National institutional frameworks and high-technology innovation in Germany: the case of biotechnology

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National Institutional Frameworks and High-Technology Innovation in Germany

The Case of Biotechnology

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Abstract

Can German national institutional frameworks be reconfigured to allow radical innovation in science-based industries? This paper examines the development of commercial technologies for entrepreneurial biotechnology start-up firms in Germany. During the 1980s and early 1990s an inadequate institutional infrastructure stifled virtually all attempts to organize entrepreneurial biotech start-up firms within Germany, while most large German pharmaceutical firms quickly invested in international alliances with US biotechnology companies and university research labs.

The paper links the poor performance of the German biotech industry with a variety of institutional disincentives created by the broad institutional orientation of the German economy. Problems discussed include inadequate performance incentives within German firms, rigidities within the labor market for scientists and managers, and constraints on the provision of venture capital created by the broadly bank-centered orientation of German capital markets. Because these institutional arrangements strongly advantage a large coalition of German firms in a wide variety of engineering intensive industries, the paper argues that fundamental institutional reforms to better support science-based industries like biotechnology are unlikely.

However, noting the recent upswing in the German biotechnology industry, the paper suggests that sector-specific policies may create an atmosphere conducive to large-scale entry into some quickly growing market segments of biotechnology in which the financial and technological risks are lower than in pure therapeutics research.

Zusammenfassung

Können Deutschlands nationale institutionelle Rahmenbedingungen so verändert werden, daß radikale Innovationen in forschungsintensiven Industrien möglich werden? Der Beitrag untersucht die Entwicklung marktorientierter Technologien für Unternehmensneugründungen im Biotechnologie-Sektor in Deutschland.

In den 80er und frühen 90er Jahre blockierte eine ungeeignete institutionelle Infrastruktur fast alle Versuche unternehmerischer Biotechnologie-Neugründungen in Deutschland. Die meisten großen deutschen Pharma-Konzerne investierten demzufolge in internationale Verbindungen mit Biotechnologie-Firmen und universitären Forschungslaboren in den USA. Der Beitrag zeigt die Wechselwirkung zwischen der schwachen Leistungsfähigkeit der deutschen Biotechnologie-Industrie

mit den institutionellen Hindernisse in der deutschen Volkswirtschaft. Zu den angesprochenen Problemen gehören unzureichende Leistungsanreize in den deutschen Unternehmen, mangelnde Flexibilität auf dem Arbeitsmarkt für Wissenschaftler und Manager und Beschränkungen im Angebot von Wagniskapital, bedingt durch die weitgehend bankzentrierten deutsche Kapitalmärkte. Weil diese institutionellen Gegebenheiten große Vorzüge für viele Unternehmen in der verarbeitenden Industrien bieten, wird hier die These vertreten, daß grundlegende institutionelle Reformen zur besseren Unterstützung forschungsintensiver Industrien wie Biotechnologie unwahrscheinlich sind.

Dennoch ist angesichts des jüngsten Aufschwungs in der deutschen Biotechnologie-Industrie vorstellbar, daß sektor-spezifische Maßnahmen dazu beitragen können, daß zahlreiche Unternehmensgründungen in jenen schnell wachsenden Marktsegmenten der Biotechnologie-Branche erfolgen, in denen die finanziellen und technologischen Risiken niedriger sind als in der reinen Therapeutika-Forschung.

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1. Introduction

Since the early 1980s, the US political economy has evolved to support commercial innovation in biotechnology, software, and a variety of other industries relying on radical innovation, often with close links with basic science. US national institutional frameworks have fostered a dramatic expansion of innovative activities within the economy. Institutional frameworks have been reconfigured to foster high-risk venture capital financing of dynamic start-up companies, new links between university scientists and companies, and the reorganization of large company decision-making and incentive schemes. In Germany firms and policy-makers are anxiously experimenting with their own institutional frameworks to foster organizational structures supporting radical science-based innovation in their own country.

Can German national institutional frameworks be reconfigured to allow radical innovation in science-based industries? This paper examines the development of commercial technologies for entrepreneurial biotechnology start-up firms in Germany. The broader goal is to examine the degree to which national institutional frameworks can be reconfigured to better support commercial innovation in newly emerging science-based industries. National institutional frameworks provide incentives and impose constraints that influence the ability of firms to create a variety of organizational structures and human resource competencies needed to innovate. In the biotechnology case important national institutional frameworks include the financial system, the education and training system, laws and other institutions influencing the development of careers and decision-making within large companies, and the system governing relations between companies.

Germany presents an especially intriguing case. During the 1980s and early 1990s an inadequate institutional infrastructure stifled virtually all attempts to organize entrepreneurial biotech start-up firms within Germany, while most large German pharmaceutical firms quickly invested in international alliances with US biotechnology companies and university research labs. The technological regime underpinning biotechnology necessitates the creation of company organizational structures that are difficult to sustain within Germany's business-coordinated market economy. Long-term career structures within most German firms, combined with the willingness of German courts to uphold anti-poaching clauses within labor contracts, limits the active labor market of scientists and financial experts needed to form start-up companies. Similarly, the lack of a strong NASDAQ-style market by which start-ups can go public limits the availability of high-risk venture capital. This makes it difficult for German start-up companies to create high-powered incentives for employees. Furthermore, the lack of an exit option limits the emergence of a refinancing mechanism for start-up capital based on funds generated through initial

public offerings (IPOs). This also may prevent venture capitalists from engaging in „portfolio“ strategies when investing in start-up companies.

However, in recent years the tide may be shifting. In Germany there is currently a large push by the government to promote the development of a biotechnology sector comparable to that in the United States. The official goal of the German government is to be the European leader in biotechnology by the turn of the century. To promote this goal, the federal and *Länder* governments have spent large sums in support of „Gene centers“ that include new basic research facilities, „incubator labs“ for start-up companies, and the inclusion of matching funds up to a fifty percent basis for virtually all private venture or bank-based capital for biotechnology activities. This catalyst has created a biotech boom in Germany, particularly within the Munich area. From scarcely a handful of companies at the beginning of the 1990s, there are now several hundred bio-tech start-up firms in Germany.

The recent success of German biotechnology promotion programs presents an important puzzle for research. The short-term success of German industrial policies to support biotechnology indicates that, at the local level, the company organizational structures, financial links, and networks with universities needed for radical innovation can exist within Germany. This paper focuses primarily on only one part of the puzzle: the creation of viable institutional structures to stimulate and nurture high-technology start-up firms in biotechnology. It thus ignores equally important problems associated with the creation of biotechnology competencies in large firms as well as the creation of links between universities and other public research institutes and the private sector.

The paper is organized into two general sections, followed by a conclusion. The first section examines the generally static situation during the 1980s. During the 1980s commercial biotechnology research was largely moribund in Germany. I first briefly describing the newfound importance during the 1980s of biotechnology methodologies to pharmaceutical research strategies through examining the comparative performance of US and UK firms (which had access to new biotechnology start-up firms) to German firms (which generally did not). I then examine more carefully the technological regime underpinning therapeutics research within biotechnology and how German national institutional frameworks broadly disadvantage the creation of financial, company organizational, and career-structure competencies that have been developed by US biotech firms to successfully innovate. Examining the largely static institutional frameworks during the 19080s allows a more careful appraisal of institutional reforms and governmental promotional policies that have been created during the 1990s.

The second section attempts to create a framework for examining the more fluid situation during the 1990s. It first examines general industry dynamics during this period, which are generally favorable to new entry in biotechnology. I then examine three scenarios for institutional reform in Germany: convergence, specialization, and

accommodation. There is little evidence supporting the view that German national institutional frameworks are converging to a US/UK liberal market economy model. There is strong evidence supporting view that German national institutional frameworks promote a specialization in a wide-variety of high-value niche markets in process technologies (the „DQP“ strategy) while US and UK frameworks better conduce towards radically innovative product market strategies. However, there is also evidence supporting the view that some forms of high-technology start-up activity can be „accommodated“ within Germany’s generally unfavorable institutional environment.

Incremental reforms in German financial laws supported by the bulk of German industry, combined with a number of sectoral industrial policies, have created opportunities for firms to create alternative governance structures needed to accommodate some forms of biotech start-up activity.

2. Problems Undermining the Development of German Commercial Biotechnology During the 1980s

2.1 Market and Technological Dynamics in Pharmaceuticals and the Performance of German Firms

During the 1980s there were substantial performance differences across the German as opposed to the US or UK pharmaceutical industries. Table 1 includes a number of aggregate market characteristics for the five largest pharmaceutical producing nations. Using several summary measures, we can construct a picture of a given nation’s competitive position at the beginning of the 1990s. The number of products in the Top 50 is included to account for the fact that although some new chemical compunds (NCEs) introduced are genuinely original, others may be marginal improvements only which could then make the NCE figures somewhat misleading. Market share in the US is included as a crude measure of competitiveness, because the US market is the most open and competitive market in the world.

A comparison with the United Kingdom is a good gauge for the strength of the German pharmaceutical industry during the 1980s. Taking R&D intensity into account, the German and UK pharmaceutical industries spend roughly equivalent absolute sums on R&D. However, the UK industry substantially outperformed Germany. Its leading firm, Glaxo, for example, rose from 17th in the world in terms of sales in 1983, to 1st in the world in 1995. There has also been a relative increase in R&D expenditure in the UK, and furthermore, its companies are extremely good at developing NCEs that are commercially successful. During the 1981-1990 period,

only 28 new drugs were developed, but a relatively high percentage of these turned into blockbusters. Germany, on the other hand, has a much weaker position. It developed far more drugs (67 NCEs between 1981 and 1990), spends approximately the same amount on R&D, but has a very low number of blockbusters to account for this (only 5 in 1990). As a final measure of international competitiveness. Germany's share of the US market is only 4.6%, compared to 14.6% for the UK.

Beginning in the late 1970s, competitive industry dynamics have become more complex. This was due to radical changes in the nature of the innovation process and the introduction of new marketing and distribution techniques. Though both are important (see Casper and Matraves, 1997), this project focuses primarily on changes in the technological process and their impact on company organizational competencies and alliances.

Table 1 here

How has the development of biotechnology impacted the performance of large pharmaceutical firms? Biotechnology has displaced traditional 'chemical' capabilities. The traditional methodology, prevalent in the 1950s and 1960s when knowledge about the properties of the compounds that could be used to synthesize new drugs was still lacking, screened thousands of chemical compounds for efficacy against a given disease (Schwartzman, 1976). In the 1970s, basic biomedical knowledge increased. The traditional methodology has been replaced by 'rational drug design', i.e., the development of more precise models of how particular diseases function, and the design of molecules designed to target particular cells or cause particular biological interactions within the body (see Werth, 1995; Powell, 1996: 204). In addition, genetic engineering techniques have allowed biotechnology companies to manipulate the structure and functioning of so-called „large molecule" proteins that cannot be synthesized through traditional chemical processes.

When a fundamentally new research methodology is created, it is often the case that organizational rigidity and inertia hinder incumbents' ability to take advantage of new opportunities. Following the logic of technological life-cycles, radical innovations in biotechnology have created incentives for hundreds of new firms to enter the market, paralleling periods of rapid market entry following similar periods of rapid technological change in semiconductors, software, and other high-technology industries. As research is one of the highly specialized and hence value-added processes, the fact that most biotechnological research is taking place within small start-ups rather than large firms is an important change (see Powell, 1996). However, although the discovery process is changing, the specialized assets needed for development and commercialization are not, and these assets continue to be owned by the largest firms (see Teece, 1986). Only about 10% of the total R&D costs of a new patented drug are in discovery; the vast majority of costs are found in development, clinical trials, and the regulatory approval process. Tiny

biotechnology start-up firms rarely evolve into large pharmaceutical firms. Rather, due to the high cost and long time-horizons in therapeutics research (see below), most biotechnology companies sell or license their patents to pharmaceutical firms for continuing financing long before their discoveries reach the market. Further development and commercialization is then taken over by large pharmaceutical firms.

The challenge created by biotechnology for large firms is primarily one of rivalry with other integrated pharmaceutical companies. Having access to new competencies in drug design, disease modeling, and screening created by biotechnology are widely viewed as critical for competitive success (see Zucker et al., 1997). In the world of rational drug design, research in complex disease areas usually takes place along a number of distinct research trajectories. For example, Penan (1996) identifies over fifteen distinct research programs to fight Alzheimer's disease, each of which was supported by a different constellation of university departments, large pharmaceutical firms, and in some cases, biotechnology firms. In addition, the therapies for some of the more complicated diseases, such as AIDS and most likely Alzheimer's disease, often consist of 'cocktails' of two or more compounds developed through separate research programs. Developing alliances with biotech firms helps pharmaceutical firms diversify the lines of research within which the large firm can take part.

Developing licensing arrangements and research collaborations with biotechnology firms helps diversify the pharmaceutical firm's 'bets' across a number of research programs. Each therapeutic area becomes a platform from which the firm can monitor the field, purchase promising compounds from third parties, or develop collaborative research projects with universities or research firms, or starting in-house research projects. Nurturing third party research firms can also help to diversify commercial risks. Developing drugs is an inherently risky business: it is estimated that 1 compound from an initial 5,000 will be successful (PhRMA, 1997). If in-house research in one therapeutic area is unsuccessful, purchasing compounds developed by third parties can help to fill gaps in the development pipeline.

It follows from this discussion that the pharmaceutical firms with easy access to biotech start-up firms, via strategic alliances, research networks, mergers, and so forth should have an important competitive advantage in responding to these changed technological conditions over firms that do not. The superior performance of the UK and US industries compared to Germany follows directly from this second conclusion. The United States and, to an increasing extent, the United Kingdom, have national systems of innovation conducive to the support of high-risk start-up firms in emerging technologies. Large clusters of biotechnology start-up firms were created in the US and (to a substantial, but lesser extent) UK. To obtain long-term financing, access to development and marketing expertise, and forge research networks, large numbers of these start-up firms quickly formed alliances with local pharmaceutical companies. Through these networks large pharmaceutical

companies could monitor technology developments, license or co-develop compounds, and begin to develop internal competencies through mergers, equity holdings, or the recruitment of scientists working within biotech firms.

I thus link these performance differences to the ability of firms in Germany to plug into emerging networks of commercial biotech research that were blooming in the UK and especially the US but largely moribund in Germany. During the 1990s the situation has changed. To close the technology gap, German pharmaceutical firms have created a massive network of international research networks, primarily with US biotechnology firms and public research universities and hospitals (Sharpe and Patel, 1996). At the same time, German national and regional government offices have undertaken a number of substantial technology promotion programs in the area of biotechnology. This raises the possibility of institutional reforms that could lead to a national system of innovation more conducive to the creation and nurturing of high-tech start-up firms. However, during the 1980s German pharmaceutical firms relied primarily on domestic R&D while a variety of national institutional frameworks that are important in nurturing clusters of start-up firms were stable. This allows a relatively clear analysis of the German situation in the 1980s, which can then be used later to understand scenarios for reform during the 1990s.

2.2 National Institutional Frameworks and Competency Building

How do national institutional frameworks impede the creation of the human capital skills and organizational relationships needed for small-firms to innovate in biotechnology? National institutional frameworks influence the governance costs of embarking on particular product market strategies. My argument differs from the „embededness“ approach often found in sociological studies (see Hollingsworth and Boyer, 1997). In its simplest form, this position holds that company organizational structures are shaped directly by the orientation of national institutional frameworks. Rather, I assume that company management, faced with international competition, can survey the spectrum of possible organizational arrangements prevalent within their industry, and attempt to shape a coherent strategy. National institutional frameworks play a strong role through influencing the relative cost of building the organizational competencies needed to pursue each strategy.

To create successful product market strategies, the management of companies must create and sustain relationships with a number of different groups: workers, technicians and scientists, owners and banks, and other companies. Economists, game theorists, and political scientists have in recent years combined rational choice theory, strategic bargaining models, and organizational analysis to form a broad body of theoretical and empirical analysis exploring each of these relationships (see Milgrom and Roberts, 1992 and Miller, 1992 for overviews). This literature, the economics of organization, has developed a unified methodology showing that most

substantive management problems are not just technical challenges but also pose strategic conflicts of interest between participants (so called „relational problems“).

The economics of organization approach has, along these lines, developed a competency-based view to understanding technology and innovation. The technologies needed to innovate rarely consist of specialized machines or codifiable knowledge that can be transferred to any organization regardless of institutional environment, and simply be „turned on“. Rather, most technologies are dispersed across highly skilled experts embedded within complex organizational structures. Innovative capacity usually consists of tacit knowledge spread over networks of managers, scientists, and skilled-workers within a complex organizational environment (which often spreads across several discrete firms, or, in science-based industries, firms and public research institutes).

The complex of legal and private rules that are created to manage organizational relationships are commonly called „governance structures“ (Williamson, 1985). Because its goal is the development of a universal approach to understanding industrial organization, economics of organization scholars often implicitly assumes that companies create their own, private governance structures to solve their contracting dilemmas. This ignores the fact that there are systematic differences in the governance structures developed within Germany and the United States. These variations will be linked to differences in national institutional frameworks governing company relationships in the US and Germany. I first present thumbnail sketches of these institutional differences, and then examine more specifically how particular aspects of these institutions influence the creation of viable company organizational competencies needed for radical innovation (see Soskice, 1994).

The **United States** is characterized by a liberal market economy. Business organization depends primarily on market transactions and the use of a flexible, enabling private legal system to facilitate a variety of complex contracting situations. Because courts refuse to adjudicate incomplete contracts (see Schwarz, 1992), market participants need to specify control rights in contract to as full an extent as possible or, when this is not possible, to use extremely high-powered performance incentives to align interests within and across organizations. Rather paradoxically, this system of legal and corporate governance advantages the creation of governance structures suitable for two very dissimilar product market strategies. On one hand, it promotes a variety of price-based mass production industries dependent on complete, often asymmetrical and opportunistic contracts between large firms/top managers and dedicated suppliers/unskilled workers, respectively. On the other hand, and of more interest in this project, the US system of legal and corporate governance also advantages the creation of complex, incentive based governance structures needed to support radical innovation in newly emerging technologies (see Casper, 1998).

Germany is characterized by a „coordinated market economy“ (Soskice, 1994) underpinned by a regulatory private law system. German business is organized in nature, primarily due to the embeddedness of large firms within networks of powerful trade and industry associations, as well as a similar, often legally mandated, organization of labor and other interest organizations within para-public institutions (Katzenstein, 1987, 1989). Businesses engage these associations to solve a variety of incomplete contracting dilemmas and create important non-market collective goods. For example, German employers associations maintain tacit norms and a monitoring capacity to prevent employee poaching and in doing so lower the risks to German large companies of training highly skilled workers within nationally specified curriculums. To discourage individual companies from exiting the collective business system, German public policy uses private law to regulate a wide variety of inter-firm and labor contracts as well as create neo-corporatist bargaining environments through the delegation of issue-area specific bargaining rights to unions and other stake-holders within firms. German courts use standardized business agreements produced through neo-corporatist arrangements as the basis to apply regulatory corporate laws throughout the broader economy (Casper, 1998).

German national institutional frameworks advantage what Streeck labels „diversified quality production“ (DQP) product market strategies that lead to specialization in a wide number of high-quality niche markets such as industrial machinery, specialty chemicals, high-end automobiles, and so forth (Streeck, 1992). The German system also creates strong prohibitions against opportunistic (largely low price competitive) product market strategies that depend on the delegation of important risks to weaker market participants. As already noted, German industry has suffered in high-technology industries such as biotechnology. I argue that this weakness in high-technology industry is a direct consequence of laws and other institutions constructed by German business and public policy-makers. Through creating institutional frameworks to advantage a series of company organizational competencies for DQP-style industries and – to discourage free-riding on the collective goods necessary to make this system viable for companies competing on world markets – punish opportunistic strategies, German firms and public policy-makers simultaneously create institutions that dramatically raise the governance cost of creating the competencies needed to innovate in high-technology industries. To explore this argument in more detail, I now compare how US and German institutional frameworks influence the creation of three of the most important competencies for innovative start-up firms: high-powered incentive structures for employees, high-risk financing, and the creation of viable career structures for employees of firms that run a high risk of failure.

2.2.1 High-Risk Financing

Requirement: Biotechnology start-ups need access to a continuous stream of high-risk finance. Three industry characteristics combine to make biotechnology one of the riskiest segments in high-technology industry. First, the failure rate is very high.

The vast majority of biotechnology firms do not succeed in bringing a product to market. In addition to cases when the firm simply is not able to successfully innovate, even successful innovators can quickly see their intellectual property eroded by technological advances by other firms who are quicker to market. To give an indication of the failure problem, while there are hundreds of biotechnology start-ups active in therapeutics research, as of 1997 only 40 drugs designed through biotechnology research techniques had reached the market (BIO, 1998).

Second, the „burn rate“ is very high in biotechnology. Basic research costs for specialist equipment, high salaries for scientists and researchers, and supplies (cell cultures, tissue samples, etc.) are high. Therapeutic companies face additional costs for testing and trials; even early stage animal and human clinical trials can run into the tens of millions of dollars. The total R&D cost to bring a new drug to market is between 200-325 million dollars (PhRMA, 1997). High burn rates are compounded by a third problem, the long time-horizons before most biotech products reach the market. This is particularly the case for therapeutic companies, which must bear a minimum 5-7 year clinical trial and regulatory approval period before their discovers are approved and reach the market.

„Solution“ in the US. In the United States most biotechnology firms are initially funded by venture capitalists (see Florida and Kenney, 1986). There are important institutional reasons why the venture capital market is so large in the US. First, very substantial private legal competencies exist and, due to the „enabling“ nature of ownership and contract law, can be used to create sophisticated legal structures used to support risky new ventures. These include the high-powered performance incentives for managers and scientists discussed above.

Second, and probably most important, in the United States the ownership of firms is primarily financial in structure, and rooted in large capital markets (e.g. NASDAQ, NYSE). A liquid market for corporate control is critical for venture capitalists, as it creates a viable *exit option* via initial public offerings and mergers or acquisitions by other biomedical companies. Without this exit option, it is difficult for venture capitalists to diversify risks across several investments or create a viable refinancing mechanism. Typically, a venture capitalists will invest in a number of companies, expecting one or two to become successful in a few years, one or two to survive, and several others to fail. Successful start-ups will be given supplementary „mezzanine“ financing and eventually taken public through an IPO or sold to a larger pharmaceutical company, usually creating a very high return for the venture capitalists. These profits may be used to offset the losses on other companies and thus make a portfolio strategy more viable. The exit option created by large capital markets allows venture capitalists to shorten the time-horizon for investments (usually to 3-5 years). Finally, by taking a firm public within a few years, venture capitalists create a viable refinancing mechanism. They can use the profits from IPOs to seed new ventures as well as provide secondary funding for other start-ups (for example, to take promising candidate compounds into clinical testing).

„Problem“ in Germany. In Germany the ownership of most firms is only partially financial in nature. It is also based on non-financial rights of employees and other „stakeholders“. In connection with the historical development of German financial markets, German company law creates incentives for most investment to be debt-based (see Vitols et al., 1997). Shareholdings of German public firms have traditionally been concentrated and dispersed through stable cross-shareholding arrangements between the large German commercial banks and other large firms. The low-risk nature of bank loans entails that most German firms have traditionally financed R&D and other speculative investments with retained earnings. Germany has never developed a „hostile“ market for corporate control. Until very recently, share offerings have not served as a primary source of funding for German firms, large or small.

The lack of developed capital markets willing to invest in speculative IPOs for technology firms create important barriers for prospective venture capitalists. If share offerings cannot be supported, then the „exit option“ for venture capitalists becomes limited (primarily to M&A activities). This has two important consequences. First without an established IPO market, possible refinancing mechanisms are decreased. The profits from IPOs are the primary continuing source of seed money for venture capital. Without this, venture capitalists must return to original investors to obtain new funds. Lacking a relatively short-term prospect of a high return, it seems unlikely that investors can be relied on to continually finance high burn-rate biotech start-ups. Second, without the short-term returns created by IPOs, it becomes difficult for venture capitalists to diversify risks through a portfolio strategy. The venture capitalist must assume that it is making a long-term investment in each firm that becomes successful, making it difficult to quickly offset loses on unsuccessful firms.

Hypothesis: Legal restraints combined with the bank-based financial system limits the creation of market structures needed to support high-risk venture capital. High-risk start-ups in biotechnology are thus difficult to fund in Germany.

2.2.2 Low Career Risk from Failure

Problem: As already noted, most biotech start-ups involved in therapeutics research eventually fail. In addition, biotechnology research, even within successful firms, is often is characterized by patterns of internal competency destruction. The technology trajectories of even successful biotech firms are often very volatile, meaning that as the course of technology races with other firms evolve they must often shed research competencies in one area in order to build up new ones in another. As a result, the career risk of working within any given biotech firm must be low. This entails the development of an active labor market for scientists, technicians, and managerial experts within biotechnology. If one firm fails or decided to shed competencies in one area, employees must be able to obtain similar employment without severe loss of salary or status. Top executives at start-up firms

typically come from large pharmaceutical companies or public university research laboratories. These often senior scientists/managers would hesitate in making the move to a start-up if the career risk of doing so were large.

Furthermore, as Powell (1996) and others have discussed, biotechnology is a network based industry. Innovation is dependent on the flow of knowledge between university labs, start-up research firms, and large pharmaceutical firms. While joint research projects, strategic alliances and so forth facilitate this exchange of knowledge, these network externalities are also supported by the rapid movement of scientists and technicians across firms. Thus, if the labor market did not support extensive lateral career mobility across firms, these network externalities would be difficult to sustain.

„Solution" in the US: In the United States there is an extremely active labor market. Particularly in California (but generally throughout the US), courts have refused to enforce „competition clauses" written into labor contracts. While firms can ask employees to sign non-disclosure agreements covering specific technologies, scientists and managers are generally free to move from firm to firm as they see fit. This has facilitated extensive poaching and the organization of career paths within firms based on the probability of frequent employee turnover. As a result, the risk of failure is very small (see Saxenian, 1993 for a general discussion of career-paths in Silicon Valley).

„Problem" in Germany. In Germany the organization of labor and company law combined with the organizational strategies of most large companies severely constrains the development of US-style active labor markets. Both sides of the „hire and fire" equation are muted. German courts routinely uphold competition clauses written into employment contracts, with the result that scientists/managers often cannot leave one firm to perform a similar job at a competitor for up to 1-3 years after leaving the original firm. Similarly, German company law grants important representative rights over personnel and working-time policy (training, overtime, work organization) to legally mandated councils of works and middle-management, as well as seats on the supervisory boards of public companies to employee representatives, unions, and other „stakeholders." In return for cooperative labor and employee relations and acceptance of very low powered performance incentives within the firm, German companies have traditionally offered lifetime employment to any employee that survives an initial six months to two-year probationary periods. While large German firms can sell entire subsidiaries or business units or send some lower-productivity older employees into early retirement, individual employees or groups of employees cannot be fired within German firms as part of the „normal" course of business.

Though there is often some lateral movement across firms very early in a person's career, the vast majority of German employees build careers within one firm. Partly as a consequence, the structure of decision-making, remuneration, and

career-paths within German firms differ fundamentally from common practice within the United States or United Kingdom (see full discussion in Vitols et al., 1997). Because employment is usually long-term, German firms must refrain from alienating particular constituencies. As a result, most decision-making is consensual. Career paths tend to be well-specified, incremental, and based on rank hierarchies. Salary is primarily determined by seniority and educational status, rather than short-term performance. Higher levels of salary and responsibility are only obtained as a result of long careers within the firm.

This structure of large company organization has been found ideal for a number of „DQP" industries dependent on long-term investment strategies in relatively stable technologies and the diffusion of deep skills throughout the firm (see Streeck, 1992). In particular, it encourages the creation of tacit organizational knowledge throughout the firm that enhances flexibility. However, this system creates fundamental obstacles to the creation of high-risk technology start-up firms. The risk of „jumping ship" from an established large company (or – though there is less research in this area – a prestigious university professorship) to a start-up firm is extremely high. This risk includes not just the possible legal consequences (if competition clauses are enforced), but the risk of finding oneself on the outside of an extremely rigid labor market at mid-career. Because large German firms encourage the creation of firm-specific tacit knowledge, mid-career managers cannot easily find similar positions inside other large firms. In order to compensate for the career risk of joining a risky start-up, it would seem that the start-up would have to offer very high levels of status and/or salary in order to successfully recruit higher-level management or scientists.

Hypothesis: German start-up biotechnology companies have a difficult time recruiting mid career and especially senior level management and science staff, due to the career-risk of leaving positions in large German companies.

2.2.3 High-Powered Performance Incentives

Problem: Successful research in high-technology firms requires the recruitment of scientists with very specialized knowledge. The decentralization of knowledge creates agency problems within the firm. It is difficult for non-scientist managers and, in many cases, even fellow scientists to determine whether or not specialist workers within the firm are efficiently working towards firm goals (see generally Miller, 1992). Scientists often have strong incentives to work on projects with substantial *private* returns but inferior *collective* returns for the company. In addition to pure agency problems, the existence of „high-powered" incentive structures is commonly associated with the willingness of employees within high-technology firms to „sign-on" to extremely challenging work assignments requiring long hours and an extraordinary commitment to the firm.

Ethnographic accounts of US biotechnology firms contain numerous examples of agency dilemmas. One example comes from Werth's book *The Billion Dollar Molecule*. A goal of many biotech firms to uncover the chemical structure of large proteins involved in disease processes. Werth examines problems encountered by the biotech start-up Vertex in its quest to uncover the molecular structure of an important protein thought to be involved in the immune system. The firm invested in two approaches, traditional X-ray crystallography and a newer approach based on MRI scanning. The firm hired a specialist for each area, both of which began working independently to discover the protein structure. Each scientist had a tremendous incentive to discover the protein by himself, in order to gain sole credit for an important discovery in the subsequent journal publication. As a result, the two scientists refused for months to share their partial results, which could have been combined to uncover the complete structure at an earlier stage of research. Finally, company management forced the scientists to work jointly, but the delay eventually forced the firm to share publication priority with rivals outside the firm.

„Solution" in the US. Agency problems are perhaps the major reason why most biotechnology firms are small (rarely more than 10-50 people, including administrative staff) or, in the case of larger companies investing in biotechnology, organized into semi-autonomous decentralized labs. Small numbers facilitates mutual monitoring. However, the vast majority of US start-up technology firms have complemented small-numbers with very strong financial incentives. Most companies do this with share-options, coupled with the announced intention of owners and venture capitalist to take the firm public within a few years. In the cases of successful firms that have gone public, share options can be worth tens of thousands of dollars to junior staff to millions to senior scientists and owner/managers. The prospect of large financial rewards helps align the private incentives of scientists with those of companies and is a prime reason why US high-tech firms have become associated with extremely long work-weeks and general dedication to projects.

„Problem" in Germany. Financial incentives cannot easily be used to resolve agency problems within German firms. This area is undergoing extensive change during the late 1990s, but during the 1980s the organization of German financial markets and property rights law made share-based financial systems difficult to implement. In order to limit share-price speculation, German financial laws have until very recently prohibited listed companies from buying back shares already on the market. Doing so eliminates the strategy of issuing pure share-options. Privately held start-up companies could instead grant shares to employees. However, particularly during the 1980s and early 1990s nothing comparable to the NASDAQ or other small-firm technology market existed in Germany. Stock market capitalization was, even for large companies, small, and there was no established IPO (initial public offering) market for high-tech firms. At most, employers holding shares could hope that another firm would acquire the company.

Hypothesis. The lack of „high-powered“ incentives within German start-up firms exacerbates agency problems while making it difficult for mangers to convince employees to „sign-on“ to complex projects (i.e. through long work-weeks, intense work environments, and so forth). Table 2 summarizes these arguments. [1]

Table 2 here

3. Developments During the 1990s and Possibilities for Institutional Reform

During the 1990s the creation of high-tech industry has become a major preoccupation with German political and business leaders. In Germany there is currently a large push by the government to promote the development of a biotechnology sector comparable to that in the United States. The federal and *Länder* governments have created a framework to support over a dozen local „BioRegio“ technology promotion infrastructures. While the total amount of money spent on the BioRegio program is difficult to assess due to the program's decentralization, over a billion DM has been spent in support of the Munich Gene Center alone, and Berlin, Cologne, Stuttgart, and the Heidelberg region each have programs of smaller size. Public spending has been aimed primarily in two areas: infrastructure and subsidies. Infrastructure includes the creation of technology parks and „incubator labs,“ often tied closely to existing or newly created basic research facilities tied to local universities or Max Planck Institutes. Subsidies are usually provided as seed-capital for start-up firms. Programs vary, but in general money is provided only if applicants are able to concurrently secure private investment capital.

This catalyst has created a biotech boom in Germany. From scarcely a handful of companies at the beginning of the 1990s, as of mid-1998 there were over 400 firms in Germany (Ernst and Young, 1998c). Given these substantial institutional hurdles to the creation of viable organizational, financial, and career-structures for biotechnology, why has German technology policy targeted biotechnology as a major „industry of the future“?

Before returning to the core theme of creating a viable institutional environment for start-up firms, it is first important to examine whether, from an industry-dynamics

[1] This analysis has largely ignored an important alternative explanation. Legal restrictions requiring administrative authorizations of all biotechnology testing combined with hostile public opinion are commonly held to be the primary cause of Germany's poor performance in biotechnology during the 1980s (see Handelsblatt 1996). These legal restrictions were phased out in 1993.

perspective, large-scale entry into the biotechnology industry is still possible during the 1990s.

3.1. Is it Feasible for German Firms to Compete in Biotechnology?

From the perspective of industry dynamics alone, barriers to entry into most segments of the biotechnology sector remain low. This conclusion derives from three major features of the biotechnology sector:

3.1.1 The Markets for Biotechnology is Booming.

In recent years the spectrum of molecular biology based advanced drug design and gene-engineering techniques has emerged as the dominant science paradigm in the pharmaceutical and life-science industries more generally. As a result, biotechnology-based drugs should obtain an increasingly larger share of the world pharmaceutical market. Revenues for the biotechnology industry were over $13 billion in 1997 (of which $9 billion went to the US industry), and while the number of drugs actually approved remains small, over 290 drugs are in clinical testing phases in the United States (BIO, 1998:5).

As a response to this boom, biotechnology has during the 1990s taken off in Europe. The European industry is now approaching in size that of the United States. As of 1997 there were 1287 biotechnology companies in the United States and 1027 in the European Union (though overall employment was much higher in the US due to relative maturity of the US industry) (BIO, 1998: 5; Ernst and Young, 1998b: 3). High-risk venture capital for biotechnology has shifted to Europe. Ernst and Young estimates that in 1997 European biotech firms raised about Ecu 385 million, compared to the $773 million in the Untied States (Ernst and Young 1998a: 49; Ernst and Young 1998b: 19). While there has been a moderate biotech boom in Germany, biotechnology start-up firms have particularly thrived in the United Kingdom, a country that has developed an institutional environment for high technology that mimics crucial aspects of that in the US. In both 1995 and 1996 well over half of all European biotech venture capital has been invested in the UK (Ernst and Young 1998b: 41), and the UK continues to support the most biotech start-ups in the EU (Ernst and Young, 1998b: 3).

Of particular importance to German firms is the emergence in recent years of a large market for „platform technologies.“ While intellectual property and general know-how remains extremely specialized across therapeutic areas, there are an increasing number of generic biotechnology competencies applicable across large segments of the field. Examples include firms that apply information technology and advanced testing methods to small-molecule drug design (combinatorial chemistry), firms specializing in gene sequencing and the construction of specialized libraries

from the human genome, and firms that specialize in the creation of equipment and research methods used in genetic engineering (PCR, for example). Lead-times are much shorter for most platform technology firms, since sales are usually on a contract basis and immediate. As we will see below, targeting platform technologies is an especially viable option for German firms, since the relative financial and technological stability of these firms may „fit“ better with normal German financial and labor market institutions.

3.1.2 Existence of Advanced Lead Users.

In industries where technologies are changing very quickly, the success of particular companies often depends on the development of dynamic relationships with the users of the end-technology. For example, Borrus and Cohen (1998) argue that US networking firms have dominated data-driven communication markets in part because large American corporations demanded a wealth of new IT technologies much earlier than their European or Japanese counterparts.

A similar logic exists in pharmaceuticals. The large pharmaceutical companies are the primary market for biotechnology start-ups; it is the existing large pharmaceutical companies that eventually purchase or license, or market most of the drugs or other products created at biotech companies. Pharmaceutical companies have access to vast small-molecule libraries, testing facilities, manufacturing process expertise, and, of particular importance, know-how in guiding candidate drugs through clinical testing and regulatory approval. Pharmaceutical companies have massively invested in joint-research projects with biotech start-ups – creating the network-based learning possibilities that are often crucial to success in quickly changing technologies.

In Germany advanced lead users exist, in the form of the pre-existing large integrated chemical/pharmaceutical companies (Hoechst, Bayer, BASF, Schering). While German computer and telecommunication firms languished in part because German business was very late to switch to advanced IT networks, German pharmaceutical companies have in recent years recognized that biotechnology (broadly defined) has become a defining methodology in life-science industries. Hoechst and Bayer are shedding industrial chemical subsidiaries to focus primarily on „life-science“ competencies. Hoechst has gone the furthest down this route, announcing that biotechnology has become the core unifying science methodology throughout the company. While German pharmaceutical companies have invested large amounts of resources in the US and UK biotechnology industries, they have a natural interest in nurturing German biotechnology. This is in part because local research networks are easier to maintain (e.g. fewer cultural barriers, plus the local firms should have an advantage in accessing the German market). Moreover, by nurturing German biotechnology firms, human resource and organizational expertise will be developed that can (through buy-outs or alliances) then be transferred to the

existing pharmaceutical companies as they develop their own in-house biotechnology competencies.

3.1.3 Technological and Intellectual Property Structures Favor Entry.

Ease of market entry is a chief reason why thousands of biotechnology start-ups have emerged world-wide over the last 25 years. For an industry some 25 years old, the lack of concentration within biotechnology is amazing. Firm size remains relatively small: some 39,000 people are employed in the EU industry, while the average employement within the EU's top ten biotech firms, in terms of market capitalization, stands at only 390 (Ernst and Young, 1998b: 12-13). Notwithstanding the recent appearance of platform technologies, intellectual property in pharmaceuticals is very fragmented across literally hundreds of separate research trajectories. Though patents for individual drugs (and artificially created gene sequences) are strong, in very few disease areas do „blocking" patents exist. For example, in the study of Alzheimer's Disease mentioned earlier, Penan showed that there were 15 ongoing separate research clusters for this one disease. Intellectual property across these separate research clusters apparently has not overlapped in such a way as to „block" on-going research within competing research clusters. To give another indication of the ease of entry, according to a recent industry analysis, some 90% of patented drugs have direct competitors, and there exist three or more direct competitors for 15 of the 20 top selling drugs (Powell, 1996: 204).

The situation in pharmaceuticals differs dramatically from that within semiconductors and computers, another industry in which intellectual property plays a defining role. Grindley and Teece (1997) have argued that intellectual property in semiconductors can block new entry. Patents in this area tend to be very broad, in that patents for new circuit designs and so forth cannot be easily „reengineered" and thus circumvented. Furthermore, there tend to be a number of key technologies in each area that tend to be held by several firms. These firms must sign cross license each other's intellectual property in order to innovate. This creates a severe handicap on small start-ups that lack tradable patents.

3.2 Possibilities for Institutional Reform

German national institutional frameworks are likely to develop along one of three trajectories. A first scenario is *convergence*. According to this view, given the pressures of globalization and the inability to reconfigure existing German institutional arrangements to support radical innovation, Germany must be transformed into a liberal market economy, allowing German companies to adopt forms of organization advantaged by liberal-market economies. Resistance to these changes, driven by a robustness of the current institutional equilibrium, could result

in a second scenario, *specialization*. This is the arrangement widely seen to exist in the 1980s and early 1990s (see Hollingsworth, 1997). Differences in national institutional structures advantage a different constellation of organizational structures and associated product market strategies. In this scenario, globalization, rather than a cause of convergence, could actually strengthen national differences, as large multinational companies create international product chains locating activities in the political economy best advantaging the required company organizational characteristics. A final, advantageous solution for Germany is an *accommodation* of the present institutional frameworks to support at least minimal forms of entrepreneurial science-based innovation, without undermining the country's ability to support other medium-tech high value-added industries. Organizational patterns might differ substantially from those in the United States, but nevertheless allow successful innovation strategies to ensue.

Although some interesting changes are taking place, there is little evidence that the convergence scenario is coming to pass. The case against the convergence scenario is best presented through data comparing the relative specialization of the US and Germany during the 1990s in a broad array of industries. Recent EPO patent data suggest that, as of 1993/94, extreme differences continue to exist in US and German industry specialization (Casper et. al., forthcoming). Drawing on this data, table 3 ranks the top and bottom five industries for the US and Germany in terms of patent specialization.

Table 3 here

This data reveals close to an inverse relationship in terms of patent specialization. Germany excels relative to the United States in a number of engineering industries (civil and nuclear engineering, engines, transport) - all of which are process-oriented industries that broadly fit into the „diversified quality production" classification. US industry, on the other hand, excels relative to Germany in an array of high-tech industries (information technology, semiconductors, optics). Based on these industry specialization statistics, the convergence scenario appears weakly supported.

Furthermore, while changes to German national institutional framework are ongoing, these changes are incremental in nature and still aim primarily to advantage DQP rather than high-technology company organizational strategies. Among the most important institutional reform is a new law that permits companies to introduce share-option schemes. As knowledge continues to become more decentralized across most sectors in the economy, a general interest within the German business community in developing sharper incentive structures for employees has emerged. This led to a debate over the role of share-options in large German firms. The advantage of share options is that they can be introduced on a collective basis across the firm, without disturbing normal consensus-based decision-making patterns. After circulating within the German parliament for over two

years, a legislative bill allowing companies to buy and sell their own shares (the prerequisite for share-option schemes) was approved in March 1998.

Otherwise, there are no other signs that the broadly „social“ constitution of German large firms will be replaced by a more US/UK style financial system of ownership. There has been very little debate on dismantling other aspects of German company organization, such as the two-tier board system or the installation of powerful employee counsels for labor and middle-management. Similarly, competition clauses are still upheld by courts while German company and labor law continues to continues to promote a stake-holder system, which strongly encourages firms to adopt the lifetime employment model and its consequent impact on company decision-making, career-trajectories, and remuneration. As a result, active labor markets for mid-career managers and scientists continue to be underdeveloped.

Incremental changes are also occurring within the financial system. Often in combination with the introduction of share-option performance incentives, many large German firms have embraced dispersed equity offerings as a common instrument to raise investment capital. Public interest has been catalyzed by the highly publicized Deutsche Telekom share offering in 1996, the emergence of numerous low-cost stock brokerages in Germany (especially on the Internet), and exuberance created by the soaring level of the blue-chip DAX index, which has more than doubled in the last two years. In 1997 a new exchange tailored for smaller, higher risk companies was created, the *Neue Markt*. Over sixty companies have since sold shares on the *Neue Markt*, including one highly successful Dutch-German platform technology biotech company (Qiagen) and a Swiss-based venture capital company that specializes in biotechnology investments (BB-Biotech).

What do these changes entail for prospective German high-tech start-up companies? Most promising, German start-up firms will soon be able to offer high-powered incentive structures in the form of share-options. In addition, the *Neue Markt*, if it continues to develop, presents the opportunity of a legitimate market for small-firm IPOs in Germany. If a legitimate market for German high-tech IPOs is sustained, this will also go a long way towards creating an „exit option“ for venture capitalists. As already noted, this is critical if a viable refinancing mechanism is to develop in Germany and also allows venture capitalists to more easily diversify risks.

While these changes are important, it is important to ask which *type* of firms are likely to be funded through these new markets. As of mid-1998, extremely high market valuations for not just „blue chip“ established large firms but also most of the higher risk *Neue Markt* suggests that German investors are willing to accept risks on a level with those commonly found in the United States or United Kingdom. Such a conclusion, however, ignores several important facts about the structure of German equity markets and the effect of German company law on company strategy.

The major source of finance in Germany continues to be debt and, for established firms, retained earnings. German equity market capitalization in November 1996 was only 27% of GDP, compared to 122% in the United States and 152% in the United Kingdom (of the major OECD countries, only Austria comes in lower, at 14%) (Deutsche Bundesbank, 1996:28). Furthermore, despite increased interest in the stock market, actual equity ownership is extremely narrow: while some 47% of US citizens directly own stocks or equity-based mutual funds, only about 5% of Germans directly hold equities. Though international investors (e.g. US/UK pension funds) are an important new source of finance, as a source of finance German equity markets remain much thinner than in the US or UK.

It is also questionable whether the current, highly speculative company valuations can be maintained in Germany. As the current expansion of the DAX into a market with widely traded and dispersed shares is only a few years old, the market has no track record of performance through the normal business cycle. German equity prices are also buoyed by high earning expectations due to the fact that the economy is (during 1998) finally emerging from a multi-year recession.

Furthermore, it is likely that new and especially international holders of German equities hold the mistaken assumption that German firms are operating within a similar institutional environment as US or UK companies. While important changes are taking place, it would be erroneous to conclude that Germany is marching towards the US/UK national institutional infrastructure. As already highlighted, virtually no changes have occurred in German company or labor law. German firms are encouraged to make long-term bets on market and technological trajectories, to train deeply within the firm, and make use of these resources when making decisions. German management cannot quickly cut assets or embark on the „hire and fire“ trajectories often seen in the United States (and increasingly, the UK). In part because they are controlled by coalitions of company representatives and concentrated share-holders (e.g. banks), German supervisory boards have systematically refused to offer top management the extremely high performance related pay packages coupled with extreme managerial control that is typical in US or UK public firms (Vitols et al., 1997)

While German firms have successfully competed in the variety of „DQP“ product market segments noted above, these established, largely process-innovation based markets usually do not create the growth opportunities presented in the high-tech product innovation based markets that US and UK firms tend to dominate. In contrast to the Anglo-Saxon „high-risk, high return“ model of company strategy, the strategies advantaged in Germany are best seen through a „low risk, low return“ lens. While German organizational structures usually prevents firms from making large strategic errors, this means that these firms are usually much slower to react and fully commit to major changes in technology or market organization. Biotechnology is a good case in point. As discussed above, the big-three German

chemical/pharma companies were very slow in reacting to the changed scientific and market conditions in pharmaceuticals during the 1980s.

In general, there is little evidence that German national institutional frameworks have converged to a liberal market economy model. They do not facilitate the use of similar governance structures to support high-technology start-up firms that have been created in the United States and Germany. More open to debate is whether German managers, scientists, and investors can embrace piece-meal reforms in company law as well as a slight deepening in German equity markets to make the accommodation scenario viable.

The final strategy, „accommodation“, recognizes that important national institutional frameworks in Germany are oriented primarily to advantage other company strategies, but attempts to use a variety of alternative private sector or governmental devices to create governance structures supporting at least minimal forms of the desired company organizational structures. For this to happen, however, German companies would need to create new governance structures for biotechnology that do not merely mimic those already developed in the United States. Because the accommodation strategy relies on the creative design or reconstruction of new governance structures, it is difficult to specify with precision what this strategy might entail. However, focusing again on biotechnology start-ups, there are at least four components of an accommodation strategy that firms and interested governmental actors might usefully keep in mind:

a) Firms should specialize in lower-risk niche markets. Table 4 summarizes the four principal market segments in bio-medical related biotechnology. Important differences exist in risk profile across these segments. Given the difficulties that exist in sustaining high-risk strategies within the German institutional environment, it follows that German firms should gravitate into market niches that avoid the high-risk „races“ to develop highly specific intellectual property in particular disease areas and the long-lead times that characterize the therapeutics area. In fact, this is the preferred strategy of most German bio-tech start-ups. In a recent survey of Europe’s biotech firms, Ernst and Young found that while close to 40% of European biotech firms are developing therapeutic products, less than 20% of German firms are in this field. Conversely, about 30% of German firms are developing platform technologies, compared to less than 20% for the European industry as a whole (Ernst and Young, 1998c: 19). When German biotech firms were asked to list the areas of their research activities, therapeutics came in fifth, ranked well below contract research and manufacturing, platform technologies, diagnostics, and „other services.“ (Ernst and Young, 1998c: 17).

As foreshadowed earlier, it is no surprise that the most successful German biotechnology firms are in platform technology and other service-provision segments. In addition to Qiagen, which has become one of the few profitable European biotech firms, three of the four German biotech start-ups that are close to

launching share-offerings on the *Neue Markt* are platform technology firms (*Wirtschaftswoche,* 1998: 138-139). These firms are not „typical“ German organizations, in that they use high-powered incentive structures and often rely upon the intense work-environments that characterize American or British high-tech firms. However, because the platform technologies are generic, scientific competencies are generally much more stable than in therapeutic firms. Unlike most therapeutic research, platform technology research is generally not competency destroying. Furthermore, as intermediary producers of products used by other biomedical firms or labs, lead-times are generally shorter. These factors lower the need for long-term high-risk finance and the career-risk of working within such a firm.

Table 4 here

b) Create new governance structures. Firms can create supplementary governance structures to compensate for underlying institutional weakness. Organizational patterns might differ substantially from those in liberal market economies, but nevertheless allow successful radical innovation strategies to ensue. For this to happen, however, German companies would need to create new governance structures for biotechnology that do not merely mimic those created in the US or UK. Such hybrid organizational forms might emulate characteristics of the US model (smaller network forms of organization with high-powered performance incentives), but with more stability in structure of labor markets or finance.

One example of this strategy has originated within large pharmaceutical firms. Hoechst and BASF have both initiated in-house incubator labs designed to allow employees to organize start-up firms. Ownership will be divided between the host-firm and the managers and scientists that organizing the new venture. Successful firms are expected to be placed on German or international equity markets through IPOs. While these incubator firms will have preferential access to materials, scientific equipment, and other assets, the hope is that high-powered incentive structures and autonomy will help recreate the highly creative atmospheres found in „true“ start-ups. Schemes of this sort should provide an effective solution to the career-structure problem: if a large company incubator firm fails, the managers and scientists presumably can return to normal positions within the firm

A second new organizational form has originated out of many of the regional „BioRegio“ programs in connection with universities and other public research labs. In contrast to the wide engagement of US academics in the biotechnology industry, during the 1980s and early 1990s German academic researchers in the biosciences were usually portrayed as aloof from commercial developments in their research fields. During the late 1990s this situation has dramatically changed: perhaps the most common source of most biotech start-ups are established public research labs in the bio-sciences. German research labs differ from those in the United States and the United Kingdom in one key regard: while US/UK universities have jealously

guarded intellectual property developed by their employees, German universities generally cede full control over intellectual property to the professor/student inventors.

This intellectual property has become a prime source of collateral used to secure venture capital start-up financing for biotech start-ups. Many German universities and public research institutes have worked with regional „BioRegio“ technology agencies to develop „gene centers“ affiliated with established institutions. These often include „incubator labs“ located in technology parks located in close proximity to public bioscience labs. Many of Germany's biotech start-up firms are actually tiny offices designed to manage commercial spin-offs that emerge out of basic research conducted within public bio-medical labs. If a discovery merits further development (i.e. early stage trials) that cannot be paid through normal basic research grants, scientists connected to the basic research lab can take full-time employment at the company. However, this governance form again provides employment protection for senior scientists. If the spin-off company becomes extremely successful and obtains long-term financing (through, for example, the licensing of a discovery to a large pharmaceutical firm), senior scientists may leave their public research posts to work in the private sector. Otherwise, senior scientists can safely retain their public professor/research post while retaining a large financial stake in the associated spin-off firm.

c) Embrace globalization to develop competencies that cannot be easily developed within Germany. While German large pharmaceutical firms during the late 1980s attempted to bridge their internal technology gaps through investing in US biotech, the opposite can also be true. One option is to tap into international equity markets through taking listings on foreign exchanges. For example, Qiagen used its success to tap into US financial markets through being listed on NASDAQ.

A second option is to recruit foreign scientists and managers to work in German start-ups. Personnel recruited from the United States or United Kingdom, for example, can easily move back into their more flexible home labor markets. Recruiting foreign specialists is a core strategy of firms working in connection with the Munich Gene Center, the most successful of the German biotech clusters. Most start-ups associated with the Munich Gene Center, for example, have recruited American or British chief financial officers or have enticed German expatriates working within the US pharmaceutical industry to return to manage many of the new firms. Similarly, having created a world class infrastructure to support molecular biology research, the University of Munich has been able to use a large fellowship program to attract a number of experienced scientists from foreign countries, many of which spend part of their time within local start-up firms.

d) Make selective use of governmental policy to fill gaps in private-sector incentive structures. German industrial policy has circumvented the critical problem of finding seed-money for most of the current crop of biotech start-up firms. Most of

the German subsidy programs demand that each applicant find a private investor (usually a bank but occasionally a venture capital firm or large pharmaceutical firm). Governmental subsidies then supplement the seed money provided by venture capitalist. The vast majority of German biotech start-ups founded since 1995 have depended on governmental matching grants. Through essentially halving the cost of capital governmental subsidies have created incentives for foreign and domestic venture capital firms to invest in German biotech. According to German biotech experts, the subsidies provided by the BioRegio and various *Länder* programs have essentially solved the capital formation problem in Germany

Governmental subsidy programs are short-term in nature. They do not assure a viable long-term source of capital for German start-up firms; neither are these programs geared to provide the „mezzanine“ financing needed to sustain the high burn-rates commonly found in biotechnology. In the long-term, German firms should work to develop governance structures that do not rely on direct governmental intervention. Only then will institutional frameworks exist that can create and reproduce viable governance structures for high-tech firms over the long-term. Both the US and UK biotech industries rely primarily on favorable national institutional frameworks in the finance and company organizational areas discussed throughout the paper. In the long-term, the best German governmental policy for biotechnology will most likely consist of large financing for basic research in molecular biology and medicine. The German Research Ministry (BMBF) now spends some DM 3.5 billion annually on Max Planck Institutes and university labs involved in bio-medical research. However, even correcting for differences in country size, this sum pales in comparison with the some $14 billion annually spent by the US National Institute of Health on bio-medical research (about $3.5 billion of which is for biotechnology research) (Abramson et. al 1997).

4. Conclusion: Reconfiguring National Institutions to Promote Innovation.

Why has the creation of viable institutions to support biotech start-ups in Germany been so difficult? A general conclusion emerging from this case study is that national institutional frameworks are *complementary* in nature. Complementarities are present when „doing more of one activity increases (or at least does not decrease) the marginal profitability of each other activity in the group“ (Milgrom and Roberts, 1992: 108; see also Hall and Soskice, forthcoming). While in Germany the institutional complementarities between finance, career development and skill-formation, and company organization advantage a variety of „DQP“ product market strategies, we have seen how, especially during the 1980s these same institutions

create severe problems for German firms attempting to create high-technology start-up firms.

When institutional frameworks are highly interdependent in this sense, dramatic institutional reforms that run counter to the broad logic of industry coordination in an economy become difficult. While some German high-tech firms currently demand the opening of labor markets and the deregulation of wage bargaining, most German firms resist this because it could radically lower the value of vocational and career training while increasing wage costs for highly skilled workers and managers. Reforms to support high-technology are only possible when they gain the support of German industry more widely. The important reform of German financial law that allows high-tech start-ups to distribute share-options was viable because most German large companies are interested in using share-options to strengthen group performance incentives.

Given these constraints, the short-term success of German promotional policies for biotechnology is quite remarkable. We have seen that the governance structures used to organize start-ups generally follow the „accommodation“ strategy. Firms have made use of generous infrastructure provision and financial subsidies provided by the numerous German „BioRegio“ programs to reduce much of the financial risk imposed by biotechnology. Career-risks have been reduced through importing foreign financial and scientific specialists to fill many of the higher-risk positions, while creating new employment relationships that have allowed senior German mangers and scientists to maintain positions public research labs or larger firms while working within start-up firms. Finally, German firms have by and large avoided the higher-risk, longer time-horizon therapeutic area by specializing in the lower-risk product segments in platform technologies and related service areas.

However, the problem of creating viable institutions to promote firms with radical innovation competencies is by no means resolved in Germany. German technology policy has been aimed primarily to fill gaps in the institutional frameworks that influence new firm creation. Now that large numbers of start-up firms exist, new problems associated with nurturing these firms in viable commercial enterprises are inevitable.

For example, the German industry must develop viable refinancing mechanisms to satisfy the constant hunger of biotech start-ups for fresh investment capital. In their recent survey of German biotechnology, the consulting firm Ernst and Young see the lack of capital investment in new product development equipment as a key weakness of the German industry (Ernst and Young, 1998c: 8). German venture capital is currently abundant, but due to the availability of large subsidies for start-up firms, might be flowing primarily in this direction rather than as „mezzanine“ financing for established firms. This would force firms to invest their initial seed capital much more conservatively than their competitors with fairly secure access to secondary financing, accounting for lower capital investment in Germany.

Similarly, it is unclear if the German biotechnology industry has developed institutions that can effectively deal with firm failures. Will unsuccessful firms be allowed to fail and, if so, can the resources within these firms be efficiently recombined into new ventures or absorbed by other companies? What will happen to the scientists and mangers of failed start-ups? Will they be quickly absorbed into other start-ups along the US/UK labor market model, or will they retreat back into their prior public research or large firm careers? Overall, creating viable governance structure to support high-technology start-up firms in Germany will remain a difficult challenge for the foreseeable future.

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Table 1: International Comparison of Market Characteristics

	USA	Japan	Ger	Fra	UK
Market size ($ bn)					
1987	39.3	30.2	11.8	10.2	8.2
1993	70.8	51.1	19.5	17.1	14.9
R&D Intensity (%)					
1983	10.6	6.7	8.4	7.1	11.7
1992	14.3	9.8	9.2	8.7	16.3
New Chemical Entities (NCEs)					
1971-80	154	74	91	98	29
1981-90	142	129	67	37	28
No. of products in Top 50					
1985	23	5	5	1	9
1990	27	2	5	0	12
Patent trends					
1980-84	49.8	13.3	10.4	5.1	7.5
1990-94	54.6	14.7	7.8	4.7	5.3
Firm's market share in the US					
1991	70.2	0.3	4.6	1.2	14.6

Source: Casper and Matraves, 1997

Table 2: Company Organizational Requirements and Institutional Frameworks in the United States and Germany

Company Organizational Requirement		„Solution“ in US	„Problem“ in Germany
High-powered performance incentives	Risky research requires recruitment of scientists with very specialized knowledge. High-powered incentives needed to reduce monitoring problems/align incentives.	Extensive use of share-options or outright share dispersal coupled with possibility of IPO or buy-out is used to align private preferences with firms'.	Stock options illegal until March 1998; lack of IPO market limits „strength“ of other share schemes.
Low career risk from failure	Most therapeutics oriented biotech start-ups fail, so career risk of failure must be low. Innovation might require knowledge transfer created by networks of scientists moving between start-ups, university labs, and pharma firms.	Extremely active labor market. Competition clauses illegal. This facilitates extensive poaching and the organization of career paths within firms based on probability of frequent employee turnover.	Competition clauses and long-term career paths at large German firms prevent the creation of an active labor market for mid-career scientists/managers. Risk of joining-start-ups high.
High risk financing	Most biotech start-ups in therapeutics require very high risk financing due to long-term nature of discovery and development process plus risk of losing innovation races.	Large venture capital market. IPOs and large market for M&As allows VCs to diversify risks across several investments and also creates a short to medium term refinancing market.	Bank-centered financial system. Small IPO market limits private-sector refinancing mechanisms. VCs do not have viable „exit strategy,“ meaning most investments are long-term.

Table 3: US and German Patent Specialization Rankings 1993/94

	United States	**Germany**
1	Information technology	Civil engineering
2	Medical engineering	Nuclear engineering
3	Semiconductors	Agricultural machines
4	Organic chemistry	Transport
5	Optics	Engines
…		
26	Consumer goods	Semiconductors
27	Agricultural machines	New materials
28	Nuclear engineering	Audiovisual technology
29	Civil engineering	Optics
30	Machine tools	Information technology

Source: Specialization index of European Patent Office (EPO) patents of German and United States Origin in relation to the average distribution at the EPO for the period 1993 to 1994. The rankings are derived from the complete tables in Harhoff and Soskice (forthcoming) based on the methodology introduced in ISI/FhI 1997. The ranking for biotechnology is 6 in the United States and 22 in Germany.

Table 4: Bio-Medical Related Market Segments

Category	*Definition*	Examples	R&D costs	Time to Market	Risk Profile
Therapeutics	Develop products to improve the treatment of disease	Apply a variety of molecular biology methodologies to discover/design drugs	**High** (due to uncertainty of research results and high costs of preclinical and clinical testing)	**Long** (usually 7-10 years, due to length of testing and regulatory approval process)	**High**
Diagnostics	Develop tools to help identify diseases	Develop antibodies for use in diagnostic procedures; Some use of genetic technologies (e.g. PCR) to test for herediatary or acquired genetic diseases	***Medium to high*** *(research risk can be high; testing and regulatory costs exist, but are lower than in therapeutics)*	**Medium** (regulatory approval and testing requirements are shorter/less severe)	**Medium to High**
Platform Technologies	Create enabling technologies with broad application	Genetic sequencing or engineering services; the creatioon of consumables for use in molecular biology lab procedures; combinatorial chemistry and other automation technologies; genomics	**Low to medium** (technologies can be very uncertain, but usually few regulatory approval or testing requirements)	**Short** (direct sales to other life-science companies/labs)	Varies, but generally **Low to Medium**
Contract Research / Manufacturing	Perform customized biochemical related services for other companies	The manufacturing of customized biochemical products; specialized services such as equipment servicing or quality control certification	**Low**	**Short** (direct sales to other life-science companies/labs)	**Low**

Categories and definitions paraphrased from Ernst and Young 1998 European Life Sciences Report, pp. 5-6

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