markenamt, München.
- Howells, J., 1999: Regional Systems of Innovation, in D. Archibugi et. al. (eds.), *Innovations Policy in a Global Economy*, Cambridge University Press, Cambridge, pp.67-93.
- Jaffe, A., Trajtenberg, M., Henderson, R., 1993: Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics* 108 (3), pp. 577-598.
- Lev, B., 2001: *Intangibles: Management, Measurement, and Reporting*, Brookings Institution Press, Washington D.C.

- Lundvall, B.A., 1988: Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation, in: G. Dosi et. al. (eds.), *Technical Change and Economic Theory*, Pinter Publishers, London, pp. 349-369.
- Milmo, S., 1999: German Biotech Comes of Age, *Chemical Market Reporter* 255 (19), pp.13-14.
- Krugmann, P., 1991: *Geography and Trade*, Leuven University and MIT Press, Leuven and Cambridge.
- Zeller, C., 2001: Clustering Biotech: A Recipe for Success? Spatial Patterns of Growth of Biotechnology in Munich, Rhineland and Hamburg, *Small Business Economics* 17, pp. 123-141.
- Zucker, L., Darby, M. and Brewer, M., 1997: Intellectual Human Capital and the Birth of the U.S. Biotechnology Enterprise. *American Economic Review* 87 (1), pp. 290-306.