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Public R&D Policy: The Right Turns of the Wrong Screw? The Case of the German Biotechnology Industry

Andreas Fier and Oliver Heneric

ZEW
Zentrum für Europäische
Wirtschaftsforschung GmbH
Centre for European
Economic Research

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Non-technical Summary

The biotechnology industry still has considerable expectations concerning its growth rates in employment, new products, patents and profits. The technology is most relevant for policy makers to foster the national competitiveness, employment and social wealth. It is of particular importance for pharmaceutical companies to develop new products and its future profit margin is promising for private investors. Biotechnology start-ups have received special attention in most OECD countries. At present, industrialized countries invest a high amount of tax payers' money in laboratories, incubators, R&D projects etc. to support biotechnology entrepreneurs and to ensure future competitiveness and independence. However, it is largely recognized that Germany, one of the largest European economies, missed the accession of this upcoming key technology in the eighties, while it evolved in other countries led by the USA. Today, German R&D policy invests about Euro 600 Mio. each year by matching grants and just in private business projects to catch up with leading countries like the UK, the US or Asian competitors in this field.

In this paper we analyze if R&D policy in private business, respective public funding in biotechnology lost its origins, its mission and in the end its power. We assume that too many technologies and their increasing complexity overtax policy makers as much as their staff to follow their own strategies. It is assumed that authorities and public funding agencies neglect 'risk' as most important triggers for public R&D funding: it becomes arbitrary. We assume that public R&D funding degenerates in a public policy without discriminating between firms which suffer from financial risk, technical risk or market risk. Today, and especially in biotechnology, every firm which likes to be funded will be funded, because the R&D policy does not care for different risks any longer. Bureaucrats and experts decide by their own which projects and firms will be funded and become totally screwed on the target population.

This study combines data of all German biotech companies and all publicly funded R&D biotech projects on the firm level from 2000 to 2003. The survey contains data of 1,529 firms from the largest German credit rating agency called "Creditreform" as much as mission-orientated R&D project data of 326 firms from the Federal Ministry for Research and Education (BMBF). The BMBF funding data on R&D projects in the field of Biotechnology remains the most important and extensive instrument to foster R&D in Germany. We carry out Probit and Tobit estimations to determine public funded R&D. In the estimated models we control e.g. for industries, age, credit history, turnover, legal form, patents as well as for particular business fields which might have influence on the probability to receive public R&D subsidies.

Public R&D policy: The right turns of the wrong screw? The case of the German Biotechnology Industry

Andreas Fier and Oliver Heneric[1]

Centre for European Economic Research (ZEW), Mannheim

Abstract

The German biotechnology industry missed the accession of this key technology in the 1980s. Policy makers make different efforts to overcome shortcomings and recent gaps. Public funding schemes have been implemented to establish a flourish biotech industry in Germany. We assume that R&D policy was driven blind by the idea to catch up with world's biotech leaders and analyse if Germany's R&D policy lost its origins. We do examine, if Germany sacrifice economic funding principles, in particular not discriminating different kinds of 'risk' in the field of biotechnology. The study combines survey data of German biotech companies and public R&D funding data on the firm level. The results shed light on the factors which determine public R&D funding and firm's probability of being funded.

Keywords: Biotechnology, Public Policy, Innovation, Subsidies
JEL-Classification: C21, H32, L21, L65, M13, O38

Address: Centre for European Economic Research (ZEW)
Department of Industrial Economics and International Management
P.O.Box 10 34 43, 68034 Mannheim, Germany
Phone: +49/621/1235-180, -234
Fax: +49/621/1235-170
E-mail: fier@zew.de, heneric@zew.de

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1 Introduction

The biotechnology industry still has considerable expectations concerning its growth rates in employment, new products, patents and profits. The technology is most relevant for policy makers to foster the national competitiveness, employment and social wealth. It is of particular importance for pharmaceutical companies to develop new products and its future profit margin is promising for private investors. Biotechnology start-ups have received special attention to investors and policy makers in most OECD countries. Actually, industrialized countries invest a high amount of tax payers' money in laboratories, incubators and R&D projects. The common intention is to support biotechnology entrepreneurs and to ensure future competitiveness. However, it is largely recognized, that Germany, one of the largest European economies, missed the accession of this upcoming key technology in the 1980s, while it evolved in other countries directing by the USA. Today, German R&D policy invests a great deal of money each year by funding private business projects, to catch up with leading countries like the UK, the US or Asian competitors in this field.

We assume that too many technologies and its increasing complexity overtax policy makers as much as their staff to follow their own strategies. In this paper we analyze if R&D policy in private business, respective public funding in biotechnology lost its origins, its mission and in the end its power. Our main hypothesis, that R&D policy and one of its most important policy tools, the R&D project funding failed in the German biotechnology industry. While more and more administrative is necessary to control R&D funds to steer technologies, and while more and more firms participate in R&D-funding, the whole system is getting inefficient. It is assumed that authorities and public funding agencies neglect to discriminate 'risk' as most important triggers for public R&D funding: it becomes arbitrary. We assume that public R&D funding degenerates in a public policy without discriminating between firms which suffer from financial risk, technical risk or market risk. Today, and especially in biotechnology, every firm which likes to be funded will be funded, because the R&D policy did not care for different risks any longer. Bureaucrats and experts decide by their own which projects and firms will be funded and become totally screwed on the target population.

First, we give a brief overview of the status quo of Biotechnology in Germany. In the second section, we review the literature on market failure and R&D policy instruments to foster biotechnology. In the empirical section we describe the data, the econometrics applied and finally, we present the results for Germany. Our main question focus on which factors determine public R&D funding in the biotechnology industry in Germany and if R&D policy is a steering policy tool towards new technologies or just another kind of industrial policy.

2 The need to foster technology

The mechanisms behind the utilization of science and technology fostering economic wealth is eclectic and quite complex but it is common sense that a lot of scientific results play a fundamental role in advanced modern economies. The technology and its resulting innovation are closely connected with the expectations of benefits to society and economic growth. The success of turning hope towards reality is rather associated with investments of a firms' R&D activity.

Unfortunately, the participants of the private sector will only consider their own particular benefits as well as choosing their own level of commitment to the innovation process i.e. R&D investments (Leiden/Link 1992). As a result of this, market failure could occur, mainly characterized by indivisibilities and monopoly, uncertainty, and externalities.

The bulk of analysis by academics on government support for technology development has focused on the issue on social returns. Traditionally it is justified on the grounds that the social returns to research are likely to significantly exceed private returns, and thus that the private sector will under invest in research relative to the social optimum. Arrow (1963) proposes his view "that, when the market fails to achieve an optimal state, society will, to some extend at least, recognize the gap, and non-market social institutions will arise attempting to bridge it". Spence (1994) established this kind of market failure by the issues of appropriation and diffusion of knowledge as crucial characterizing R&D activities: (i) the existence of spillover effects makes it difficult for investors to capture the full social benefits of their innovation and (ii) leading firms charge to much for their new knowledge, such that the diffusion of knowledge is less than the social optimum. Thus, there is a trade-off between incentives for the socially efficient production of new knowledge and the incentives for its socially efficient diffusion.

In this respect economists argue that it is economically desirable to overcome the gap of private costs and social benefits by a financial back up provided by public authorities. Public incentives to private business R&D are generally preferred instead of regulations, because incentives aim to induce behaviour rather than command it. Subsidies and tax credits are market-compatible forms of direct government intervention and broadly used by policy.[2] In recent years government commit funds for stimulating business performed research to reduce costs caused by uncertainties and risks as much as fostering knowledge diffusion. Governments use different R&D policy instruments to overcome market failures such as a lack of appropriation by regulation (patent law), a lack of know-how diffusion by incentives

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[2] Although governments are the major player in stimulating private business R&D, private foundations offer R&D grants, too. However, non-profit foundations fostering R&D – especially technology driven scientific foundations – are in particular more established in the USA rather than in Europe.

to co-operate (exchange of R&D staff, collaborative R&D activities) and a lack of risks by financial incentives such as tax credits or R&D project grants. In general these policy tools are aimed at correcting for externalities in particular markets and to enhance efficiency.

Among most OECD countries government agencies intends to bridge these gaps concerning appropriation, diffusion and technical and market risks by similar justification of public R&D policies:

- In the USA, for instance, the Advanced Technology Program (ATP) illustrates these policy rationales, because “it provides cost-shared funding to industry for fledgling technologies, that are *high risk* in nature, but which could lead to positive spillovers”. It “seeks to fund R&D where the resulting knowledge and technologies are fully appropriable; that is investors cannot fully capture the financial returns to their investment. Instead the benefits flow to other firms, industries, consumers, and the general public” (NIST 2004).
- The European Commission argues that businesses have difficulties to incorporate technologies which are not part of their traditional field of activity and to access new types of skills. In particular, “*financial risks* are seen high for innovation and profitability may be delayed by development hitches, and tax may not be neutral between success and failure.” This calls for “general measures to streamline innovation processes and direct action on specific market failures” (European Commission 2004).
- The German Federal Government justifies its public R&D funding in industry by “external effects, i.e. if third parties can use research results and thus gain an economic advantage without paying the technology developer a fee. In such cases the incentives may bee to weak for innovative companies to develop private R&D activities in these areas to the extent desirable if economic profitability considerations were included.” Public policy offer R&D funds “where R&D projects have long time horizons, a *high economic risk* and great financial needs and therefore are beyond the possibilities of individual companies” (BMBF 1993).

Do government agencies bridge these gaps, taking into account different ‘risks’ by funding firms which suffer from financial, technical or market risk? In the last decade several new technologies, such as information and communication technologies, biotechnology or nanotechnology make great progress and governments invests extensive amounts to foster these technologies. However, it is less clear if governments and its R&D policy addresses the projects and entrepreneurs they aimed to address in the sense of eliminating market failure – or if governments just tends to surf on attraction and public attention to win elections (cf. Downs 1957).

The following analysis of missions of the German biotech policy in the field of publicly funded R&D projects is of particular interest, because the German industry was pretty late in this technology. Even so, we recognise significant numbers of biotech start-ups and simultaneous significant new public R&D policy schemes since the mid 1990s. We investigate if R&D policy and government funding agencies in such a dynamic environment still follows their basic principles of justification for market intervention, or if R&D policy tends to follow general expectations of public attention and lobbyists.

3 Institutional and historical background

The origins of biotechnology in terms of a publicly funded scientific discipline are close related to the origin of penicillin during World War II (Melak 1974, Perlman 1975). After the effect of penicillin has been discovered by *Fleming* in his laboratory 1928, it becomes obvious that this medicine was of particular importance for society's medical care, workforce and productivity. The British and the U.S. government were the first which funded research in this area since the 1930s but did not achieve large scaled industrial production until the outbreak of the war. Finally, the United States succeeded in the industrial production of penicillin by large R&D subsidies for scientific efforts. At the end of the 1940s the term of "Biochemical Engineering" was created, mainly in Anglo-Saxon countries and Japan who become world leaders in the new so called fermentation industry (antibiotics, enzymes), while Europe was a leading player in traditional biotechnological products, such as beer and wine.

In Germany the new fermentation technology was imported in the 1950s where the USA gave licences to the German chemical and pharmaceutical industry[3]. After the epoch making discovery of the DNA[4] by *Crick* and *Watson* in 1953 followed by the innovation of the recombinant DNA technique developed by *Boyer* and *Cohen* in 1973, the foundation stone of the biotechnology industry was set. Even the recombinant DNA method which means to have the possibility to produce hybrid gene material by joining pieces of DNA from different organisms and then inserting this hybrid material into a host cell offered a lot of opportunities for business ideas and its commercialization (Orsegnio 1989). The crucial factor was the possibility to manipulate, create and reconstruct life. Based on technologies derived from the latest results in molecular biology, genetics, biochemistry, informatics or physics, the development of new therapeutics or diagnostics ("red" biotechnology), new products or services for the agricultural and food markets ("green" biotechnology) or for environmental activities ("grey" biotechnology) frame this industry. The value chain within the biotechnology industry contains further services and supplying activities.

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[3] Hoechst Inc. (1950) and Bayer Inc. (1952) used these licences to use these new technologies.

[4] DNA=deoxyribonucleic acid and proteins are the biological molecules most often used in biotechnology. DNA provides instructions for making cells and performing cellular tasks, while proteins provide the building materials for producing new cells and are responsible for carrying out the DNA's instructions.

However, German industry i.e. the chemical and the pharmaceutical sector, was reserved towards biotechnology until the end of the 1960 and as innovation is concerned; it behaves like a follower instead of a pioneer. The motive of behaving like this is determined by firms' research strategy which was based on organic chemistry that time. This strategy was in the 1950s and 1960s the road to success for the German industry (Peter 2002). The change towards biotechnological research strategies in German R&D departments came quite late. In the 1960s, R&D policy and the conviction to set future trends become more and more important in Europe. The OECD (1966) stated, that "the traditional mix of market mechanisms and policy intervention is less suitable to overcome the complexity of technologies in industrial societies". In this period the German Government decided to push science and research within a pro-active R&D policy which has to tackle problems of the next 20 years (BMBW 1971, BMFT 1972). The issue of biological and medical technologies first appeared in Germany in the public policy scheme called 'New Technologies' in 1968 (BMwF 1969). In this context the first large scaled and publicly funded projects started in three companies in Germany.[5]

In 1971 the framework programme 'Biology, Medicine and Technology' was initiated to foster science and to stimulate private business. Subordinated funding schemes were designed to offer direct R&D project grants to science and industry. The typical characteristic of this kind of funding is the direct financial support in a concrete field of research. Until today, such grants to the German high tech industries are given as matching grants, i.e. firms have to contribute a minimum of 50 percent own R&D capital to the publicly funded projects. In the early 1970s R&D on the structure and function of proteins (proteomics) was publicly funded by the German Government as much as resources derived from organic matter (biomass) and sustainable bio production. In the 1980s the direct project funding of biotechnological R&D was widened by programmes searching for substitutes for animal experiments and by research scholar-/partnerships to improve know-how.

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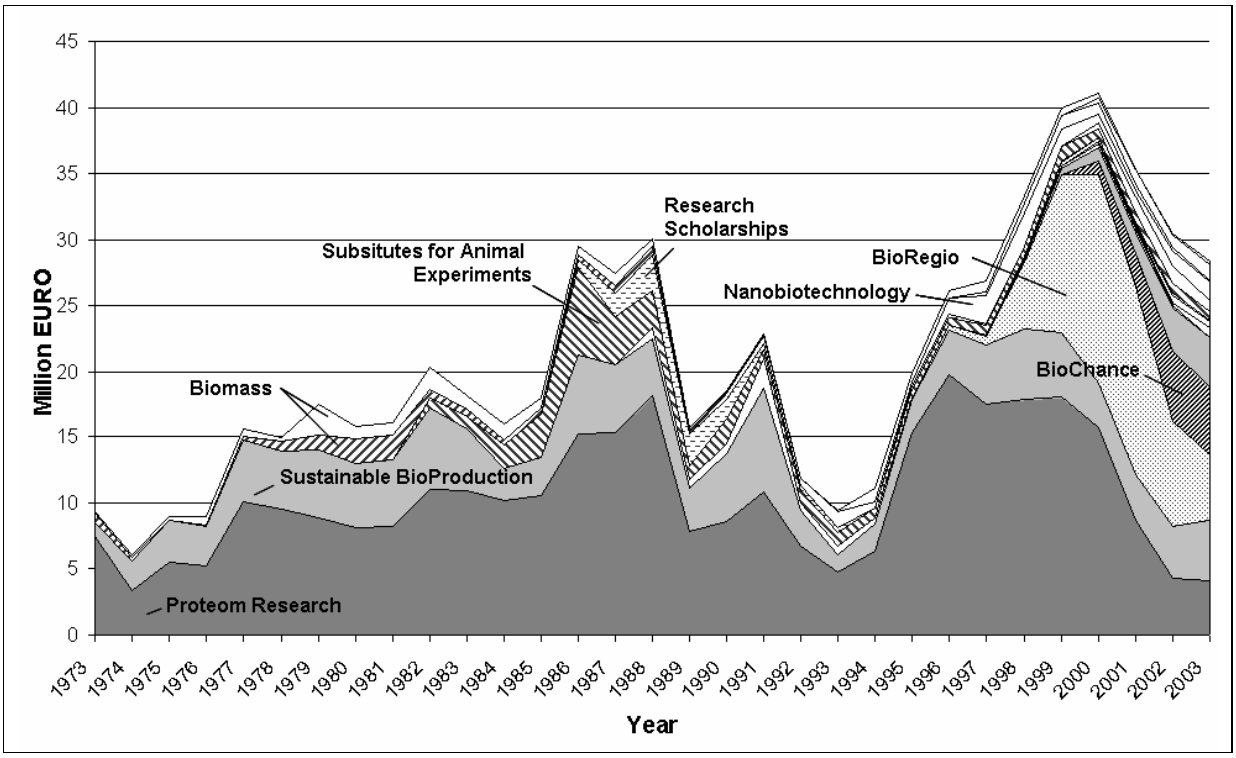
[5] After the 2nd World War the allies decide to break up the major war maschinery industries into single and civilian companies: The Uhde Ltd. was decentralised as a former part of the IG Farben Inc. In the 1950 it becomes a subsidiary of the Hoechst Inc. The know-how of Hoechst, which use licensed US technologies, was passed to Uhde Ltd. in the fields of organic chemicals, plastics and synthetic fibres. Uhde's 'Hoechst Branch' is a company of ThyssenKrupp Technologies Coop., today. The Gelsenberg Fuel Inc. was Germany's most important fuel and gas provider during the war and destroyed 1944. After 1950 the company was build up and becomes in 1955 an important fuel company, again. Gelsenberg Inc. was integrated into the Vereinigte Elektrizitäts- und Bergwerks-AG (VEBA). VEBA and Gelsenberg AG, like all shareholders of Ruhrkohle AG, were formerly mining companies and transferred their mining holdings to Ruhrkohle AG in 1969.

Figure 1: Federal funding by biotechnology programmes in the business enterprise sector (Germany 1973-2003)



At the end of the 1980s firms wind down their R&D activities in biotechnology, because legal restrictions on R&D were widely discussed and restrain research intensive firms from further investments in Germany. The period of the German unification was marked by high uncertainties in different economic respects. Large companies had to think about investments strategies and the future legal framework conditions were less clear. Germany, in particular, was also marked by a less developed biotechnology sector at the beginning of the 1990s. The awareness of the importance of biotechnology as a key technology combined with the possibility of gaining commercial products did not become a real topic in Germany for a long time (Wörner et al. 2001). For a quite long time there was no adequate legal framework concerning the requirements of the use of biotechnology. The provisions of national genetic law were first set in 1990. Furthermore, the mistrust of the positive effects of biotechnology was caused by the negative association with genetic manipulation within the public opinion (Harding 2003). Legal restrictions on R&D, like the first Genetic Engineering Act from 1990, set up barriers causing a negative effect not only for the biotechnology industry as well as for the pharmaceutical industry. As a result pharmaceutical companies with German headquarters relocated R&D facilities to biotechnological centres outside of Germany.[6] The political

[6] In 1989, Hoechst Inc. was forced to close a production facility of genetic products by law and relocated it outside of Germany.

climate and public opinion was not in favour of pharmaceutical biotechnology either (Giesecke 2000, Müller/Fujiwara 2003, Wink 2003).

However, the amendment of the law on Genetic Engineering in 1993 and gradually increasing economic activity changed the downward trend: about nine important biotech schemes, including Nanobiotechnology and Biological Safety Research characterise the public funding priorities in the 1990s and achieved its peak in numbers of R&D funding programmes, R&D funding amounts and companies at the beginning of 2001. In this boom period of biotech enterprises 15 different R&D funding programmes do not just reflect policy maker's expectations concerning jobs and welfare, but also investor's hope on profits in this technology (cf. figure 1).

The distinctiveness of this industry is characterized by some special conditions. Newly created biotech firms carrying out research and development projects face financial problems that are typical for young innovative companies. One specificity of the biotechnology sector is the high level of financing that is required over a long period of time to carry out R&D projects. As a matter of fact, development costs for a new drug – from biological target identification to authorization to commercialization – amount to more than 600 million US-dollars and more than ten years (DiMasi et al 2003, Ollig 2001).

The general change in R&D funding priorities concerning biotechnology can be observed in the mid 1990s, close related to the so called 'BioRegio competition' (Dohse 2000). This funding concept aimed at developing a new holistic approach for research and technology policy and was planned to integrate biotechnological capacities and scientific, economic and administrative activities. The governmental purpose of funding biotechnology was – and still is – to ensure that the high international standard of performance in the life sciences will be maintained. BioRegio was initiated to push the commercialisation of biotechnology in Germany and thus create internationally outstanding centres of excellence. At the same time the BioRegio contest changed the general Federal Governments' philosophy in public R&D funding: programmes were restructured to increase more transparency and linked with other funding programmes, e.g. for health research and production engineering. Moreover the corporate design of funding programmes was changed for biotechnology in Bio'X', such as BioRegio, BioChance, BioFutur, BioProfile.

4 The principles of R&D policy and its dramatic changes

In the biotech-boom of 1994 to 2001 the public R&D funding was basically justified by improving human health, making careful use of the environment, as well as safeguarding and creating jobs. A comparison of key technologies and public budgets show significant changes. In the particularly funding area of biotechnology funding stepped up in 1997 with 137 percent and again doubled until 2000 (BMBF 1998). While the number and projects of German biotech firms was small and manageable until the unification, the situation of R&D policy changed dramatically since the 1990s by four reasons:

- Policy makers did believe in a technology driving a “catching-up” process and a further economic takeoff in the new Länder (former German Democratic Republic). For this reason and in the context of the demand of (new) firms and research facilities, the direct R&D project schemes were not just opened to East-Germany but improved in terms of easy funding application conditions.

- Germany takes part in the world-wide race to decode human genotype. In 1996 the German Human Genome Project (DHGP) was launched by politics, science and industry in which funds increased by 70 percent. Moreover, Germany has pushed and agreed to the Fourth EU-Framework Programme for Research which appropriates three times as many funds for biotechnology as the previous programmes.

- Biotechnology patents – one of the most important aspect for industry, start-up firms and R&D policy – were recognised as crucial and a contemporary issue. In this respect, the DHGP was aimed at the systematic and comprehensive patenting of research results, thus ensuring the efficient translation of these results into innovative products and services.

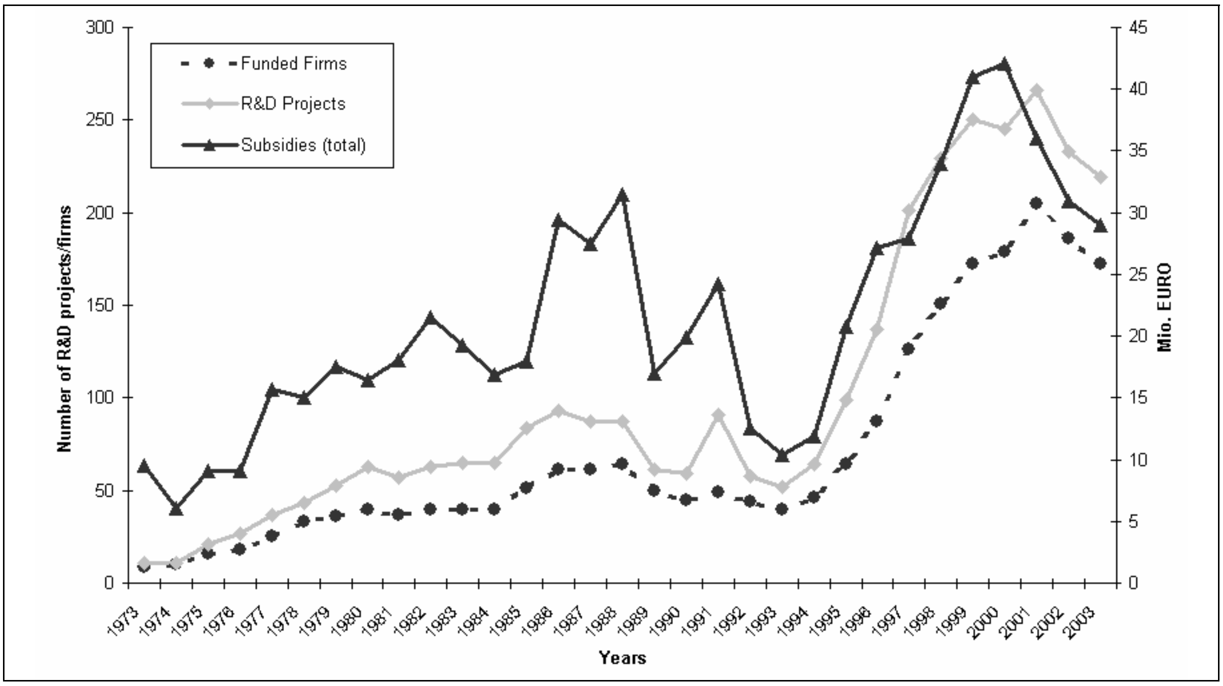
- National and foreign investors were searching for new fast growing technologies, firms and markets. European governments recognise venture capital as a perfect completion to typical bank loans and public subsidies in the field of high innovative new technology firms. A new culture of financing close to the NASDAQ in the US and similar activities in the UK was asked for and implemented as an own segment at most stock markets (e.g. ‘New Market’ at the German Stock Exchange).

While the number of German biotech companies was pretty small and all companies well known to R&D policy makers, the “takeoff” in biotech exceeded all expectations: After the kick off period of the biotechnology industry in the 1990s, more 300 companies were established at the beginning of the century. The slow down of the economic growth of the last three years affected the expected number of biotechnology companies but still result in 350 companies in 2003 (Ernst&Young, 2004).

This boom of biotech firms was accompanied – and maybe initiated – by the Federal Governments R&D policy. The BMBF pushed its project management agencies. Each project proposal is embedded in research programme announcements which clarify the funding objectives for each company to receive a potential financial support. The majority of the programmes straighten out in their byelaws that a fundamental precondition is a substantial research as well as a market risk which represents a clear disadvantage for the company. In addition, the risk must take a shape of preventing access to different resources e.g. financial resources. The funding objectives of the other programmes underline the fact that the research content should meet a potential market, should have a great innovation potential, and should foster joint ventures with already established companies in the particular market.

While in 1993 about 40 biotech firms have already achieved a public R&D project grant this number increased up to 130 firms in 1997. In this period, the traditional public funding procedures split up in several new approaches such as contests, competitions and lead-projects. In 1999 the Federal Government counts for 280 biotech firms in Germany and publicly funded at least 180 firms (64 %) by direct project grants.

Figure 2: Number of funded firms, R&D projects and total amounts of public R&D biotech funding in the business enterprise sector (BMBF 1993-2003)



The total number of publicly funded R&D projects was increasing from 52 projects in 1993 to 266 projects in 2001. If we take into account that firms carry out several R&D activities and apply for different biotech policy schemes the mean number of publicly funded R&D projects per firm is about 1.5 projects. In the year 2003 we do observe a total number of 350 Biotech companies in Germany. About 170 firms (49 %) have been publicly funded in 219 R&D projects. The total amount of public R&D project funding in the German biotech industry is almost € 28.8 million on average and because of the matching grants requirements (cost-sharing) almost € 57.8 million have been invested by industry and government each year.

The forthcoming empirical study focuses on this commitment. The hypothesis, we will inspect is, whether R&D policy in the field of biotechnology was carried away by the enthusiastic mood concerning this technology and if R&D policy tends to ignore its own principles. Do we observe a private business R&D funding which did not discriminate biotech firms in different 'risks'? Do we observe a "watering-can R&D funding policy"? In this case, public R&D project grants might damage a suspected economic uplift, because firms are forced to concentrate on (basic) R&D activities while they become totally engrossed of the needs of the market.

5 Empirical approaches towards public funding

5.1 Financial-, technical- and market risk in the field of biotechnology

New technologies and their relationship towards uncertainty and risk is subject of some of the classic works in economics (Knight 1921, Schumpeter 1912, 1942, Kirzner 1973). Besides notable studies which focus on science and public basic research economists in particular analyse the commercialisation of new discoveries and in this context different risks. Risk and uncertainty are inherent in the nature of high-tech innovation. In general three major kinds of risk occur: financial risk, technical risk and market risk. The embodiment of a the specific risk structure of the biotechnology industry can be characterised as follows:

Financial risk: Recently, but more apparent in the high-tech boom years of the 1990s, technology entrepreneurs complain about a shortage of R&D funding capital while large sums still remain in Venture Capital funds or banks. Because of this observation economists and governments diagnose that established markets do not internalize risk capital to early-stage technologies. With respect to Spence' (1984) theoretical reflection such inefficiency concerns limits of the ability of investors in early stage technologies to fully appropriate returns from the investment. Moreover and even worse serious inadequacies in information to both entrepreneurs and investors arise because of technical uncertainties. Given these uncertainties investors prefer to hold back rather than to make speculative investments (Carpenter and Petersen 2002). Considering the credit market model by Diamond (1989), a long credit history does have a positive impact on the interest charges. In the contrary, a bad credit history occurs by young companies facing risky projects which lead into a moral hazard problem. The credit history is displaying the reputation in a market.[7] The crucial point is that past performance of a company meets a reputation effect. Newly created high-tech biotechnology firms carrying out research and development projects require considerable financial resources up to one billion US$ depending on the business model and business field. Especially the red biotechnology sector which is comparable with the pharmaceutical industry faces high R&D cost. The product companies of this sector are confronted with the uncertainty of a regular drug development process. This argumentation is underlined by using business field and business model variables to measure risk. Therefore, central concerns are

[7] There is a growing literature on the effect of reputation in markets noteworthy the papers by Klein and Leffler (1981), Shapiro (1983), Rogerson (1983) and Allen (1984).

the existing financial constraints which hamper the possibility of growth and future development, especially at a start up stage.

Technical risk: A second group of risks centres on the technical risks of innovation. After substantial investments in R&D, a new product may not be feasible, or may have only limited market appeal (Chesbrough 1999). This sort of risk refers to the probability that a development project eventually turns into a marketable product. Nelson (1959) emphasized the importance of uncertainty in distinguishing the research process from development process. He argues that the uncertainty of research is much greater than for the development part. Hartmann/Myers (2001) classify technical risk into three groups: availability of competencies and complementary technologies required to deliver the technology, specification achievability and probability of success. All of them merge in upcoming young biotechnology companies. In particular, the technological risk is portrayed again by the business model and the business field. The high uncertainty of the R&D process which is preferably undertaken by product companies is especially subject to the red biotechnology. The drug development process could spend over twelve years without realizing any returns (DiMasi et al 2002). The combination of the long term development process and the high risk of product failure characterize the biotechnology industry (Müller et al. 2004).

Market risk: Market risk, or systematic risk, has often been described in the literature as the degree of uncertainty associated with gaining a competitive advantage due to environmental factors (Barney et al. 1989, Fiet 1991, 1995, Porter 1980). The notion of "risk" and "uncertainty" in economics and the distinction between these concepts was preconised by Knight (1921). In his view risk and uncertainty are associated with imperfect knowledge. Therefore, risk in a biotechnological project, is a measure of the inability to achieve the objectives within cost and time schedule, and the surrounding financial constraints. Fiet (1995) focused his study of market risk on start-ups and identified the following indicators as a proxy for market risk: technical obsolesce, many competitors, many potential, new competitors, many substitute products, weak customer demand, and market attractiveness.

A major task of innovation policy is to overcome such economic burdens and different measures like low-interest loans, grants, tax incentives are in place aiming to stimulate R&D activities. The most important German measure is the so called ‘direct R&D project funding’ of the Federal Government, because of a lack of tax incentives. Its general purpose is the “support of particular risky, extensive and long-term projects” (BMBF 2003). More detailed and in the case of biotechnology, the application requirements explicitly mention R&D projects with a “high risk in research” related to financial gaps in this concern. Innovative firms involved in the biotech sector are technological pioneers and do have a larger probability to fail compared to traditional businesses. These firms have to be characterised as being more risky with regard to their technologies and prospects.

In line with our thesis, we argue that receiving public funding does not happen accidentally but rather being subject to a selection processes and public funding principles. Therefore, a possible strategy of the decision maker could be the selection of very promising applicants to pursue a “picking a winner” strategy. Several information asymmetries could occur as well, in case of very small companies which do not have the information of the public funding programmes or the resources to apply for. All together have an great impact on these selection processes which could distort the analysis by not taking them into account. The probability of public funding measures the effect of not being funded by chance. The estimation of this probability is a crucial part of the analysis to consider the selectivity of being just applicant to a funding programme or being funded.

The following analysis focuses on the risk issue. We test if public R&D funding processes take any risk related to biotech companies into account. If public R&D policy works, we would expect a higher probability of public funding for companies which have to fight specific risks. We will measure ‘financial risks’ by the credit rating of a biotech firm. Biotech companies, which do not have a long track record suffer from financial constraints which is observed in low credit ratings. If public funding take into account such risk, we would expect a higher probability for applying and getting funds if firms do have low credit ratings. We will measure ‘technical and market risks’ by indicating the business field and the business model a biotech firm is involved. The business field (red, green, grey biotech) indicates technical risk, because the red biotech is much more demanding in legal requirements, development cycles and extensive tests compared to the green or grey biotechnology. In this context the red biotechnology has higher risks of failure and should get a higher probability of being publicly funded. In the current case of biotechnology, the classical differentiation of ‘market risk’ is especially portrayed in the business model services i.e. a lot of companies could provide the same service of e.g. DNA-sequencing which leads to many competitors in one special domain. The greatest market attractiveness is of course shown by the red biotechnology sector which have the possibility in case of success to develop a blockbuster drug which provides high benefits.

In our research setting we first identify variables which represent firm’s risk concerning R&D, investments and markets. Using a probit model we estimate the probability of getting public R&D project grants simultaneous controlling for different measures of ‘risk’.

5.2 Data

The analyses are based on data from the ZEW-Foundation Panel, which was started in early 1990. The firm-specific data are provided by the largest German credit rating agency CREDITREFORM. This agency systematically records all firms which have a commercial registration (‘Handelsregistereintrag’). In addition, inquiries about the financial situation of the respective firm by customers or suppliers play a major role regarding the recording of new, incorporated firms (Stahl 1991, Harhoff/Stahl 1992). Almost every six months, information on newly recorded start-ups and updated information on existing firms are delivered and integrated into the panel, though updated information is not available for each firm at each delivery (Harhoff/Steil 1997). Information collection from public registers, newspapers, company reports, and in firm interviews is an ongoing process such that the frequency of information updating varies among firms. A typical firm record in the panels provides a lot of information about firm formation, insolvency fillings and liquidation. Moreover, it indicates the firm's location, industry classification, number of employees, legal status, ownership and management details (Prantl 2003). The CREDITREFORM data set covers more than eight million firms. For this reason it is now possible to identify all German biotechnology companies in this data set.

Besides the above-named available information, CREDITREFORM provides a so called “free float text” with additional information about the firm, among other things a detailed description of the firm’s business activities. The information about the business activities specifies the biotechnology company. Being interested in the subset of all biotechnology companies, a special search algorithm is used to identify them. In a second step, a list with biotechnology related words e.g. genetic, biotechnology, DNA etc. is created to describe the business activities of a biotechnology company. The search is now an iterative process i.e. it takes different runs until the subset is ready. During the different search processes, the “biotech-word list” must be adjusted different times to specify the search process. Before declaring the final data set as a final one, the subset has to be checked with the BIOCOM database, one of the biggest commercial databases in Germany. After this process the final data set contain 1.529 biotechnology companies in Germany.

In order to perform an empirical analysis, we link the CREDITREFORM data with the PROFI database. The PROFI database covers the civilian R&D funding of the German Federal Government. The PROFI database includes reliable information on all projects and recipients funded by the BMBF and BMWA since 1980, i.e. almost all subsidized civilian R&D projects are covered. The database permits an analysis of expenditure in terms of research themes, projects, recipients, funding procedure etc. (Czarnitzki/Fier 2003). The match of these two datasets has resulted in a new subset of 158 biotechnology companies which have been subsidized by the German government.

5.3 Empirical consideration and descriptive statistics

We use the complete survey of German biotech firm characteristics from 1994 to 2004. Within this eleven years period of time, we count for 1,529 different biotech companies in Germany. For about 41 per cent of these firms we have eleven years panel observations, where we notice the number of employees, the credit rating, the number of patent applications and further firm characteristics in every year. For about 56 per cent of the firms we do observe at least three or more observations. With regard to public funding we know the exact year of being funded for the first time in a biotech scheme and the size/amount of the award in Euro. Cross-section we do have 12,433 observations (see table 1 for descriptive statistics).

The dependent variable in the empirical analysis is the firm's status concerning public project funding. This status depends from a firm's decision to apply for public R&D funding as much as it depends on the Federal Government's decision to award a R&D project proposal. In this context we estimate the probability for applying and awarding a public grant at the same time. In the probit analysis we use a dummy variable ($FUND_{it}$) indicating whether the particular firm *i* has received public funding in time *t*. With regard to the tobit estimation we use $FUNDSUM_{it}$ which shows the total amount of the grant. For both models, we control for firm characteristics using variables which are important with regard to the funding application and awarding process (financial risk, technical risk, market risk).

Our exogenous firm's indicator for 'financial risk' is the credit rating index *(CREDIT)*. This measure indicates whether a firm has financial constraints and might apply for public R&D funding as an alternative to the capital market to finance its R&D activities. In the total sample the credit rating index is about 262 in the mean, while 100 is the best and 600 the worst index. Moreover, a *VC* dummy shows if venture capital company hold shares and is involved in the biotech's business. Venture capital seems to be very important in this field of technology because about 19 percent of all German biotech companies are backed by VC. 'Technical and market risk' is measured by the business field and the business model a biotech firm is involved: the dummy variables *RED* and *GREEN* indicate whether the company's main field of biotechnology belongs to the red or green biotech activities (gray biotech is the basis). The business model is characterized by suppliers (*SUPP*), producers (*PROD*) and service providers (*SERV*) to differentiate between market orientation and kind of R&D activities.

Of course, we include firm size measured as the log of number of employees *LNEMPLO*. Since Schumpeter's seminal thoughts about innovation (Schumpeter 1934, Schumpeter 1942), it is indisputable that firm size has an impact on innovative activities, e.g. such as patenting. We also include $LNEMPLO^2$ to allow for non-(log)linearity. Additionally to firm size, we also include firms' age defined by age as explanatory variable *AGE as well as* AGE^2. Because biotechnology started to become famous in the 1990s in Germany, it is assumed that very young firms may be more likely to get a public R&D project grant. All regressions include a dummy which denotes Eastern German firms as those may behave different due to the still ongoing transformation process of the Eastern German economy (*EAST*). The variable *COMP* indicates if a company of any industry holds shares of a particular biotechnology company. The variable *PATENT* represents the patent stock which is computed from the time-series of patent applications at the European Patent Office. The patent stock controls for the variation of the propensity to patent among firms. Moreover, seven sector dummies on basis of the NACE classification should capture different technological opportunities among business sectors. In principle, these dummies are created according to the NACE two-digit sectoral classification. However, some sectors are merged due to a low number of observations.

Table 1: Descriptive Statistics of the German Biotech Survey (1,529 firms)

Variables		**Mean**	**Std. Dev.**	**Min.**	**Max.**
Endogenous					
FUND	Public funding dummy [0/1]	*0.187*	*0.135*	*0*	*1*
FUNDSUM	Total public funding amount [€]	*13,272.4*	*141,689*	*0*	*4,669,610*
Exogenous					
AGE	Age [years]	9.352	18.728	0	145
EMPLOY	Employees [number]	64.742	462.952	0	9700
CREDIT	Credit rating [index]	255.050	78.783	101	600
PATENT	Patent applications [number]	1.794	2.910	0	6.596
GREEN	Business field: green biotech [0/1]	0.133	0.340	0	1
RED	Business field: red biotech [0/1]	0.677	0.467	0	1
GREY	Business field: grey biotech [0/1]	0.097	0.296	0	1
PROD	Business model: producer [0/1]	0.550	0.497	0	1
SUPP	Business model: supplier [0/1]	0.218	0.413	0	1
SERV	Business model: service provider [0/1]	0.260	0.439	0	1
EAST	Location East Germany [0/1]	0.169	0.375	0	1
VC	Venture capitalist involved [0/1]	0.190	0.392	0	1
COMP	Further company's shares [0/1]	0.311	0.463	0	1

Note: The variables in the analysis also include seven industry dummies (IND1-IND7) and eleven time dummies (TIME1-TIME11) not reported in this table.

6 Empirical Study

We apply different models to analyse firm characteristics and their impact of being funded. Most of the OECD Governments as much as Germany commit themselves to stimulate basic research and high risky R&D to reduce the private cost of innovation. Therefore, firms' incentives for carrying out R&D could be fully re-established through appropriated public funding (Spence 1984).

Subsequent to our hypothesis we estimate probit and tobit models on the likelihood of public funding first and consider a homoscedastic and a heteroscedastic model, too. We also performed *LM* tests and *LR* tests (Greene 2000). In our robust probit a dummy variable is indicating whether the firm received public R&D funding or not. In a tobit model we take into account the *amount* of public grants. Considering the amount is important, because firm's might only apply for a R&D funding or will be funded if the total project amount is considerable and cover the expenses of funding application process.

The following multivariate analysis enables to control for effects of other variables simultaneously. Accordingly, we estimate separately the likelihood of the funding status (*FUND*) and serving as dependent variables with the following estimation equation:

$$P(FUND_i = 1 \mid x_i) = F(x_i^{'}\beta), \qquad [1]$$

where x_i contains the explanatory variables and F is the cumulative standard normal distribution. The equations for the other co-operation dummies are analogous (see Green 2003).[8] On the basis of the estimation results, we check if the variables of the hypotheses still have a significant impact. In the aforementioned context we control for firm-specific characteristics as well as for project-specific issues (public funding/amount). The results of the models are presented in table 2.

Table 2: Probit and Tobit estimations on public R&D funding

	PROBIT-Estimation		**TOBIT-Estimation**	
Endogenous	**FUND**		**FUNDSUM**	
	Dummy variable [0/1]		**Public funding amount [€]**	
Exogenous Var.	Coefficient	t-value	Coefficient	t-value
Log(Employ)	0,285	4,25***	450690,7	4,05***
Log(Employ2)	-0,042	-3,82***	-65790,7	-3,53***
CREDIT	-0,001	-2,23**	-1855,5	-1,67*
AGE	-0,045	-7,42***	-76782,2	-6,07***
AGE2	0,000	7,70***	715,5	6,77***
PATENT	0,070	5,97***	118719,7	6,30***
RED	0,344	3,44***	475132,5	3,12***
GREY	0,251	2,07**	313954,8	1,62
PROD	0,131	1,67*	242012,4	1,93*
SERV	-0,149	-1,92*	-221296,5	-1,75*
VC	0,097	1,26	134660,4	1,10
COMP	0,114	1,57	229258,6	2,02*
EAST	-0,077	-0,85	-123277,6	-0,84
const.	-3,747	-8,26***	-6075651,0	-7,31***
Observations	N=8.213		N=8.213	
Pseudo R-Quadrat	0,20		0,18	

Note: *Significant at the 1%-level (***), 5%-level (**), 10%-level (*);*
The variables in the analysis also include seven industry dummies (IND1-IND7) and eleven time dummies (TIME1-TIME11) not reported in this table.

[8] In the tobit model we use the amount of the grant (*FUNDSUM*).

With respect to the probability of participating in the Federal Government's public R&D funding schemes and the particular 'risk' status of biotech companies, we do observe similar results in the probit and tobit estimations: Concerning *financial risk* we do observe a negative relationship on the credit rating index, means whether the credit rating index is going worse *(CREDIT)* the chance of getting public funds is also poor. Moreover, we did not find influences on public R&D funding if a venture capital company *(VC)* is involved. With regard to *technical risk* and *market risk*, there is a good chance for biotech companies which are producers *(PROD)* and belong to the business field of red biotechnology *(RED)*. These companies do have a have significant higher probabilities to get public R&D grants compared to their counterparts. Especially service providers *(SERV)* just have poor chances of being publicly funded if they compete with supplying or producing applicants. Moreover, we do find an inverse U-shaped relationship of getting R&D grants if we consider the size of biotech firms *(EMLOY)* and a U-shaped relationship concerning age *(AGE)*. In general, the probability of being publicly funded is higher the more employees are registered and if a biotech firm is pretty young. The patent dummy indicates if a biotech company does have a knowledge stock and hence the potential to innovate. These firms also have higher probability of getting R&D project funds. However, we do not realize any significant influences on the probability of being funded if other companies are involved in a biotech firm or if the biotech company is based in Eastern Germany.

7 Conclusions

This study focused on the emerging biotechnology industry in Germany in the last couple of years. Investors and business leaders still have considerable expectations concerning its growth rates in employment, new products, patents and profits. The technology is most relevant for society to foster the national competitiveness, employment and social wealth. Especially policy makers do attache importance to the biotechnology industry in the last decade.

Therefore, we report empirical results on the German R&D policy regarding biotechnology companies. We first explain the low numbers of companies involved in this technology until the 1990s and give reasons for the pleasant catching-up process we do observe in the following years. However, our main thesis is that public R&D policy did not discriminate in funding new technologies such as biotechnology any more. We maintain that public R&D funding neglects its own principles if we focus on different characteristics of 'risk'. In general we would expect that biotech firms which have high financial, technical or market risks belong to the recipients of public R&D grants.

For this reason, we carry out probit and tobit estimations to determine public funded R&D. In the estimated model we control e.g. for different industries, age, credit history, number of employees, venture capital investments, company investments, patent stock, East Germany as well as for particular business fields and business models which might have influence on the probability to receive public R&D subsidies.

According to financial constraints we find that firms with a poor credit history i.e. with a lower credit rating do have poor chances of being publicly funded. Having a closer look on the particular activities of the biotechnology companies, the results give us significance concerning other risk issues. Technical and market risk is measured by different business models and we found that high risky producing biotech firm are in favour of being publicly funded. This is in line with the business fields *(RED)* which have a higher probability of receiving funding than firms engaged primarily in the green biotech *(GREEN)* sector. The red biotechnology is characterized by uncertainty which is tied with the duration and the costs of the R&D process. This could take more than a decade including costs up to 600 million U.S. dollars. Another interesting fact is that a venture capital investment does not yield in a higher probability of getting R&D subsidies which seems to be a signal of having a financial resource to undertake R&D projects. It is important to mention that the results described above, do indicate the present picture of the biotechnology scene in Germany. In fact, there is no biotechnology company which is producing products in the red sector and at the same time having an outstanding credit history.

The governments' strategy of public funding is not focused on companies which have to fight financial risks. Companies which have a poor credit history *(CREDIT)* and for this reason even slight chances to get loans at the capital markets do also have a smaller chance of being publicly funded. In this respect public funding authorities prefer to 'pick potential winners' but hold away to foster firms and technologies which have poor credit ratings. On the other hand, we do observe a higher probability of being funded if a firm is involved in the high risky red biotechnology. We assume that these firms do have a higher probability, because Government's tends to fund human life sciences, first. Moreover, public funding agencies do not prefer East German firms. Our results represent that our dummy *EAST* is not significant which indicates that R&D funding seems to be independent from a regional emphasize of East Germany. However, we just controlled for East Germany without going closer to a regional level but according to earlier studies, East Germany did benefit from different funding tools. We find no evidence for a stronger consideration of biotechnology companies located in East Germany.

In case of size and age of companies, larger and younger biotechnology firms do have a higher probability of receiving public funding. We do assume that such large and young biotech companies are large company spin-offs instead of university spin-offs or start ups. This is in line with the significance of the *PATENT* variable. The accumulation of knowledge i.e. having patents, give a clear signal for every investor that the company have the ability to formulate new scientific findings. Companies which have been founded out of large pharmaceutical or chemical firms do count for more patents compared to original start-ups. For this reason, we control for further company shares *(COMP)*, but just can not find a small hint in the tobit model.

On the basis of these empirical results, we see that the German R&D policy is not strictly focused on biotech companies which have to fight a bundle of risks (financial, technical, market risk). However, the government do not misapply their funding by fostering e.g. companies which are already playing in a non-risk business field with a non-risk business model. But it is important to mention that these results do not give any implication of the efficiency and the excellence of these selected companies of this emerging industry.

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Appendix

Figure 3: Large scaled R&D funding schemes in the business enterprise sector (BMBF 1993-2003)