REVERSAL OF FORTUNE?
AN ASSESSMENT OF THE GERMAN BIOTECHNOLOGY SECTOR IN COMPARATIVE PERSPECTIVE

Edited by
STEPHEN J. SILVIA

ECONOMIC STUDIES PROGRAM SERIES
VOLUME 5

American Institute for Contemporary German Studies
The Johns Hopkins University

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The American Institute for Contemporary German Studies (AICGS) is a center for advanced research, study and discussion on the politics, culture and society of the Federal Republic of Germany. Established in 1983 and affiliated with The Johns Hopkins University but governed by its own Board of Trustees, AICGS is a privately incorporated institute dedicated to independent, critical and comprehensive analysis and assessment of current German issues. Its goals are to help develop a new generation of American scholars with a thorough understanding of contemporary Germany, deepen American knowledge and understanding of current German developments, contribute to American policy analysis of problems relating to Germany, and promote interdisciplinary and comparative research on Germany.

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FOREWORD

The P.J. Hoenmans Program on Economic Policy Issues in Germany, Europe, and Transatlantic Relations of the American Institute for Contemporary German Studies hosted a workshop on July 10, 1998 entitled, "Reversal of Fortune? A Comparative Discussion of Biotechnology in Germany: The Roles of Regulation, Expertise and Regional Economic Assistance in the Promotion of a Leading Edge Sector." The earliest versions of the papers included in this volume were first presented then.

The German biotechnology sector is in many ways a test case of the impact of government regulation on economic success. In 1990, the German government enacted a strict set of regulations for the biotechnology sector. The Kohl government's motives were straightforward and understandable. It wanted to protect the German people from the potential risks of genetic manipulation. In practice, however, the 1990 Gene Technology Act (*Gentechnikgesetz*) stunted the fledgling German biotech sector. Several chemical manufacturers transferred their biotechnological research abroad, thousands of biotechnological entrepreneurs left Germany, and investment in this sector remained relatively small. Once the deleterious economic impact of this law became clear, the German government responded by enacting a comprehensive deregulation of the biotechnological industry. This workshop investigated the impact of this radical regulatory reversal on the flow of capital and talent within the German biotechnological sector.

Deregulation produced a radical reversal of fortune in the German biotech sector. During the second half of the 1990s, business dailies and specialty journals on both sides of the Atlantic increasingly sported headlines proclaiming, "German Biotech Sees Flood of Capital and Ideas," "Startup Boom in German Biotechnology" and "Germany Leads Challenge to U.S. Biotechnology Stronghold." Five years ago, such articles would have been unimaginable. Strict regulations, little venture capital and a shortage of academic entrepreneurs had seemed to doom biotechnology in the Federal Republic to perpetual stagnation. Yet, the biotech sector has now taken root in Germany and expanded in ways that many other cutting-edge sectors have not (e.g., microelectronics). Why has the biotech industry been able to make such great strides in the Federal Republic so quickly? What are the strengths and weaknesses of the German biotechnology sector in comparison to the United States and other leading biotechnology countries? Will biotechnology continue to flourish in Germany?

The workshop brought together a group of leading German and American experts to discuss the forces behind the rise of the German biotechnology sector and its future prospects in comparative perspective. This report contains revised versions of three of the papers presented at the workshop. Horst Domdey, managing director and CEO, Bio^{M} AG, CEO of Munich BioTech Development, cofounder of MediGene AG and Switch Biotech AG, and former professor of Biochemistry at the Ludwig-Maximilians-Universität, Munich, opened the workshop with a report on "Germany as a Location for Biotechnological Entrepreneurship." Domdey stresses that German biotechnology entrepreneurs worked closely with government officials to clear away most of the formal barriers impeding expansion in this sector. This largely accounts for the German biotech boom of the latter half of the 1990s. The short and medium-term prospects for the sector look excellent. Intractable bottlenecks remain, however, that threaten to dampen long-term growth in the biotechnology sector. A shortage of skilled managers and weaknesses in Germany's entrepreneurial tradition may restrict the growth of the sector in the long run.

Maryann P. Feldman, Cynthia R. Ronzio and Oliver Pfirrmann compare the biotech industries of greater Berlin and Montgomery County, Maryland. They also find that Germany's biotech industry is expanding despite some remaining institutional challenges, particularly in the areas of academic infrastructure, the protection of intellectual property and managerial skills.

Arthur Daemmrich, in contrast, finds that despite recent German and European strides in the field of biotechnology, the United States and its biotechnology enterprises still enjoy an overwhelming lead as the "first mover." It will remain exceedingly difficult to overtake the U.S. and its firms for many years to come.

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GERMANY AS A LOCATION FOR BIOTECHNOLOGICAL ENTREPRENEURSHIP: ACHIEVEMENTS AND CHALLENGES[1]

Horst Domdey

Before beginning I would like to tell you a little about my background. I am a former professor of biochemistry at the Ludwig Maximilian University in Munich. This is where I began my research in 1984, after I returned from a happy stay in the United States at the University of California, San Diego and California Institute of Technology in Pasadena. Since then I have been working in the field of molecular biology, researching RNA processing and lately the genome.

We started a company—the second biotech firm in the Munich area—some four years ago when the money for biology research temporarily dried up a little bit. This period was also perhaps one of the first times in Germany that there was an opportunity to replicate some things that have already been done in the United States. I am the first professor ever to resign from the University of Munich in order to switch to the private sector. The university administration had no forms for this type of resignation and it took them some time to develop a procedure. The university finally decided that I could keep the title "Professor," but I could no longer call myself a professor of biochemistry.

This presentation provides an overview of recent developments in the German biotechnology sector. Many, including myself, have named it a "dawn." A recent Ernst and Young *European Life Sciences Report* declared, "Indeed, the new dawn in Germany has also given the rest of Europe, including the UK, a wake-up call." Sleeping Beauty has clearly awoken now; things are becoming interesting.

Here are some quantitative data about the German biotechnology sector. *Ernst and Young* and *Prognose* reports show a huge increase in start-up companies since 1997. The data from mid-1998 show that we now have 465 biotech companies in Germany if you define the sector broadly, 442 of which are small and medium-sized enterprises. You have almost a doubling of the number of firms each year. A comparison of European countries—Germany, Great Britain, France, and Sweden—reveals that, of course, Britain is still the leader especially when you look at mid-size and large companies with more than 100 employees. When you look at the start-up companies, the situation

has really improved a lot and Germany is taking the lead. That is true in terms of both employees and sales.

Let us compare Germany to the United States. Using the more narrow ELISCO definition of biotech enterprises that only counts firms actively engaged in research and development, the United States has something like 1,270 biotech companies. In Germany, we have 173. So we have reached a level in Germany of around 10 percent. Now, if Germany were to reach a value of, let us say, 20 to 25 percent when compared to the United States, we would be on a really good track, although with a lag-time of twenty years or so, which is something typical for Germany, especially in the biotechnology field. On the other hand, one has to divide the current number of German firms by around seven to make the comparison more accurate because a much larger share of these companies are recent start-ups when compared to the United States, so they have less capital and fewer employees. In other words, you cannot really say that the value of these German biotech companies has already reached 15 percent of that found in the United States even though the number of German firms has reached that mark. So, we are still lagging behind the United States a lot. On the other hand, we are on the right track.

It is not yet clear, however, if the positive trends in this industry represent a lasting change. How others will perceive and receive the wakeup call of German biotechnology, especially in the United Kingdom, is another question altogether. Consultancies, entrepreneurs and financing agencies, including some from the UK, are looking at Germany. U.S. venture capitalists interested in the biotech sector, who used to stay in the greater London area when they came over from the United States, now increasingly use Heathrow Airport simply to change to planes going to Frankfurt, Munich, Berlin and so on. Of course, UK managers and government officials do not like this shift too much, but foreign investors on the other hand initially went to Germany simply to see if there were any worthwhile investments there. Of course, our big goal in the German biotechnology sector is still to reach the level of development of the biotechnology industry in the United States. The fifty billion dollar market valuation of U.S. biotechnology is very impressive. Whether this really represents the true value of the sector is another question. It is interesting to see that there is still a four billion dollar deficit between expenditures and revenues. Of course, the U.S. biotech industry does not want that to persist.

Today we are talking about a process called innovation. The difference between science and innovation is that science turns money into knowledge, and innovation turns knowledge into money! Actually, the German biotechnological sector has had a lot of experience in science; and I think we have some quite good science. The quality of German science is the reason why German postdocs love it here in the United States. They can have a good worldwide exchange. Their education opens up good opportunities when they come over here. Then, of course, they go back to Germany once they have gained experience. The reason why I came to the United States to do research to begin with, for example, was because there was no opportunity in Germany at the time to learn something about molecular biology.

The process of innovation, however, was not happening in Germany, at least not in biotechnology. Now, to have an innovation process, you need an innovation culture. For innovation culture, we need some important elements. I will list the most important ones. First of all, there must be a critical mass of excellent science. As I stated earlier, I am fairly sure that we have this critical mass, because a lot of money and effort has been put in over the past ten, twenty, thirty years into science. That has not been the problem at all.

Second, excellent science also requires qualified personnel. Germany has good personnel, but just like in any other country, students react to changes in policy and the availability of jobs. The number of students studying chemistry has really dropped since the downturn in the pharmaceuticals and chemical industries over the past few years. For example, there are hardly any students in chemistry anymore. At the University of Munich where I worked, the number of students fell from 248 to 61. As a result of the recent growth of the biotechnology sector in Germany, we hope that high school students will increasingly realize that it might once again be worthwhile to get a university degree in chemistry and then to work in the field for one of the small or big companies in Germany, which may become more important in the future.

A third and equally important element of an innovation culture is technology transfer. I will not say too much about the acceptance of technology, but this has been a big problem. This psychological complex had to be changed dramatically in Germany. In Germany, everybody at first thought that in the United States everything was working automatically. We thought that you did not have to work to attain acceptance of biotechnology from politicians and the general public. We had to find out that that is not the case. Things tend to

improve only if you work for acceptance, as you have seen perhaps in the past weeks in Switzerland.

Fourth, ambience matters, too. When you look at the map, innovation is happening in interesting places. It occurs in places where you have ambience, like the Heidelberg region, the Rhine region around Düsseldorf and Cologne, Berlin and, last but not least, the Munich area.

Fifth, good examples are also very important. It is crucial that you have some prototypes, for example, biotech start-ups show that you can manage the first three to four years and that you will not drown. Even if you do not make money, the value of the company has increased during that period of time.

Sixth and most important, something that I think is the most difficult to change—because it is also probably the most difficult to teach—is this spirit of entrepreneurism, which means that you take risks. I am personally one of the very few examples of someone who went from a university to industry. As you may know, a professor in Germany is a civil servant. I had just nineteen years to go to receive an excellent pension from a fund into which I did not have to pay anything. It was stupid of me to ask my tax lawyer about the implications of moving to the private sector only **after** I had left the university. Actually, I left the university because I could not be on my own. I had to ask the Bavarian Minister of Cultural Affairs to dismiss me, which he did. It took some time for him to write the letter, but the direct deposit of my salary stopped immediately, so I knew he would agree to do it.

Anyway, between the perfect pension plan and all the other opportunities that you have as a professor who is also a civil servant; you are supposed to work, but you are not forced to work. It is difficult for most people to leave these positions. I hope that I might be a good example, as well. I hope that I will not go under in the coming years. On the other hand, I realize maybe some of you have read the recent issue of *Nature Biotechnology*. I was harshly attacked in one of the articles, since some people do not like steps like this.

Let me return to some of the points I have mentioned before, such as technology transfer from university to business. I think all of you know the point of technology transfer. Every partner gets something. The industrial partners get the technology and the scientists get a little bit of money so that they can continue to create knowledge. I think this is a nice exchange that is taking place. It has not been very popular in Germany until very recently, however. Now, things have changed. There are now transfer offices at universities. For

example, four years ago, we had one person in such a transfer office at the University of Munich. Now there are eight people. So there has been an eight-fold increase in four years.

Now universities are even thinking of further expanding these kinds of offices, doubling them within a year, because they have realized it is very important for the universities themselves. They also have a kind of duty to provide the means for jobs or possibilities for jobs for the students. It has even developed to the point where universities are offering office and lab space. At least for a limited amount of time—six months or a year—you can rent offices or a lab. Of course, you have to pay more than you have to pay on the open market. On the other hand, you have more possibilities at the university. You can use a centrifuge. You can perhaps get easy access to the Internet. That is why universities charge, let us say, around fifty percent more than you would have to pay on the open market. They give these start-up companies a very good opportunity.

Well, you realize that I am focusing on Munich, because that is the place where I live and work. There, for example, we have two universities and they compete with each other. So, if one university takes a step then the other one has to match it. That is what is promoting the process there. There are also similar mechanisms at the national level. We have business-plan competitions. Not only the people who have won these business-plan competitions, but also those who have not, have learned how to write a business plan and have started companies. *Land* (state) governments are also providing "incubators," that is "small science" technology parks where you can get office and lab space for a reasonable price. Well, it is not actually a lower price. It is the market price, but, on the other hand, you get other kinds of support.

The acquisition of capital had been a problem, as well, but the climate has greatly improved. Four years ago when we started one of the first biotech companies in Munich. There were only two venture capital companies; each made one deal per year in biotechnology. So, the odds of start-ups getting money were very small. Things have changed. For example, in Munich—which has become a hot spot for venture capital—we now have sixteen venture-capital companies. Seven out of these sixteen invest in biotechnology. They make not just one deal, but up to ten deals per year. So things have changed dramatically. Money is no longer a real problem.

In the meantime, we have excellent opportunities for the acquisition of additional capital. For example, if a firm gets one dollar, one mark, one million deutschmarks from a venture-capital company, you can get double that amount in the form of loans from federal economic-development banks, such as the *Deutsche Ausgleichsbank* (German Burden Equalization Bank, *ed.*), which was founded after the Second World War, or the *Kreditanstalt für Wiederaufbau* (Credit Authority for Reconstruction, *ed.*), or something similar. It is not an automatic process, however. You have to apply for such funds, of course, and the grantor will check everything.

There is also aid at the *Land* level. In Bavaria, for example, there is a state bank called Bayern Kredit. It was created because Bavaria had no other means to support these companies. This stands in contrast to the new *Länder* (states) in eastern Germany or the old northern industrial *Länder*, such as North Rhine-Westphalia. These *Länder* receive official restructuring assistance to move away from reliance on coal mining and heavy industry, and toward high technology. Start-up companies get money from the *Land* governments. The *Land* governments get money from Brussels, from the European Union. That is not possible in Bavaria, because the Bavarian economy is "perfect." Since the economy is so strong and the standard of living is so high in Bavaria, it is not permitted to use economic development subsidies. So the only possibility open to us was to create a bank. From this bank, a firm can get a loan.

Okay, you have leveraged one million into three million deutschmarks. You did not give away any shares, so you did not lose any equity. With this money, let us say three million deutschmarks, you can write a grant application. If you apply, for example, to the Federal Ministry of Education, Science, Research, and Technology (*Bundesministerium für Bildung, Wissenschaft, Forschung und Entwicklung*, BMBF, *ed.*) or to some local programs, let us say the Bavarian Research Foundation, you have a good chance of receiving matching capital from them, for example, two million deutschmarks. You cannot use all these funds as venture capital, but you can use them to cover basic expenses, which frees up the rest of your money.

Some venture capital is coming from venture capital companies, for example, Technoventure Management, located in Boston and in Munich; MPF in Boston; or Atlas, located in Holland, Boston and Munich. Also in Germany and Switzerland, for example, some new venture capital concerns have increasingly included life science ventures in their portfolios. Not all German

money stays in Germany. For example, the BMW money of the Quandt family went to the United States biotech sector. There is money from (the pharmaceutical firm, *ed.*) Boehringer Mannheim and more from Bayern Kredit. Another portion comes from ING Bank in Holland. Deutsche Bank has created a venture capital fund. In Switzerland, similar things are happening. What is not possible yet or at least is not done in Germany is the kind of pension fund you have in the United States (i.e., 401k plans, *ed.*). The law, I think, forbids that. The insurance companies are also not involved yet, but there are different sources.

If the venture fails, then the biotechnological firm does not have to pay back the loan. Actually, it is also a good deal for the venture-capital company. If a venture capitalist invested one million deutschmarks in a biotech firm that has failed, the venture capitalist is likely to get back at least half a million deutschmarks from the economic development banks. So, the risk is lowered this way, if everything goes under. There are institutional and project funds as well, to which I will come in a moment. To sum up, venture capital is no problem any more. Getting seed capital still can be, though.

In Munich we have created a small seed-capital fund to help start-up companies find start-up capital. There are also local banks that invest in the range of four or five hundred thousand dollars. We created a fifteen million deutschmark fund, which is about eight million dollars. It is not a lot, but it should be enough, for example, for financing thirty start-ups at the outset. There was money from the big pharmaceutical firms, money from the banks and also a little, or let us say a comparable, part of money from the government. So this is a real breakthrough. The banks now take into consideration that it is possible and interesting to put money there.

We think the research and development funding of biotechnology in Germany is impressive, at least for our standards. Of course, things could be improved, but you can see that biotechnology received one billion deutschmarks in public funding over the past year. Most of that money goes to foundations, such as the *Deutsche Forschungsgemeinschaft* (DFG, German Research Society, the German federal government's general research foundation, *ed.*) and the Fraunhofer Institute.

In 1996, the *Bundesministerium für Bildung, Wissenschaft, Forschung und Entwicklung* sponsored a now famous bio-research initiative called BioRegio, which really gave a push to the biotech sector in Germany. This was

one of the brightest ideas that anyone has ever had at that ministry. The competition was meant to support and to showcase the kinds of biotechnology practiced in Germany. Any German region could apply for the grant; seventeen regions altogether applied. Each application laid out the assets available for biotechnological entrepreneurship and a proposal for further developing and commercializing biotechnology in the region. The objective was to produce a consensus among industry, science, politics, and government officials. Without spending virtually any money at all, BioRegio pushed German biotechnology into a position that had never been seen before. It was even successful in states like Hesse where it used to be difficult to utter the words "genetic engineering." The politicians stepped forward and said, "We won't call it genetic engineering; we'll call it biotechnology." There was a competition for funds.

In his BioRegio award speech, (former BMBF, *ed.*) Minister Jürgen Rüttgers said there were no losers; actually all of the regions had won because all had put together outstanding proposals. In the end, however, although there were no losers, there were three winners: the Rhineland, including the cities of Düsseldorf, Cologne and Aachen; the Heidelberg area; and greater Munich. Although I must admit, it was a very close shave between Munich and Berlin. The only reason that Berlin did not win was all the upheavals going on there not so long after unification.

Now, what were the consequences of the BioRegio competition two years after the awards were given? There has been a dramatic change in political awareness of the positive aspects of biotechnology within all political parties. This political awareness can be found not only at the national level, but also at the regional and local levels. Even with the Greens, a change has taken place, at least concerning biotechnology, biomedicine and so on. There is, of course, no uncritical acceptance by the Green Party; the Greens still complicate biotechnological research. BioRegio created successful networking. All of the different institutions and players now work together; science with industry, clinics, investors, the administration and politicians. Actually that was also one of my reasons for leaving my secure place at the university. I found out it is a lot of fun to create such a network; to talk with politicians and bring the politicians together with the scientists, and scientists with the CEOs of the companies, and so forth. The next step is to transfer research from know-how to new products, to have this innovation process turn science into money and, last but not least, to create new jobs, which is a major concern in Germany.

I would also like to say a few words regarding public perception of biotechnology in Germany. Public acceptance is no longer a disadvantage. Seventy percent approve of genetic engineering or, let us say, modern biotechnology in the medical field. It is different still in the Green Party, but on the other hand, it is also getting more and more acceptance there. We had a referendum in Bavaria some two months ago, which the Green Party initiated, to create a label, "Not genetically engineered from Bavaria." Less than 5 percent of the population voted for that. So this was soundly defeated.

Regarding the legal framework, we cannot complain any more. We had this "gene tech" law in Germany in 1990, which was a source of all of the problems that we had before. This law did not change anything about the security level. It just put a huge bureaucratic burden on scientists. So, after a few years—due to the numerous complaints coming from scientists—a process of deregulation began. After deregulation, there have been no more complaints. For example, if you start a biotech company in Germany, you still need to complete some administrative procedures, but it takes less than a month to get everything. In Munich some weeks ago, there was actually a case that took three days. The advantage now is that it is all self-contained within this revised *Gentechnikgesetz* (1993 Gene Technology Act, *ed.*). You only have to go to one office and everything is handled there. You do not have to think, "well, where do I have to go next?" and go to ten different places to ask for a permit. You get your permit within a very, very short time.

We are very much interested in attracting American biotech companies to invest in Germany, because we would like to learn from them. We need their spirit, their examples of best practice. In contrast, a lot of German biotech start-ups still work in the spirit of Hoechst, BASF and the other large German companies because most people establishing them come from these big pharmaceutical companies. The atmosphere is completely different than when you have a chance to attract the scientists who worked here, for example, at Genentech or Biogen, coming over to Germany. So that is the first thing. We would especially like to have American companies in Germany. Until recently, U.S. firms have gone elsewhere in Europe, but they never came to Germany because of the regulations. Now I realize that U.S. biotech companies still do not really accept German biotech firms as good partners. For example, if a product is developed in Germany, it is also developed in the United States. If the patent is already owned by the German side, the Americans do not care.

They say, "Why should we care about those German firms? They don't have enough money. So we will proceed with our research." From that experience, I realize that German biotech companies, although they might be three, four, five years old, are not yet fully accepted by Americans as equivalent partners.

The growth of the German biotech start-up is much slower. You start perhaps with five people. After a year, if you are successful, you will have fifteen or twenty. Maybe after four years, you will have forty or fifty. That does not compare to American start-ups, however. So American entrepreneurs think, how can the German firms compete with us? They do not have enough money, and so on. Slower growth is also a sign that in Germany these companies take fewer risks. It also comes, on the other hand, from labor-market rigidities. When you have hired up to ten people, it is no problem dismissing one. If you hire more than ten people, however, you have to keep this person. You cannot fire a person. This causes problems. For example, let us say you at first need a molecular biologist, but then you need an expert in chromatography. You cannot fire the molecular biologist without paying a big severance package, so you teach him chromatography instead. So that is why I think the American companies do not fully accept the German firms as equals yet, although we try hard.

On the other hand, some good joint ventures already exist. It is actually easier for German biotech start-ups to make joint ventures with large American pharmaceutical companies than with large German pharmaceuticals. A typical example is Morphosis, which is located in Munich. It chose to partner with Upjohn over Bayer or BASF. This shows that Germans start-ups do not trust the big German pharmaceuticals and that big German pharmaceuticals do not trust the small German biotech start-ups. A prophet is without honor in his own country.

The risk of personal failure is also a big problem with us, whereas in the United States things are seen in a different way. When you fail once in the U.S., you are readily hired again because the investor figures you have learned from your earlier mistakes. Whereas in Germany, you do not get a second chance. This is really a big problem. And that is why we need this American spirit in Germany, to show that there are different ways.

Now, generally it has become very easy to start a biotech company, but shortages in management and administrative skills pose a serious problem.

Communication between business science and the natural sciences is not very good in our country, because they are very much separated from each other.

Stock options are also still a very big problem in Germany because we have a big contrast between normal shares, which are tax-free, and stock options, which are treated as taxable income when you receive your options. So, many have to exercise their options immediately simply to pay the taxes, but exercising a stock option triggers a second tax. The total tax bill can consume up to sixty percent of the stock option.

This is the emerging situation for biotechnology in Germany. The legal standards comply with European standards. There is enhanced public recognition. There is an excellent scientific base, growing attention from industry and sufficient venture capital. There was the federally sponsored BioRegio competition among the *Länder* to facilitate the establishment of a biotech industry. You have a well-developed public infrastructure and a commercializing strategy through the BioRegio competition.

ENDNOTES

[1] This is an edited version of remarks presented on July 10, 1998.

HOW SCIENCE COMES TO LIFE: A COMPARATIVE STUDY OF BIO-ENTREPRENEURSHIP IN THE U.S. AND GERMANY

Maryann P. Feldman, Cynthia R. Ronzio and Oliver Pfirrmann

ABSTRACT

Biotechnology is a science-based industry on the verge of worldwide commercialization. In this paper we describe, compare and contrast the German and American biotech industries with specific attention to the challenges of the restructuring of the science resources of the former GDR. We describe the academic infrastructure, public and private financing options, regulatory and personal liability concerns and the protection of intellectual property. We find that Germany's biotech industry is emerging despite institutional challenges. While biotech entrepreneurs in the U.S. have benefited from tax laws, patent regulations, diverse funding sources, and a tradition of cooperation between academia and industry, Germany is working to leverage its substantial technical and scientific resources. In the last five years, Germany has made substantial progress in building a developing biotech sector.

INTRODUCTION

Biotechnology is a promising new science-based activity that provides an opportunity to study the commercialization of science and the translation of economically valuable scientific knowledge into business enterprises. Biotechnology refers to a set of molecular biology techniques, such as cell fusion, genetic recombination and polymerase chain reaction (PCR), which employ living organisms, or parts of organisms, to manipulate and modify the genes of all living organisms in a targeted fashion. Beginning with the discovery of DNA by Crick and Watson in the late 1950s, the idea that genetic material could be manipulated opened new avenues of inquiry for scientists. As scientists perfected the means to identify, to transfer and to express specific genes over the course of the 1970s and 1980s, it became possible to "engineer" genetically the entire spectrum of organisms—microbes, plants or animals—to

express particularly useful traits. Rather than being a specific industry, biotechnology provides a knowledge base that is revolutionizing industries such as pharmaceuticals, medical diagnostic testing, agriculture, and other commercial activities based on chemical processing. This knowledge base provides the possibility for a set of products that are more efficacious, environmentally neutral and powerful than existing ones. These techniques create the potential for enormous profits. The constraints and incentives provided by national and sub-national innovation systems have a significant impact on an entrepreneur's ability to turn knowledge that is largely academic into commercially profitable products. Local history and custom as well as laws and regulations shape innovation systems. In a world where information and scientific discovery easily flow across borders it is these institutions and innovation systems that determine how and where science comes to life.

This study describes, compares and contrasts the German and American biotech industries and analyzes institutional differences. We first detail the development of the industry in both countries, using data on scientific resources, patents and new biotech entity start-up information. Second, we provide a context for the diverging development of the industry by describing the institutional differences in the U.S. and Germany. We describe the academic infrastructure, industrial policies, regulatory processes, public and private financing mechanisms, product liability issues, and intellectual property protection differences. We conclude that, despite some institutional challenges, Germany's biotech industry is emerging. Whereas biotech entrepreneurs in the U.S. have benefited from tax laws, patent regulations, diverse funding sources, and a tradition of cooperation between academia and industry, Germany is working to leverage its substantial technical and scientific resources to produce commercial success. Integrating the scientific resources from the former German Democratic Republic (GDR) provides some unique challenges but also offers opportunities as displaced scientists move over to commercial activity.

THE INDUSTRIAL ORGANIZATION OF BIOTECHNOLOGY: COMPARISON OF THE SCIENCE BASE AND COMMERCIAL ACTIVITY

Commercial biotechnology is heavily dependent on new scientific knowledge. Universities and laboratories in the United States have forged a clear scientific lead in the life sciences. One means to assess the production of new scientific knowledge is the publication of academic articles. Senker (1998) reports that U.S. researchers published nearly 60 percent of all gene-therapy articles found in the Science Citation Index between 1981 and 1993. The UK and France followed with 8 percent each and German researchers contributed 3 percent. An additional measure of the production of scientific knowledge is the rate at which scientists cite an academic publication. The Institute for Scientific Information (1998) provides information on the number of citations for top bioscientists. Of the top ten, seven are from the United States, with one each from Germany, France and Japan. The citation rate for articles written by U.S. life sciences researchers is 39.2 percent higher than the world average.

A measure that captures the commercial potential of biotechnology is the patent award rates. Patents are a less than perfect measure of innovative activity but provide a metric for comparison.[1] In general, the productivity in science and technology between Germany and the U.S. is about equal: total science and technology patent applications per 100,000 population was 286 for Germany and 283 for the U.S. (OECD, 1997).

American companies have successfully translated a national excellence in basic science into commercial claims for new bio-products and processes. The most prolific biotechnology patent generator is the United States. American institutions and individuals hold two thirds of all U.S. and two fifths of the world's biotech patent awards (Callan, 1995, p. 95).

Table 1 compares the number of German patent applications with the U.S. patent applications categorized by the residence of the inventor. The number of German biotech patent applications has increased from 479 to 821 from 1992 to 1996. Yet these numbers pale in comparison to the magnitude and growth in the number of biotech patents in the U.S. In the U.S., the number has almost tripled during the same time period. This may reflect the different stages of the development of biotech in the two countries.

Table 1: Biotechnology* Resident Patent Applications in Germany and the U.S.

Year	No. of German Patent Applications (% change from previous year)	No. of U.S. Patent Applications (% change from previous year)
1992	479	1358
1993	505 (+5.4 percent)	1778 (+30.9 percent)
1994	555 (+9.9 percent)	1711 (-3.8 percent)
1995	618 (+11.4 percent)	1905 (+11.3 percent)
1996	821 (+32.8 percent)	2154 (+13.1 percent)
1997	649 (-21 percent)	3014 (+39.9 percent)

* Includes Genetic Engineering.
Source: European Patent Office, Munich, Germany.

A major difference between the biotechnology sector in the United States and European countries lies in the size and number of firms willing to gamble on commercial biotechnology. Although it is difficult to find directly comparable data, Table 2 provides estimates of the number of biotech firms in each country. It should be noted that biotechnology is a very heterogeneous sector ranging from large diversified pharmaceutical firms that have some interest in biotechnology to small firms organized around a single scientist. Different researchers have used different definitions. Table 2 provides estimates of the number of dedicated biotech firms for the U.S. and Germany based on a comprehensive definition that includes new biotech start-ups, pharmaceutical firms that engage in biotech R&D and firms that supply intermediate-level biotech services and products. For comparison, data for the other European countries are provided from Muller *et al.* (1993). These data are provided as a point of reference: the data are not directly comparable as Muller *et al.* use more limited criteria which do not include the earliest stage companies. As a point of reference, Muller *et al.* report 104 German biotech firms, which is 40 percent less than those listed in the *Erster Deutscher Biotechnologie Report* (1998). However, other sources used for investigation like the *Life Science Report* (1998) also count 716 specialized companies in Europe for 1997.

Table 2: Number of Specialized Biotechnology Firms

Country/Region	Biotech Firms
U.S.	1,384
Germany	173
Europe	716
Great Britain	182
France	102

Sources: Data for the U.S. are taken from the Institute for Biotechnology Information database, 1997. Data for Germany are from *Erster Deutscher Biotechnologie Report* (1998). Data for the European countries are from Muller *et al.* (1993), and have been compared in *European Life Sciences 98*, Ernst and Young International's fifth annual report on the sector, for ranking, although no more recent comparative numbers are available.

Typically, starting a biotech firm requires venture capital financing; a substantial investment is required in advance of stock offerings. The U.S. system of venture capital financing is the most advanced in the world (Bygrave and Timmons, 1993). By contrast, the German venture capital sector is younger and has less capital to invest. For example, the total U.S. venture capital sector invested $2.74 trillion in 1994 while the German industry invested $811 million (Pfirrmann *et al.*, 1997, pp. 35 and 51). The table below lists the largest private placements and venture capital financing for the U.S. and Germany. Of the thirty-three companies in Europe with financing of one million ECU and above, there are only four German companies. Great Britain, in contrast, has the largest share of companies with substantial financing: fourteen of the thirty-three companies. There are ninety-eight American companies with over one million ECU in venture financing in the 1995-1996 fiscal year. To further highlight the differences in financing, the top four U.S. firms in financing for July 1995 through June 1996 are listed below (Table 3). The top U.S. companies are capitalized at more than twice the German rate.

Table 3: Private Placements and Venture Capital Financing in Large U.S. and German Firms (in ECU millions)

Firms – Germany	**Financing**
New Lab Diagnostics	10.3
MediGene	5.6
Analyticon	2.8
Micromet	2.7
Firms - U.S.	**Financing**
Darwin Molecular	24.0
Spiros Development	22.4
Coulter Pharmaceuticals	17.8
Aviron	17.4

Source: Ernst and Young International, *European Biotech 97: A New Economy* (London: Ernst and Young International, 1997); and Ernst and Young, *Biotech 97: Alignment* (Palo Alto, California: Ernst and Young LLP, 1996).

While the venture capital investment volume in Germany has recently doubled, it still appears that German venture capitalists pursue more traditional investment strategies, focusing on industries that are not necessarily risky new technologies. Table 4 provides a breakdown of the sectors of venture capital investment for each country. Whereas biotechnology ranks in the top five industries for investment by venture capitalists in the U.S., it ranked tenth in terms of dollars invested by German venture capitalists.

American firms are also larger, and, on average, more profitable, and invest more heavily in research and development (R&D). Qiagen, which is the most profitable German biotech, has a market capitalization of 472 million ECU compared to America's Genzyme (the least profitable of the top five U.S. biotech firms) with 1.37 billion ECU. This discrepancy does not appear merely to reflect the age of the industry and stage of maturity in both countries, however. The most profitable pharmaceutical companies in Germany are smaller than their U.S. counterparts. This is somewhat surprising since the German pharmaceutical industry predates the American industry, and its chemists, discoveries and products were instrumental in the growth of American pharmaceutical manufacturing (Feldman and Schreuder, 1996).

Table 4: Venture Capital Industry Distribution by Dollars Invested, 1994				
Industry (U.S.)	Total Invested (in $millions)	Percent	Number of Companies	Percent
General Products/ Services	663	24.18	110	10.88
Medical/Health	473	17.26	167	16.52
Software and Services	378	13.79	225	22.26
Biotechnology	303	11.05	101	10.00
Telephone and Data Communications	294	10.73	115	11.38
Industry (Germany)	Total Invested (in $millions)	Percent	Number of Companies	Percent
Mechanical Engineering	204	25.15	76	10.96
Trade	115	14.18	98	14.16
Other Products and Services	84	10.36	124	17.91
Iron/Steel	45	5.55	51	7.43
Biotechnology*	28	3.45	25	3.64

*Venture capital invested in biotech in Germany actually ranked tenth, after food, wood/paper, chemistry, construction, and leather/textiles.
Source: Pfirrmann *et al.*, (1997), pp. 35 and 51.

Table 5: German and U.S. Companies Vary in Worth and R&D Spending (in ECU millions)

GERMAN	**Market Cap**	**Turnover**	**No. of Employees**	**R&D Spending/ Employee**
Qiagen (biotech)	472	44.0	500	10.4
Bayer (chem./pharm.)	23,077	24,927	1,850	13.0
AMERICAN				
Amgen (biotech)	13,367.4	1,551.9	5,610	64.5
Genentech (biotech)	5,104.3	685.5	2,840	102.3
Chiron (biotech)	2,577.9	816.2	6,890	39.9
Biogen (biotech)	2,176.6	107.8	500	139.0
Genzyme (biotech)	1,372.8	285.6	2,286	29.1
Merck & Co. (pharm.)	68,058.3	13,344.8	45,200	23.6

Source: Ernst and Young International, *European Biotech 97: A New Economy* (London: Ernst and Young International, 1997).

American and German biotech firms also pursue different research applications. In the U.S., biotechnology is almost synonymous with pharmaceuticals: two thirds of all U.S. biotech companies are pursuing therapeutic or diagnostic applications. National research dollars via the National Institutes of Health (NIH) and other federal research grants in the basic sciences have encouraged the medical focus of biotechnology. The NIH had a total appropriation budget of $12.7 billion for 1997 (PhRMA Industry Profile, 1997). An example of the health focus of American research is the new field of genetic therapy. There were 161 genetic therapy clinical trials under review in 1996 in the U.S. and only six in Germany (Muller *et al.*, 1997, p. 47). Therapeutics is the dominant application for U.S. firms while the German firms appear to have a more diverse distribution of applications, with companies pursuing technologies in the chemicals and environmental and agro-food sectors (See Table 6). While it is always difficult to compare data across different studies, these data suggest that German firms have a more diverse portfolio of products. This may indicate that they are diversified or that they lack focus. Only a consistent data collection effort across the two countries could begin to address these concerns.

Table 6: National Comparison of R&D Specialization by Market Segment (in %)

Sector	U.S.*	EC	Germany
Therapeutic	41	19	25
Diagnostic	28	15	36
Suppliers	28	17	34
Agro-Bio	17	12	21
Chemical & Environment.	22 percent	15 percent	48 percent

*Note: Numbers do not add up to 100 percent because multiple references are possible.
Sources: U.S. data, Institute for Biotechnology database (1997); EC data, Ernst and Young International (1997); German data, Schitag, Ernst and Young (1998).

In conclusion, the U.S. system of bioentrepreneurship is more developed than the German system. To investigate the reasons behind this situation we now consider the innovation system and institutions in each country separately.

THE U.S. SYSTEM OF INNOVATION

Although the United States has never had a coordinated industrial policy for biotechnology, its commitment to basic research in the health sciences and a strong structure of innovation has encouraged the development of the biotech field. Bioentrepreneurship exemplifies America's competitive system of innovation: strong basic science, mobile researchers who work both in academia and industry, the ready availability of funding for new ventures and the financial rewards as well as intellectual property protection for entrepreneurs. Indeed, Persidia (1998) concludes that the United States offers the most supportive environment for bioentrepreneurship in the world. The purpose of this section is to provide a brief review the of attributes of the American system.

Public Resources and Infrastructure of the Basic Health Sciences

In contrast to other advanced technology-intensive industries, such as computers or software, commercial advance in biotech relies on the interaction between the public and private sectors due to the early maturity stage of development of the technology. Typically, different levels of government fund basic research because of financial disincentives for private firms to invest in R&D. Academic scientists who made commercially valuable discoveries while working at a university or research institute have started the majority of biotech firms. A variety of incentives and financial resources have motivated the process of taking a discovery outside of the lab. There are many legal and regulatory hurdles that temper the financial incentives of bioentrepreneurship. Financing a new biotech company can be prohibitively expensive; financing strategies proceed from early "angel," or private financing, to venture capital financing, and finally to public equity markets. Each of these components will be discussed briefly here.

The discovery of commercially useful entities continues to be tied to basic research in biotechnology to a much greater extent than in many other high-technology sectors. In 1994 the United States spent approximately $4.3 billion on biotechnology, 75 percent of which was money from the Department of Health and Human Services (Callan, 1995, p.174). No other country has dedicated as much funding to biotechnology research nor has funding whose bias towards health and medicine is so pronounced. In addition to the NIH

presence in biotechnology, the Department of Defense (DoD) also supports basic research for chemical and environmental applications. Whereas the dollar amount of DoD support is larger than the Department of Health and Human Services, DoD's biotech applications are limited and the exact amount is not available. Other public agencies that contribute to basic biotech research are the Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA), however the amounts are substantially smaller. This may partially explain the underperformance of the biotech industry in the agro-bio and environment sectors.

The majority of government funding is provided to the university system in the United States. Under this mechanism, scientists write grants that are evaluated under competitive peer review. Scientists in the U.S. are also free to act as consultants on a part-time basis, and industry can help fund laboratory expenses, thus creating tight links between the public and private sector. In addition, American researchers are much more mobile than their European colleagues. During their careers they move frequently from university to university and, to a more limited extent, between the public and the private sectors. The risk involved in interrupting an academic career to pursue an idea for a new business is less daunting for an American than for a European because the American is likely to find another job if the venture fails. In fact, in the business world moving from company to company is a sign of experience and is a proven way to advance a career.

The advantage of this flexible system is precisely that it allows science-based firms to flourish. A biotech firm and an academic laboratory share a common culture, and to a certain degree, a common set of objectives. This makes the transference of knowledge very fluid and almost seamless.

Financial Market Support for Venture Firms

In addition, American biotechnology companies have benefited from a variety of funding sources. In the United States, companies can string together sources of capital to fund research and development work over several years from a mixture of venture capital, private equity, public offerings, and strategic alliances. This financial security encourages biotech start-ups and also allows some flexibility for entrepreneurs whose initial company fails. Financing is crucial to the survival of biotechnology firms. More than any other element of the U.S. system of innovation, the financial system, which made available capital

for idea-based companies with no revenues, was critical to the explosion of biotechnology firms in the United States.

In order to attract investment in the form of a joint venture or public offerings, new biotech entities must prove their competitiveness. Progress in the regulatory approval process indicates value to the market. The next section explores the U.S. regulatory system and new product development procedures.

New Product Development and Protection

Information on the status of a product approval yields far more detail about the quality and safety of a product—and therefore about the future value of a company—than a patent can. Investors and stockholders follow regulatory approvals of the Food and Drug Administration (FDA), the Environmental Protection Agency and the U.S. Department of Agriculture very closely.

The Food and Drug Administration regulates the development, manufacturing and sale of drugs. If a product seems to be safe (i.e., having few side effects) and effective in treating a disease in animal studies, a company will file an Investigational New Drug Application (IND) with the FDA to start testing on humans. The company has to complete three phases of tests before it can ask the FDA to review its product. Phase I trials are small-scale experiments to establish that the drug is safe in healthy human subjects and to determine its appropriate dosage. Phase II trials assess the drug's efficacy in actually treating or curing the target disease in sick patients and Phase III extends the safety and efficacy tests to a much larger population (one to three thousand patients) for better statistical analyses. The assembled data from the three tests is submitted to the FDA as a Product License Application. The FDA then reviews the data and judges whether the product is effective. The regulatory approval system can make or break a product, so the disclosure of trial results are critical to the stock value of public companies and to potential strategic alliance partners. Approvals affect not only the individual company, but occasionally pull valuations for the entire biotechnology "industry." In 1993 and 1994, disappointing results for antisepsis drugs (which combat acute infections)—the core activity of companies like Synergen, Centocor, and Xoma—made institutional investors bearish about the biotechnology industry as a whole. Wall Street concerns about the future of biopharmaceuticals approvals caused many initial public offerings to be withdrawn or delayed.

The investment community follows a new biotech company's progress via two signals: the status of regulatory approval for new products and patent applications and awards. The importance of patents as information sources about biotechnology companies is apparent from the fact that "due diligence" reviews of patent portfolios are routinely requested by venture capital firms, corporations, and biotechnology companies every time they are considering investing in or collaborating with another group of researchers. Though by no means guaranteeing the ability to exclude others from a market, patents call attention to useful products or processes a company has developed, and thereby indicate the commercial value of the company's research. It is important to note that in the pharmaceutical and biotechnology industries, a product and its patent create a market. Patents are issued for new chemical entities or processes for making those entities. Courts ruling on biotech patent issues have tended not to enable the product beyond the very specific delineation of the initial patent. Unlike in many other industries, few patents are issued for minor improvements, so there is little incentive to cross-license.

The Cultural Context of Biotechnology

Consumer advocates, environmentalists, religious leaders, and even some scientists are critical of the potential dangers of and the ethical questions surrounding genetic engineering. Initially, the sheer novelty of transgenic organisms made it difficult to determine what effects they would have on ecological stability and public health. The National Institutes of Health thus created a regulatory framework for research and development as a precautionary measure to allay public fears. The guidelines for rDNA (recombinant DNA) progressively have relaxed as confidence in safety mounted. Nevertheless, regulations have contributed to the uncertainty surrounding recombinant products and slowed their development. A public distaste for bioengineering also engendered a certain distrust of biotechnologically-derived products, especially in areas in which non-recombinant products are easily available and considered "more natural." Commercial progress for biotechnology in many fields has, for the above reasons, been slower than initially expected.

THE GERMAN SYSTEM OF INNOVATION

German biotech start-ups have a completely different institutional environment, and face different incentives. It has been argued that while other countries were creating the biotechnology revolution, German firms and academics were hampered by government regulations that limited genetic engineering (See Gassen, 1993). Although this explanation is commonly used, it does not stand up against empirical scrutiny. Germany was an initial leader in the biotech revolution. In 1980, Germany held 20 percent of the world's biotech patents, compared to 30 percent in U.S. hands (Miller and Hamilton, 1995). Germany now ranks only behind Great Britain in all European countries for number of products on the market and number of products in development.

Nonetheless, three basic institutional factors differentiate the German and American systems of commercialization and innovation. Technology transfer between the public and private sectors is less established in Germany. German universities encourage longer tenure of faculty and researchers; there was and still is arguably less mobility of researchers and ideas between public and private sectors in Germany. Second, despite several public programs for the development and generation of small high-tech firms, shortcomings in the financial system—including tax codes and the venture capital market—have made the emergence of new technology-based firms in Germany more difficult than for their American counterparts. Finally, there have been profound institutional and economic challenges due to the structural changes of reunification. Many academics from the former GDR have become unemployed and view entrepreneurship as a means to viable professional activity. The closure of many East German research institutions, such as the prestigious National Academy of Science and the State Research Centers, left many unemployed, yet highly-skilled researchers and academicians looking for work in the private sector.

Public Resources and Infrastructure of the Basic Health Sciences

Biotechnology's commercial potential is very attractive to German firms. Germany's university system trains highly-skilled scientists and technicians. Their history as leaders in the pharmaceutical field has clearly created a foundation for sophisticated chemical and biochemical research and engineering. In terms of the availability of a highly trained scientific workforce,

the U.S. and Germany are comparable. In 1991, Germany had a total of 240,802 scientists and engineers (3.016 per million population), compared to about 962,700 scientists and engineers in the U.S. (3.732 per million population) (OECD, 1995).

Almost 90 percent of all new biotech enterprises (NBEs, i.e., 204/232) are producers of biotechnology intermediary chemicals or processes (Coombs, 1997). Providing routine biotech services is a way that small firms can finance their internal R&D. This also suggests that the established pharmaceutical firms are consumers of intermediate supplies for biotech research, development and production.

The level of government funding for research was modest and targeted at the private sector. In 1995, the German government spent DM 873 millon (about $510 million) for biotechnology, compared to nearly $6 billion by the United States (BMBWF, 1996; and Miller and Hamilton, 1995). Whereas in the United States the government funds approximately 50 percent of the gross expenditures on R&D (and this is approaching 60 percent since the late 1980s according to the OECD), the private sector in Germany has a slightly greater financial burden for R&D. Industry funds more than 60 percent of all R&D (BMBWF, 1996, p. 120). However, even in biotechnology industry involvement is considerably below average: the private sector accounted for only 27 percent of all biotech project funding in 1995 (i.e., except funding of R&D institutions, see BMBWF, 1996, p.99).

The research and education system, and in particular the universities, contributed to the slower and more glacial nature of German biotechnology. The university system restrains the commercial activities of its professors and researchers. Civil servant status, strict regulations, as well as acceptability problems limit the amount of contract research or consulting work that faculty can pursue. As a consequence, the transfer of know-how and technologies to the private sector in biotechnology neither takes place on a larger scale nor has proved to be efficient. In addition, the rigid employment structure raises the risk associated with joining or creating new ventures to levels most German academics are unwilling to accept. If a start-up fails, its scientists will have great difficulty finding employment elsewhere at mid-career.

Financial Market Support for Venture Firms

There is probably a need for venture capital in Germany, although this is not undisputed (see Pfirrmann *et al.*, 1997, pp. 133ff). It can be argued, however, that since biotechnology has only really begun to be competitive in Germany over the last five years, the financial infrastructure lacks the expertise to invest in promising biotech start-ups. Although venture capital exists, there appears to be a bias against investing in early stage ventures. Established German pharmaceuticals are more likely to invest in foreign biotech firms, which are seen as more stable or profitable, than domestic ones (Unterhuber, 1995). Ironically, it is foreign firms, those with more experience in biotech entrepreneurism, that have been investing in German biotechs either through venture capital or in joint ventures (Miller and Hamilton, 1995; and Stadler, 1997).

Like most European countries, Germany does not allow companies that have not had five years of profit to post an initial public offering (IPO) on the traditional stock exchange. Thus in reaction to the growing need for start-up capital for new technology-based firms and exit options for venture capitalists, a new equity market was established at the Frankfurt stock exchange in 1997 called the "*Neuer Markt*." In addition, traditionally stock options were heavily taxed. However, tax laws have been amended recently to favor the reinvestment of profit from shares (Stadler, 1997). Without the ability to take the company public quickly, venture capitalists are wary of investing in start-ups. In addition, the lack of bankruptcy protection in Germany creates a strong disincentive for individuals to take the risks necessary to start a new company. Nor has the banking sector been a conduit for loans to new biotechnology ventures. In addition, very few tax credits are extended to make investment in high technology less onerous for small companies, as is the case in the United States.

New Product Development and Protection

A comprehensive legislative framework heavily influenced the launch of biotech products into the market. All areas of application like agriculture or food or even pharmaceuticals were "protected" by law against genetically manipulated materials. The revision of the *Gentechnikgesetz* (Gene Technology Act) in 1993 has made it easier to carry out tests and the range of the lower security levels has opened the way for the inclusion of a variety of new

biotechnological products. In addition, the review time for regulatory approval was reduced for security levels one and two. These developments have made innovation in biotech less time-consuming. Yet due to the law's narrow patent scope and weak enforcement of patent rights, the intellectual property system does not often grant strong protection for innovations. Also, some scientists have found the resources required for filing for patent protection prohibitive. However, due to European integration many laws and regulations have been changed, and national framework conditions will become less important. Thus one cannot only rely on the German framework conditions, but, also take into account the EU regulatory system that, up to now, has been a product of unharmonized national laws and norms.[2]

The Cultural Context of Biotechnology

Germany entered into a public debate about the moral acceptability and health risks of genetic engineering. Given the country's history and the strong impact of ecological thinking fostered by the Green party, the public debate was arguably necessary before scientists and citizens could fully commit to pursuing biotechnology. A survey of Europeans found that risk is a salient concept and that it entails a concept of morality, which cannot always be controlled or regulated by national political institutions (Gaskell, 1997). Germany and Austria proved to be the least supportive of biotech applications. In general "high levels of contact, high knowledge, a matter-of-fact image and low-to-moderate expectations" characterize non-supportive countries (Gaskell, 1997). This demonstrates that more information does not translate, necessarily, into greater support.

Another factor that slowed the growth of the industry, and a potentially motivating factor for the pharmaceutical firms which did not aggressively pursue biotech, was the enormous trade surpluses (US$112 billion to 134 billion in the 1980s and early 1990s) that Germany enjoyed at the time (Hodgson, 1997). There was less of a financial demand to explore lucrative industries given the general health of the German economy.

CONCLUSIONS

We believe that it is a misnomer to identify Germany as "lagging" in the biotechnology sector. Government initiatives, private industry and an

infrastructure of sophisticated science and technology education have created a vibrant, and growing, leader in European biotechnology. Germany had the a greater rate of growth in drugs under development than any other European country between 1994 and 1995. The federal and state (*Land*) governments have been aggressive in initiating projects that foster biotechnology.

Beyond the German national initiative, *Biotechnologie 2000*, the federal government started a competition, named BioRegio, in which the German states competed for investment in local biotechnology firms. Regions were asked to develop a plan for research and its commercialization, building cooperation between academia and private industry. Without doubt the BioRegio competition fostered biotechnology activities not only in the so-called "winner" regions (Aachen, Heidelberg and Munich), but also in other areas like Berlin/Brandenburg that have received no public support. The federal government is also funding a human genome program. This program requires a fifty/fifty split of federal and industry financing. Big pharmaceutical producers have been slow to commit to investing in the domestic research centers, however. Nonetheless, two centers already have been funded by the government, and the rest of the funds are allocated to support individual research projects on the human genome. Private industry will be responsible for applying the research towards the development of drugs and diagnostic techniques (Unterhuber, 1995).

These programs and incentives have strengthened the native biotech sector and in so doing will probably make Germany an important partner in international biotech R&D. The international joint ventures and foreign patenting practices exemplify the global nature of biotechnology. Regional factors in terms of taxes and regulatory boards may be of diminishing importance in attracting investment. Nevertheless, as long as biotechnology is an emerging technology its scientific origins (e.g., universities and their environment) will still play a major role in influencing Germany's position compared to the U.S. and other European countries.

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ENDNOTES

[1]. Patent applications are used as a measure of new inventive activity and provide a snapshot of new innovations which merit patent protection.

[2]. It would be misleading to regard the EU commission as an obstacle for the diffusion of biotechnology. The "Biotechnology 1994-1998" program, including financial means of ECU 552 million ($615 million), is one element of a larger support framework that is, however, mainly devoted to basic research and product development, which is less applied.

BIOTECHNOLOGY, COMPETITIVENESS AND THE REGULATORY STATE

Arthur Daemmrich

Biotechnology's striking international growth over the past two decades has paralleled economic and political polarization common to Europe and North America. The most striking of these is the opposition regularly cast between government regulation and industrial competitiveness. Despite the global appeal of free market competition to multinational corporations and the political power wielded by anti-regulatory groups during the 1980s and 1990s in Europe and North America, individual countries have followed different paths in deciding on the extent of regulatory oversight needed in the biotech arena. The United States and Germany, for example, arrived at distinctly different assessments of risks to public health from genetically modified organisms in the 1980s. As a consequence, Germany instituted stricter research guidelines and greater product regulations than did the U.S. By the mid-1990s, however, both Germany's federal government and most individual states (*Länder*) had revised regulatory policies in an effort to promote research and investment in the biotech sector. By considering interconnections between scientific expertise, public protest and regulation in Germany over the past two decades, this work provides an additional perspective on the creation of a dichotomy between regulation and competitiveness.

Articles appearing in widely-read newspapers and magazines such as *Forbes* and *Business Week* in the U.S., and *Spiegel* and *Frankfurter Rundschau* in Germany, depicted the competitive failure of Germany in the biotech sector during the late 1980s and early 1990s in terms of regulatory style and national culture.[1] Analysts blamed an anti-business culture found in European social democracies for inhibiting innovation, stifling market growth and inducing pharmaceutical and chemical companies to shift their research personnel to the U.S. According to these reports, national identity is based on the regulatory styles and investment choices of multinational corporations. More recently, the same newspapers and journals have lauded the biotechnology "boom" in Germany. The dominant narrative of these accounts casts this growth as the product of decreased regulatory oversight, brought on by changes in public opinion and European harmonization.[2] When Swiss voters rejected a ban on research involving transgenic animals and the patenting of

genetically modified organisms in May 1998, the so-called culture of naïve opposition to biotechnology was seemingly overcome by forces of rationality and progress.[3] Similarly, an industry-sponsored poll conducted in Germany in 1996 indicated that 59 percent of the public believed their country should gain a leading position in biotechnology.[4]

As scientific and technical experts become increasingly important to information-based economies, states come under pressure to modify regulatory and investment policies in order to attract skilled personnel and research investments from multinational companies. By doing so, they can achieve the elusive status of being judged as "competitive." This paper illustrates that the biotech sector is a good case for exploring competitiveness and national identity in the 1990s. Governments such as the Federal Republic of Germany are increasingly trapped into choosing between two defined identities: **regulator** (therefore inhibitor of innovation) or **deregulator** (thus promoter of competitiveness). This strict dichotomy leaves little room for more nuanced risk assessments whereby, for example, the German public may welcome improvements in medicine, but staunchly oppose the production of drugs or food by genetically modified organisms.

The first section of this work reviews the secondary literature on research strategies of multinational corporations (MNCs) and describes how MNCs have been alternately cast as threats to state authority or as providing the basis for measuring a nation's competitive performance. Next, data from recent cross-national trends in foreign direct investment (FDI) show that investments among European countries and the U.S. increased steadily during the past decade, independent of changes in exchange rates, shifts in regulation or other economic or political fluctuations. Finally, a more narrowly focused case description of the pharmaceutical company Hoechst's experience with the biotech sector in Germany provides an example of the political weight carried by the dichotomy between regulation and competitiveness. This work concludes with some thoughts on corporate and national identity associated with regulation and competitiveness in the 1990s.

MULTINATIONAL CORPORATIONS

Beginning in the 1960s, economists debated the role of MNCs in shaping notions of national identity on the one hand, and defining the competitive

standing and innovative stance of their home states on the other. By introducing the terminology of product cycles, Raymond Vernon connected these two concepts into a single theory as early as 1962. According to his model, new products originate in high-income nations—e.g., the U.S. or European countries—where an initial demand for "innovative" products or processes already exists, and research and production skills are readily available.[5] Subsequent overseas demand for the new innovation is initially met through exports. As production becomes more standardized, manufacturing moves to other high-income countries. In Vernon's analysis, expanding worldwide demand also increases the level of competition, as other firms begin producing similar items or offer similar services. In order to lower unit costs and keep up with competitors, production is subsequently shifted to less-developed countries. Vernon followed this study with a broader review of sovereign states in 1971.[6] Casting the "nation-state" as a historical anachronism, Vernon argued that increasing economic interdependence between corporations and technological advances in communications and transportation would lead the way to a new global corporatist state.

Concerns about the ability of states to maintain their authority over economic and social policy came to a head during the oil crises and economic turmoil of the mid-1970s. Richard Barnet and Ronald Müller provided a vivid depiction of the views held by MNC managers at the time. "The men who run the global corporations are the first in history with the organization, technology, money, and ideology to make a credible try at managing the world as an integrated unit."[7] Pronouncements by corporate managers that they would profit most from transcending and thereby destroying the state emerged as a revolutionary, and for some, a frightening aspect of discussions about the future in the 1970s. Contributing to uncertainty for state administrators, Dow Chairman Carl Gerstacker described his response to national ties in terms of an absolute freedom from structure, history and culture: "I have long dreamed of buying an island owned by no nation and of establishing the World Headquarters of the Dow company on the truly neutral ground of such an island, beholden to no nation or society."[8] In his "dream," Gerstacker envisioned a world operated by corporations rather than states. This would presumably free the corporate entity from shackles imposed by the institutional arrangements, tax structures and regulatory politics of different states around the world. At the same time, it would eliminate employees' diverse national identities and

cultural heritage in order to redefine all aspects of life toward the production of corporate citizenship.

Debates about threats posed to national sovereignty by MNCs declined in prominence as U.S. policy discussions shifted in the 1980s to criticize the over-regulation and stifling of business practices. Companies and conservative political allies sought to dismantle onerous environmental and consumer safety regulations, while also seeking to promote homogeneous business conduct and uniform intellectual property rights worldwide.

> Today, MNCs are sometimes unable to achieve their own internal strategic objectives in the face of government regulation. They are often constrained by conflicting demands placed on them by host and home governments and multilateral regulatory bodies. Codes of conduct, regulations, and public scrutiny restrict the ability of the MNCs to operate efficiently.[9]

According to this quotation from a management textbook, MNCs and federal governments inherently occupy opposing positions in struggles over regulation and economic prosperity. Many prominent economists and business analysts have thus shifted from criticizing the MNCs for their threats to national sovereignty to chastising governments for overextending their regulatory authority. In addition, the heterogeneity of regulations in different states came under fire in proposals to create uniform state structures that would simplify MNC technology transfers ranging from products to personnel.

Efforts to weaken regulation and forge a more homogeneous international environment for MNC operations both stem from and have implications for the location of research and development (R&D) divisions. R&D groups were traditionally centralized and located close to corporate headquarters for reasons ranging from ease of communication to the belief that scientists work better in large groups. In addition, some economists have levied arguments against conducting development and market-testing abroad, since products are then inadequately prepared for the home country market. For example, Bartlett and Ghoshal's depiction of a "center for global" R&D policy advised MNC managers to maintain a close association with corporate headquarters, primarily because of the administrative need to protect core competencies and financial pressure to achieve economies of specialization and scale in R&D.[10]

Despite claims that R&D has become a multinational phenomenon, studies of large companies indicate that most prefer to keep research divisions physically close to their headquarters. For example, a 1992 survey showed that 44 percent of the MNCs sampled spent nothing on R&D overseas and another 13 percent committed less than 5 percent of their R&D budget to other countries.[11] Only 24 percent of the companies surveyed spent over 20 percent of their R&D budget outside of central research facilities in the home country. In this case, even a study explicitly written to demonstrate the globalization of R&D indicated a reverse tendency whereby companies that invested in multiple research sites during the 1970s found it more efficient to centralize their research in the 1980s.[12]

Connections among companies with a global presence and the regulatory, economic and research policies of individual countries are necessarily complex. A shift can be found in economic and business literature between the 1970s and 1990s from interpreting MNCs as threatening national sovereignty to seeing the regulatory state as a threat to competitive standing. Despite increasing globalization in many areas, research activity remains closely linked—both geographically and structurally—to the headquarters of most MNCs. As a result, corporations are deeply concerned with restrictions on research and vigorously oppose policies that might inhibit the development of new products and expansion into new markets. During the 1980s and early 1990s, the U.S. and European countries faced similar pressures to promote national competitiveness, frequently measured in terms of the ability to bring foreign capital into the country.

FOREIGN DIRECT INVESTMENT

One classic measure of the technological position and competitive stance of a given country is based on Foreign Direct Investment (FDI) flows. Calculated on the basis of international investments by large corporations, FDI figures can be used to study the response to "national" measures of competitiveness such as employment, gross national product and skill and productivity of the workforce. FDI provides a rough measure of both the extent of technology transfer between countries and the intertwining or codependency of economies. It can also function as an indicator of corporate response to regulatory or other pressures within a particular country. If regulations on

biotechnological research and development were strongly affecting corporate performance in Germany, FDI to the U.S. should increase, since the U.S. offered fewer regulations and an equivalent or even better workforce for research in the life sciences in the 1980s and 1990s. Reports decrying Germany's loss of competitive standing during this period indicated that precisely such a shift in research dollars and institutional investment was taking place.

FDI inflows to the U.S. from all countries in the chemicals sector—a broad category that includes pharmaceuticals and biotechnology—and FDI inflows to the U.S. from Germany are depicted in the graph below. Since German investments in the U.S. are concentrated in the chemical and drug industries, their patterns correlate well with the broader chemicals category.

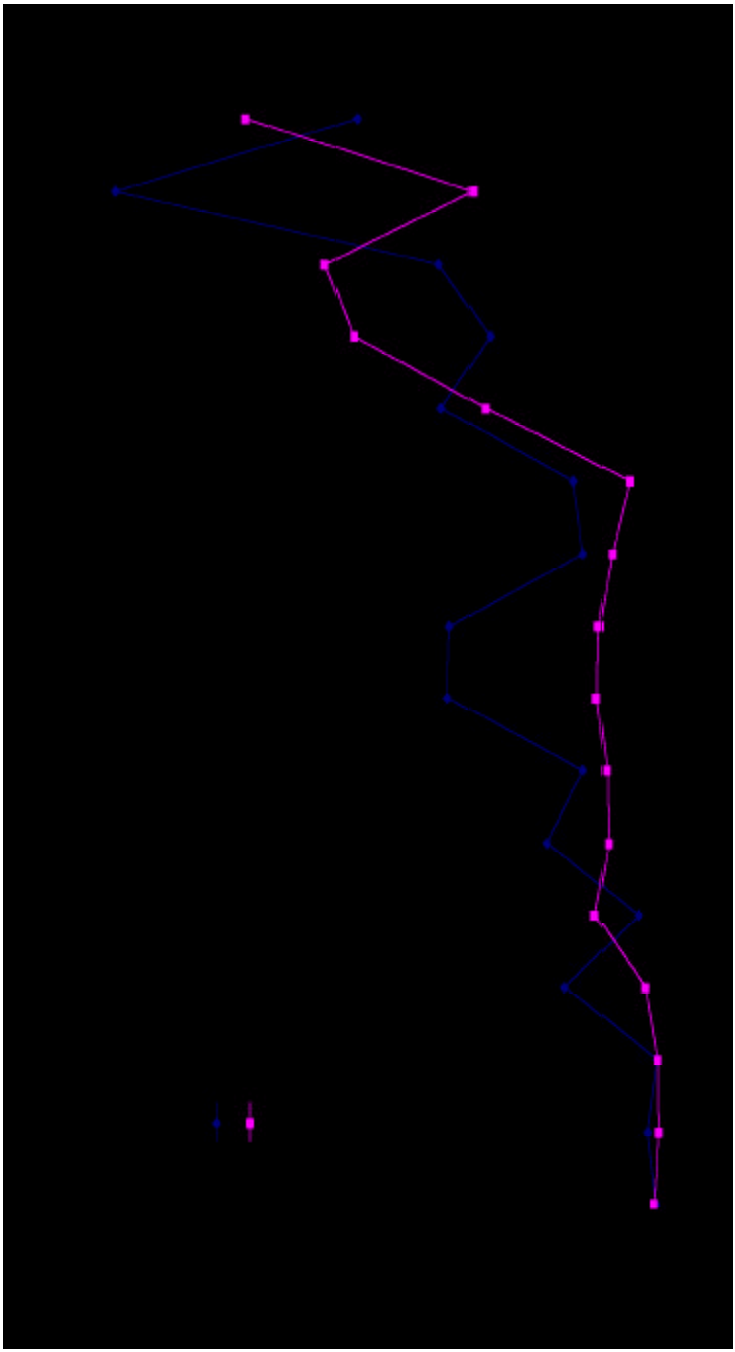
Throughout the 1980s, investments remained steady at approximately two billion dollars per year. Despite the supposedly adverse regulatory climate in Germany during the 1980s, significant growth in German FDI in the U.S. has come largely since 1992, at a point when strict regulations on research and production by means of genetically modified organisms were being relaxed. These data do not strongly support arguments that Germany was losing its competitive standing because companies were shifting investments to the U.S.

A second indicator of responses to regulation by companies involved in biotechnology is the purchase and location of affiliates. Companies responding to a harsh regulatory climate in Germany would seek both to purchase U.S. biotech firms and to move their research operations across the Atlantic.

Table 1: Employment at U.S. Affiliates

Year	German-Owned	R&D Employees
1988	3,916,000	
1989	4,456,000	
1990	5,162,000	
1991	5,172,000	
1992	5,414,000	
1993	5,657,000	192,000
1994	5,841,000	208,000
1995	5,806,000	197,000

Source: United States Department of Commerce, *Operations of U.S. Affiliates of Foreign Companies*. (Washington, D.C.: U.S. Government Printing Office, various years).



Source: United States Department of Commerce, *Survey of Current Business* . (Washington, D.C.: U.S. Government Printing Office, July 1997).

Even though U.S. employment at German-owned affiliates increased steadily during the late 1980s and early 1990s, there is little indication that MNCs were making a significant shift to North America. While only available for three years, the stability of R&D employee figures gives further support to the claim that German companies have not been responding to a strict regulatory climate by moving operations to the U.S.

BIOTECHNOLOGY AND REGULATION IN GERMANY

Data from FDI and employment figures from German-owned affiliates indicate that European MNCs regularly invest in the U.S., independent of specific changes in the regulatory climate. FDI and employment figures, however, lack specificity about the behavior of individual companies and fail to provide details on a more microeconomic scale where the influence of regulatory environments can be seen. These issues are better addressed through a historical review of events in the biotech arena during the 1980s and early 1990s. The opposition between competitiveness and regulation was constructed as a political tool based on specific responses by German companies to public protest and restrictions on research and production in the health care and food sectors.

Biotechnology's corporate foundations were laid in 1980 when the U.S. Supreme Court ruled that micro-organisms can be patented, and Genentech set a Wall Street record for the fastest price per share increase—from $35 to $89 in twenty minutes—in an initial public offering.[13] Venture capital and wildly successful stock offerings thus helped forge new relations between academic scientists and sources of research funding. European countries followed a different route during the 1980s as major chemical and pharmaceutical firms set up new in-house research labs and invested in North American start-up firms. Collaborative research agreements and outright purchases of U.S. biotech firms were often based on concerns that European MNCs, and more broadly, their home countries, were lagging behind the U.S. in an area that had suddenly become a measure of national competitiveness and economic progress. Market analysts repeatedly pointed to stricter environmental regulations on biotechnology as a major factor stifling European firms and weakening the competitive position of states such as Germany. For example, the business magazine *Forbes* reported in 1989 that uncertainty about federal and local

approval for performing gene splicing experiments and producing pharmaceutical preparations through the use of genetically modified organisms had "virtually paralyzed Germany's fledgling biotech industry."[14]

One prominent example of a German firm shifting research to the U.S. was a 1981 agreement between Hoechst and Massachusetts General Hospital. The contract stipulated that Hoechst would establish a Department of Molecular Biology at the hospital, headed by Howard Goodman. Hoechst agreed to provide seventy million dollars over a ten-year period, in return for training its scientists under Goodman and getting first choice of patents and licenses.[15] This relationship made it possible for Hoechst to train research scientists in new genetic engineering techniques in the U.S. Rather than trying to hire renowned scientists such as Howard Goodman, Hoechst instead sought to train a generation of workers who would use his approaches back in Germany. This sort of agreement between a major foreign MNC and a large U.S. research organization was repeated throughout the 1980s.

Collaborative agreements and contract research between German multinational pharmaceutical companies and U.S. biotech ventures expanded rapidly during the mid-1980s. For example, Genex, located in Gaithersburg, Maryland, announced two genetic engineering contracts and supply agreements in 1986. Although they only brought in $650,000, they were representative of foreign investment and collaboration during the 1980s. Under the agreement, Genex began performing research for Schering on plasma proteins intended to treat cardiovascular diseases. Recombinant microbial processes would be used to produce the proteins. Although fewer details are publicly available on the second agreement, the company continued research on therapeutic serum proteins for Hoechst.[16] Other agreements of this type indicate that large firms from Germany were important actors in the growth of small biotech ventures in the U.S.

Table 2: Selected Collaborative Ventures Initiated During the 1980s	
German Multinational	U.S.-based Biotechnological Firm
BASF/Knoll	Biogen, Integrated Genetics
Bayer	Genentech, Genetic Systems
Boehringer Ingelheim	Genentech, Molecular Genetics
Boehringer Mannheim	Genetic Institute, Xoma
Grünenthal	Chiron, Genentech
Hoechst	Biogen, Chiron, Genentech, Genex, Immunex, Integrated Genetics, Massachusetts General Hospital, Salk
E. Merck	Salk
Schering	Biogen, Cetus, Genex

Sources: M. Wortmann, "Multinationals and the internationalization of R&D: New developments in German companies," *Research Policy* 19 (1990): 175-183; Office of Technology Assessment, *Commercial Biotechnology: An International Analysis* (New York: Pergamon Press, 1984).

Regulations imposed on genetic engineering and biotech-based research in Europe did provide an impetus for the proliferation of such agreements. Germany and other European countries such as Switzerland adopted significantly different approaches than the U.S. in regulating research and production via genetically modified organisms.[17] For example, a 1988 change in the German "Federal Nuisance Act" increased regulation of industrial production facilities by requiring effluent to be free of any microorganisms. This act formed the legal basis for blocking production facilities such as BASF's Tumor-Neurosis-Factor plant, Behringwerke's Erythropoietin factory, and a Hoechst facility for insulin production. Similar regulations and local opposition prevented Ciba-Geigy from building a $150 million manufacturing facility in Basel during the late 1980s. After two years of debates, the firm decided to move it to nearby France. These rules contrast vividly with the U.S., which dismantled strict NIH controls over research in 1979 and never instituted significant regulations on the production of pharmaceuticals using biotechnology.[18]

Biotech production processes were halted in Germany on November 15, 1989, when the administrative court for the state of Hessen prevented Hoechst from completing a plant intended to manufacture genetically engineered human insulin. Hoechst had initially assumed the plant would be approved, based on the L2 security level assigned in a confidential deliberation by the *Zentrale*

Kommission für die biologische Sicherheit (ZKBS, Central Commission for Biological Safety) in 1984. Construction plans were initially approved in June 1985, under the *Bundesimmissionsschutzgesetz* (BimSchG, Federal Emissions Control Act), the standard law for factories and other plants producing emissions.[19] In this case, a *Regierungspräsidium* (governmental committee) classified Hoechst's facility in the same way as other biological fermentation processes, such as those used in the production of wine or cheese. This meant that no public hearing was required for the licensing and construction of Hoechst's facility.[20]

At this point, a group of residents living in the suburb of Höchst, called *Höchster Schnüffler und Maagucker*[21] (HSM), began active opposition to the plant based on fears of water and air pollution. The Green party's opposition to genetic engineering and a policy report commissioned by the nearby Darmstadt *Öko-Institut*, which emphasized the hazards of large-scale production with genetically engineered organisms, aided them.[22] HSM also began holding public meetings to rally support for their position and to articulate their position to the public by gaining the attention of the mass media. After elections in April 1987 brought in Karl Heinz Weimar (CDU) as the new Minister of Environment, he overturned his predecessor's order for public hearings and approved Hoechst's trial plant design. HSM's next move was to go to court to obtain a third-party veto (*Widerspruch*) based on German citizens' right to object to state decisions on the grounds that the decision personally affects them adversely. A court agreed in 1989, ruling that "because the law at present does not expressly permit the application of genetic engineering, such facilities may not be built and operated."[23] The *Regierungspräsidium* respected the veto and ordered a suspension of plant construction. At the time, Hoechst had already invested roughly $35 million in the facility. The plant was not allowed to open until 1994, some ten years after construction had begun. Adding to the frustration of company managers, the U.S. pharmaceutical firm Eli Lilly was able to sell recombinant human insulin manufactured in America to the German market throughout this period.

Restrictions on both research and production in Germany contributed to an environment in which some analysts feared that skilled biomedical researchers would emigrate to the U.S. Laws passed to control biotechnology shaped not only the funding available for research, but also influenced curriculum decisions at educational institutes for scientists interested in recombinant DNA

technologies. At the same time, regulations channeled the flow of resistance and opposition to the laws.[24] In this case, the tension between funding research and protecting citizens from adverse risks dragged on for roughly a decade and centered on debates between MNCs invoking issues of national competitiveness and biotechnology opponents, who crafted a discourse of danger and risk in Germany.[25]

Once pharmaceutical firms and policy analysts in Germany continued to decry the regulations and their supposed link to German scientists migrating to the U.S., efforts were made to ease research restrictions. In early 1994, the German federal government enacted changes to the "gene law" that had required all research utilizing recombinant DNA to first go through extensive review. Written statements required from researchers were significantly shortened, and the formal approval process required for level one (no risk) experiments, such as those on *escherichia coli* (*e. coli*), were abandoned. Previously such research had required the completion of nearly one hundred forms.[26]

Further changes in the beginning of 1995 led *Business Week* to report that biotechnology was "blooming" in Germany. In addition to concerns about losing elite scientists, Germany's decline from 20 percent of world biotech patents in 1980, to 12 percent in 1995, compared to the U.S. rise from 30 percent in 1980, to nearly 50 percent in 1995, contributed to changes in regulatory policy.[27] High unemployment rates in the wake of German unification gave additional impetus to the easing of regulations in the mid-1990s, since biotech programs modeled on start-up firms in the U.S. held out the promise of creating new firms and new jobs. "Many German scientists, returning from postdoctoral studies in U.S. biotech labs armed with knowledge, are eager to work in startups."[28] For example, Biopharm's research director, Jens Pohl, conducted postdoctoral work in San Diego before returning to Germany. He first had to hack "pig bones at a local butcher to get enough marrow to manipulate proteins," but has since moved on to help found an important new firm. As he put it, "I want to show the world that Germany can do important research."[29] Recently established firms such as Biopharm and Medigene have gotten upwards of $4 million in funding from large corporations and the federal government, which is now disbursing some $840 million annually for biotech research.

German multinational pharmaceutical companies are pursuing a variety of strategies for investing in biotechnology ranging from cooperative agreements to the outright purchase of small ventures. At the same time, they are structuring R&D groups in a variety of ways ranging from globally dispersed sites to single large research divisions. One feature common to these disparate strategies is an effort to train experts who can provide long-term research results. As the premier training ground for biotech researchers, the U.S. is gaining in importance for investment and expansion of MNC research, despite deregulatory efforts in Germany. Efforts to decrease regulatory oversight of research and production in the biotech field in the mid-1990s were based on a powerful lobby arguing for improved competitiveness. The rhetorically and politically tight connections between competitiveness—both of Germany as a whole and of individual multinational companies—and regulation, were able to supersede the discourse of environmental safety and public risk articulated by groups opposed to gene research and biotech-based manufacturing.

CONCLUSION

European polities have responded to the tight link drawn between competitiveness and deregulation by de-emphasizing the politics of precautionary risk assessment and preventive regulation. The result has been encouraging for industry promoters, as the number of new biotech ventures in Europe has increased from 716 in 1996 to over 1,000 in 1997.[30] Personnel employed by these firms also grew, illustrating further that growth in both small biotech ventures and in investments by MNCs are important to national economies. Nevertheless, in competition with the U.S., Germany still appears to be losing research dollars and skilled workers. As shifts in MNC capital and personnel increase, assessments of winners and losers in global competitiveness are becoming increasingly difficult to make.

This paper finds no congruence with either of two conflicting perceptions of MNCs as subservient to state structures or as supra-national, thus able to shape and control national policies. Instead, I propose that even multinational firms have distinctive identities that can be seen in a comparative framework. By competing for market shares within any given country, however, all MNCs—regardless of their "home" country—try to take on the trappings of a given place. Rather than operating only to transfer values from their home to

the host nation, a complex set of interactions takes place that influences both nations through the bridge of the MNC.

European MNC managers and business analysts created a narrative claiming that research and investment shifted to the U.S. in order to avoid restrictive regulatory climates in the 1980s and early 1990s. To further bolster this claim, they argue that biotech investment is shifting back to Europe in the late 1990s, due to less stringent regulatory oversight. One feature rapidly lost in this narrative is accounting for national identity of the firm and its employees. Since barriers instituted as part of establishing national identity and independence are so easily circumvented, scholars may be tempted to again warn of the threat posed to states by MNCs. This is unlikely to carry much resonance, because national identity is increasingly predicated on the performance of MNCs. "We are invited to experience vicariously a sense of national pride when exports rise and dejection when they fail to do so."[31] In other words, MNCs carry little threat to states because they have become increasingly state-like in their size, structure and responsiveness to disparate publics and stakeholders.

ENDNOTES

[1] For some examples see: R. Bailey, "Brain Drain," *Forbes*, November 27, 1989: 261-262; J. O'C. Hamilton, "Biotech: America's Dream Machine," *Business Week*, March 2, 1992: 66-74; H. Henzler, "Politics and Culture Thwart German Innovation," *Wall Street Journal Europe*, August 27, 1996: 25; G. Kretzschmar, "Wunderdrogen aus dem Genlabor noch umstritten," *Frankfurter Rundschau*, June 29, 1991.

[2] K. Miller, "Biotech Blooms in Germany—Again," *Business Week*, January 23, 1995: 70-71.

[3] R. Koenig, "Voters Reject Antigenetics Initiative," *Science* 280, June 12, 1998: 1685.

[4] EMNID Survey, reported in: Verband Forschender Arzneimittelhersteller, *Gentechnik* (Bonn: VFA, 1996).

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[9] A. Rugman, D. Lecraw, and L. Booth, *International Business: Firm and Environment* (New York: McGraw-Hill, 1985): 254.

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[12] For more on trends in the 1970s, see: E. Mansfield, et al., *Transfer, Productivity, and Economic Policy* (New York: W.W. Norton, 1982).

[13] *Diamond v. Chakrabarty*, 447 U.S. 303 (1980).

[14] R. Bailey, "Brain Drain," *Forbes* (November 27, 1989): 262.

[15] B. Culliton, "The Hoechst Department at Mass General," *Science* 216 (1982): 1200-1203.

[16] UN Centre on Transnational Corporations, *Transnational Corporations in Biotechnology* (New York: United Nations, 1988): 53.

[17] See: H. Gottweis, *Governing Molecules: The Discursive Politics of Genetic Engineering in Europe and the United States* (Cambridge, MA: MIT Press, 1998).

[18] See: S. Wright, *Molecular Politics: Developing American and British Regulatory Policy for Genetic Engineering* (Chicago, IL: University of Chicago Press, 1994).

[19] *Der Widerspruchsbescheid des Regierungspräsidenten in Darmstadt* vom 7. Juli 1987, 23. See also pp.142-149 for further discussion of containment guidelines. *Bundesimmissionsschutzgestez:* Act on the Prevention of Harmful Effects on the Environment Caused by Air Pollution, Noise, Vibration and Similar Phenomena.

[20] R. Robins, *The Conventional and the Controversial: Stabilising the Nature and Risk of Human Insulin Production* (Hamburg: Institut für Sozialforschung, 1992).

[21] The name *Höchster Schnüffler und Maagucker* means "Höchst Snoops and Main River Watchdogs." The word "*Schnüffler*" can also mean someone with the "sniffles." HSM claims that the Hoechst facilities have released chemicals that have caused nasal and respiratory damage in local citizens that present symptoms similar to a cold. In the local dialect, the "*Maa*" in the word "*Maagucker*" means the river Main, which runs through the Höchst district of Frankfurt/Main. "*Gucker*" means "looker," or observer, and has the connotation of watchdog.

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[23] B. Bachtler, "Court Blocks German Biotech Plant," *Science* 246 (1989): 881.

[24] S. Jasanoff, "Product, Process or Programme: Three Cultures and the Regulation of Biotechnology," in M. Bauer, ed., *Resistance to New Technology* (Cambridge: Cambridge University Press, 1995): 311-331.

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[27] K.L. Miller, "Biotech Blooms in Germany—Again," *Business Week*, January 23, 1995: 70-71.

[28] Ibid., 70.

[29] Ibid., 71.

[30] "Eurobio Coming of Age?" *Science*, May 22, 1998: 1119.

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