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MANAGING COMPETENCES IN ENTREPRENEURIAL TECHNOLOGY FIRMS: A COMPARATIVE INSTITUTIONAL ANALYSIS OF GERMANY, SWEDEN AND THE UK

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Abstract
Innovative firms face two major kinds of risks in developing new technologies: competence destruction and appropriability. High levels of technical uncertainty and radical changes in knowledge in some fields generate high technical failure risks and make it difficult to plan research and development programmes. They therefore encourage high levels of flexibility in acquiring and using skilled staff. Appropriability risks, on the other hand, encourage innovative firms to develop organisation-specific competences through investing in complementary assets, such as marketing and distribution capabilities, that involve longer-term employer-employee commitments to building complex organisations. These connections between technology risks and employment policies help to explain why different kinds of market economies with contrasting labour market institutions develop varied innovation patterns.

In particular, subsectors of the computer software and biotechnology industries that vary in their level of technical change and appropriability have developed in contrasting ways in three European countries that have quite distinct institutional frameworks: Germany, Sweden and the United Kingdom. Institutions in the UK are similar in key respects to those in the USA that encourage the development of "radically innovative" firm competences. As a result, a considerable number of biotechnology firms specialising in the development of therapeutic products and companies producing standard software have become established there. In Germany, on the other hand, institutional frameworks associated with competence enhancing human resource practices give its firms an advantage in more cumulative and generic technologies developed by more complex organisations. Consequently, more platform biotechnology and enterprise software firms have developed in that country. Labour market institutions in Sweden resemble those in Germany in many respects, and so too does the pattern of biotechnology development. However, because of the changing role of Ericsson and other factors, more firms engaged in highly risky middleware and standard software development have become established there.

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Introduction

Recent studies of sectoral specialisation and technological development across market economies have shown how contrasting patterns of technical change can be explained by the different institutional frameworks that have become established in distinct types of economy (see, e.g., Casper, 2000; Casper et al., 1999; Soskice, 1997; 1999). According to the "varieties of capitalism" framework, “liberal market economies” (LMEs) such as the US and the UK excel in developing the necessary competencies to innovate in industries dominated by rapidly emerging technologies. More organised or “coordinated market economies” (CMEs) like Germany, by contrast, have developed institutions that advantage long-term and incremental innovation strategies, but inhibit more radical innovation paths (Hall and Soskice, 2001; compare Nooteboom, 2000; Whitley, 2000; 2002). A key assertion of this view is that national patterns of specialisation are created by *comparative institutional advantages* in governing the organizational competences needed to innovate within particular technological fields.

Such contrasts help to identify core differences between advanced industrial economies, but tend to underestimate the adaptiveness of firms within an economy and important differences between sub-sectors. These help to explain a number of features of some European economies in the 1990s that appear anomalous from a simple interpretation of the varieties of capitalism approach. For example, while the dichotomy of exit and voice forms of capitalism suggests that there should be virtually no entrepreneurial technology firms within “coordinated market economies” such as Germany or Sweden, and the liberal market economies like the UK should have a comparative institutional advantage in producing radically innovative technology firms, entrepreneurial technology firms appear to be thriving in many areas of Continental Europe, and the performance of UK firms has been relatively poor in some sub-sectors of the biotechnology and software industries.

In order to explain such phenomena and identify how institutional frameworks generate distinctive strategies and organisational capabilities in more detail, we need to link institutional arrangements to the ways that companies develop different kinds of technologies in emerging industries at the subsectoral level. In this paper we consider the various sorts of problems that firms have to manage in developing new technologies in different sub-sectors of the biotechnology and software industries, and how particular institutional frameworks in Germany, Sweden and the United Kingdom affect their strategies. We suggest that the core issues faced by entrepreneurial technology firms – developing skills, managing hiring and sometimes firing personnel, and coordinating technology development with external actors – are strongly influenced by the skill formation and labour market institutions within these economies.

While liberal market economies such as the US or UK do have institutional arrangements that are conducive to the development of project-based entrepreneurial technology start-ups focusing on discontinuous radical innovations, there are other subsectors of emerging industries where more complex and stable organisations are effective. Success in such segments is strongly advantaged by institutional structures that create competence enhancing human resource structures. Coordinated market economies such as Germany and Sweden have superior institutional frameworks to govern these kinds of such collaborative enterprises and have emerged as leaders within Europe in developing them. However, in the case of the development of middleware software in Sweden, a sub-sector in which external coordination across firms is important, the activities of large firms appear to have altered "normal" institutional incentives. As a result, large numbers of software firms with high levels of technical intensity have become established there.

We discuss this case in some detail in the last section of this paper. The first section focuses on two key issues faced by entrepreneurial technology firms in different subsectors of the computer software and biotechnology industries, while the second suggests how these are connected to varied institutional arrangements. The third section provides evidence on patterns of specialisation across different sub-sectors of the software and biotechnology industries within Germany, Sweden, and the UK, while the fourth considers the German case in more detail. Finally, we examine the development of middleware software firms in Sweden.

Key Management Issues Facing Entrepreneurial Technology Firms

In seeking to explain variations in patterns of development of entrepreneurial technology companies in different subsectors, it is useful to distinguish two kinds of technological risks that affect managerial priorities (Malerba and Orsenigo, 1993; Breschi and Malerba, 1997; Dosi, 1988). First, appropriability risks reflect the ease with which competitors can imitate innovations. They are typically managed through patent and copyright protection or through controlling complementary assets, as discussed by Teece (1986). In the pharmaceutical industry, for example, patent protection is relatively effective because minor changes in the structure of therapeutic drugs can have major consequences for their operation in the human body (Gambardella, 1995). As a result, drug discovery firms are able to specialise in highly risky activities without needing to develop complementary assets to protect their innovations.

Second, competence destruction risks reflect the volatility and uncertainty of technical development that vary greatly between technologies, both in terms of the technological trajectories being followed and market acceptance. Where technological uncertainty is high, it is difficult to predict which investments and skills will be effective and firms have to be able to change direction at short notice. Consequently, the managers of radically innovative firms are faced with the need to attract and motivate expert staff to work on complex problems when unpredictable outcomes may involve dismissal and/or organizational failure.

To offset high technical or market uncertainty, most firms competing to create radical innovations in markets where winners of innovation races can expect to capture a relatively large share of emerging markets focus on technology areas in which appropriability regimes through copyright and patent protection are quite strong. When appropriability risks are relatively low because standard forms of intellectual property protection are sufficient to guard technical innovations from being copied, management can focus primarily on R&D activities. This minimises organizational complexity, allowing a relatively coherent focus on core milestones needed to develop a new product or technology. Such radically innovative firms are typically project-based organizations. Managers here organise highly skilled staff into a series of teams focused on solving complex problems under very tight time constraints. They often employ performance based incentive schemes and employee ownership plans to induce employees to commit to solve organisational problems in these intense work environments. The prospect of large financial rewards encourages the alignment of the private incentives of highly skilled employees with those of commercial managers/owners.

These two kinds of technological risk tend, then, to be inversely related. Investments in developing highly uncertain technologies are usually undertaken when appropriability risks are limited, while firms developing innovations that are more open to such risks tend to focus on more cumulative and predictable technologies. Companies racing to produce highly radical, discontinuous innovations have to be flexible in their use of key resources such as highly expert technologists and in changing direction, while those developing more imitable technologies have to acquire complementary competences and integrate them through organisational routines. They therefore are more organisationally complex than radically innovative companies.

Considering first the key issues faced by innovative firms in subsectors that combine high levels of technical uncertainty with low appropriability risks, managers here need to be able to change research and development competences quickly. To do this, they need access to a pool of scientists, technicians, and other specialists with known reputations in particular areas that can quickly be recruited to work on projects (see Bahami and Evans, 1995). If there is a cultural stigma attached to failing or changing jobs regularly, then engineers and managers may choose not to join firms with high-risk research projects, for fear that if the project fails the value of his or her engineering and/or management experiences could significantly decline. Furthermore, high levels of competence destruction create knowledge investment problems. Employees have an incentive not to invest in large amounts of firm-specific knowledge, such as proprietary software languages, when there is a strong probability that their employment tenure at the firm will be low (or that the firm could quickly fail).

The resolution of these kinds of management problems is greatly facilitated by the establishment of strong *technical communities* – networks of engineers, scientists, or software developers with common skill-sets, shared industry experienced, and a high amount of personal contact - in particular regions such as Silicon Valley (Saxenian, 1994; Kenney, 2000). Tapping into these communities can help firms reduce competency destruction risks while, for technical personnel, membership can reduce career risks created by working within risky technologies.

These kinds of project-based firms (Whitley, 2002) are widespread in many sub-sectors of the biotechnology and computer software industries. One such sub-sector is standard (or application-based) software created for large homogenous markets where demand for customisation is low. Examples include graphic application software (e.g. CAD/CAM), multimedia and computer entertainment software, and a variety of application software used to run computer networks (e.g. e-mail, FTP, groupware, and document management programs). Most companies developing such standard software are project-based firms with relatively simple organizational structures.

Low customisation and high scale economies here lead to intense competitive races to establish dominant designs and introduce new features (or “functionality”) to software products through periodic upgrades. Such competition creates high competence destruction within the software industry and the failure of small development houses. Since it is relatively easy to protect standard software products through a combination of: a) patent/copyright protection, b) secrecy over a program’s so-called source-code, or c) “lock-in” effects once a product becomes successful and a customer base develops (see Shapiro and Varian, 1999), these firms do not usually need to integrate R&D with other activities. Knowledge properties across standard software firms are relatively standardised or industry-specific. While software developers and engineers working within the firm often have advanced graduate training, their skill-sets are relatively generic across employers and customers, including industry-wide computer languages and analytical training.

Therapeutics based biotechnology is a second common example of a sub-sector populated by radically innovative technology start-ups. A defining feature of therapeutics research is its very high scientific intensity in the sense of being closely dependent upon new scientific knowledge of generic biological phenomena and processes. Firms often are constituted on the basis of theoretical expertise pertaining to particular biomedical research areas, and then develop or acquire any number of particular application technologies needed to pursue projects as research progresses. Uncertainty regarding the success of basic scientific research creates relatively high technological volatility for start-up therapeutic firms.

Ethnographic accounts consistently document the widely changing course of therapeutic firm research activities over time, which often leads to repeated changes in the competence structure of the firm (see, e.g., Werth, 1993, Rabinow, 1996). More generally, failure rates are high and time horizons are relatively long throughout the drug development process (Henderson et. al. 1999). A recent study of research dynamics within the area of Alzheimer's disease, for example, noted over twenty discrete networks of firm/lab combinations conducting competitive research (Pennan, 1996).

A final example of a radically innovative sub-sector is middleware software. Firms in this market compete to develop new interface technologies that are used to link the basic architecture of communication networks to standard application software. Typical middleware products include secure payment systems used in internet banking and e-commerce, software that transforms the content of web servers into a format that can be used in small mobile telephones or Palm Pilot devices, and search engines that are used for navigation on the World Wide Web. Most firms in middleware software race to create new technologies with superior functionality or speed to market.

However, in comparison with standard software and therapeutics-based biotechnology firms they have to deal with an additional coordination problem. Because successful innovations in this sub-sector are developed with a variety of different kinds of knowledge that are interdependent, technical standards, design interfaces and other product architecture related issues have to be integrated if firms are to have a high probability of success (see generally Perrow, 1985; Kitschelt, 1991). For middleware firms, low technological cumulativeness and the need for coordination across groups of firms in complementary markets create high standards related risks (Arthur, 1994). Firms that cannot successfully coordinate technical specifications or designs with other firms in a technology area, or join unsuccessful design or standard families, will fail.

Turning now to consider firms operating in subsectors that combine lower levels of technological uncertainty with greater appropriability risks, they are likely to attempt to integrate new technologies with other assets that generate firm-specific advantages (Teece, 1986). For example, companies facing appropriability risks often develop specialised assets in sales, distribution or a variety of technical implementation and consulting activities that are relatively customer-specific. Development work therefore becomes more complex, involving cross-functional team-organised projects in which R&D personnel work with consultants, marketing personnel, and implementation technicians to customise technology platforms for clients. In these kinds of sub-sectors firms attempt to develop learning economies or create tacit knowledge embedded within project teams that are difficult for other firms to mimic.

These kinds of collaborative firms coordinate more varied skills and activities through the managerial authority hierarchy than most project-based firms and this coordination often generates firm-specific knowledge and routines. Such organisational complexity affects employment policies. For example, when structures are relatively simple – as in the case of most R&D focused firms - straightforward and relatively short-term (and renewable) employment contracts are often adequate. Furthermore, low levels of organisational complexity reduce the likelihood that cross-functional teams will form and create firm-specific knowledge. Such simple organizational forms are associated, then, with relatively generic knowledge development that can be easily codified. This means that individual employees are less able to "hold up" the firm and management can develop relatively flexible human resource strategies.

More complex relationships between employers and employees exist when firms develop distinctive competences through the integration and enhancement of varied knowledge and skills. Employment relationships are here often characterised by incomplete, long-term employment contracts due to the existence of considerable tacit and often firm-specific knowledge developed across functional teams within the firm (see generally Miller, 1992). Though generic industry skills may be used to create and update these technologies, some skills or routines become specific to the firm (Winter, 1987). Proprietary and team-based work organization is here likely to lead to the creation of firm specific skills.

Such firm-specific knowledge is valuable to the firm, but hard to sell on open labour markets or markets for technology. Firm-specific knowledge investments, once made, could lead to opportunistic demands by employers. Employees might hesitate making such knowledge investments without a credible commitment from management that they will not be exploited. Moreover, tacit knowledge can easily lead to information asymmetries between the management and employees of a firm, creating potential difficulties for management to monitor and appropriately reward work, particularly across members of project teams.

As a result, the management of skilled staff in such situations involves quite different issues from those faced by project-based firms. When organizational complexity is high, managers need to encourage employees to collaborate in developing organisation-specific capabilities, often through long-term employment and generally consultative work place arrangements, in order to exploit tacit knowledge within the firm. They are compelled to create "credible commitments" not to act opportunistically after sunk-cost skill investments have been made (Miller, 1992). Once such commitments become credible, for example through the creation of reputations for being stable employers or the creation of "constitutional" limits on the management of the firm, risky employment contracts can become viable. While the development of corporate cultures is crucial to the success of particular firms, firm-specific commitment strategies have a relatively long time-horizon that could prove difficult for entrepreneurial technology firms to implement effectively, especially during the start-up phase.

These kinds of competence enhancing human resource policies are far more feasible when clusters of firms within a shared technology and labour market develop complementary patterns of human resource development. If cultural norms within a local labour market or, more likely, institutional structures such as legal constraints on hiring and firing, exist, then the *expectations* of scientists, engineers, and technicians will be towards long-term employment and generally consultative workplaces, leading to the rapid formation of complex organizational structures and associated knowledge investment patterns within groups of entrepreneurial start-ups. As in the case of competence destroying technologies, for these human resource strategies to be viable most firms within a local labour market must adopt similar strategies. If employee poaching, for example, is an accepted and common practice within a community of firms, then employees will naturally gravitate towards skill development strategies centred on generic and codified skills that are easily saleable on such labour markets.

Entrepreneurial firms in two sub-sectors of the software and biotechnology industries, enterprise software and platform biotechnologies, exemplify this constellation of organizational competences. In contrast to standard software, enterprise software consists of software platforms or modules that are extensively customised for individual clients. Firms in this category include those developing enterprise resource planning (ERP), customer relationship management (CRM), groupware and systems integration products as well as a number of firms creating sector-specific enterprise tools (e.g. logistics and supply chain management tools).

Companies developing platform biotechnologies share a similar pattern of business organization. They create enabling technologies that are sold to other research labs. Products include consumable kits used to rationalise common molecular biology lab processes, such as the purification of DNA and other important molecules. Platform technology firms have also developed a number of engineering and information technology based applications that have been used to automate many aspects of the discovery process within therapeutics. These include extremely high throughput "combinatorial chemistry" applications to aid the screening of potential therapeutic compounds and the development of genetic sequencing and modelling techniques.

Firms in both enterprise software and platform technology share similar patterns of industrial organization. Technologies in each segment tend to be generic with high appropriability risks. As a result, entry is relatively easy, and dozens of firms exist in most enterprise software and platform biotechnology segments. Highly competitive enterprise software markets include enterprise resource planning and, more recently, Internet software to run e-commerce. Numerous firms also compete in most platform technology markets, such as nucleic acid filtration or amplification (PCR) or information technology rich areas such as DNA sequencing and bioinformatics. In these markets, successful firms generally create complementary organizational capabilities that can be protected by the firm. These usually include assets needed to customise general technology platforms for specialised product niches. Doing so creates larger, more complex organizational structures than those seen at entrepreneurial technology firms focused more on the management of competence destruction risks.

Institutional Frameworks and Competence Development in Entrepreneurial Technology Firms

The ways that managers deal with these problems in entrepreneurial technology firms vary between market economies with different institutional frameworks (Whitley, 2000; 2002). The preceding analysis suggests that project-based entrepreneurial technology firms faced with high competence destruction risks develop quite different managerial practices to those adopted by more collaborative firms attempting to govern complex organizational structures. These latter companies encourage competence-enhancing patterns of work organization, while "hire and fire" is a virtual prerequisite for firms facing competence destruction. These different kinds of practices are greatly influenced by the skill formation and labour market institutions of different countries, in addition to their financial and political systems, as can be illustrated by contrasting coordinated and liberal market economies (Hall and Soskice, 2001; compare Whitley, 1999).

Coordinated market economies typically display quite high levels of non-market coordination through credit-based finance, strong business associations and state supported technical standards setting and technical development. Some have formally regulated labour markets with legally-binding wage bargaining between unions and industry associations for most skilled workers, organised apprenticeship based systems of technical training, and regulative patterns of company and corporate law that grant unions a strong say in corporate governance.

Institutional frameworks within CMEs strongly favour the development of managerial commitments needed for employees to willingly make firm-specific knowledge investments that are not easily saleable on open labour markets. Such arrangements tend to "lock-in" owners, managers, and skilled employees into long-term, organised relationships. Strong norms and legal obstacles to "hire and fire" combined with a long-standing tradition, buffered by co-determination laws, of consultative patterns of work organization, favour competence enhancing human resource policies. As Streeck (1984) has argued with respect to Germany, within CMEs management must treat employees as "fixed" rather than "variable costs", and as a result have a strong interest in developing long-term career structures for all skilled employees within the firm.

In terms of encouraging different kinds of entrepreneurial technology firms, this analysis suggests that CMEs have a comparative institutional advantage in creating clusters of organisationally complex collaborative firms developing firm-specific competences in cumulative technologies. In contrast, they have a comparative institutional disadvantage in the governance of radically innovative project-based firms focused on developing competence-destroying technologies with high failure risks.

In contrast to CMEs, liberal market economies tend to develop far more market-based forms of industry coordination, generally supported by less government regulation, particularly within labour markets. Typical institutions in LMEs include primarily capital market based finance, deregulated labour markets with a relatively low amount of legal support for institutionalised wage bargaining between unions and company associations, and patterns of company and corporate law that favour shareholders when making most corporate governance decisions.

Companies embracing this system face far less institutionalised "lock-in" regarding employees or other stakeholders to the company. Hire-and-fire, when embraced by most companies within a sector, can be used to create large external labour markets for most skills. On the other hand, employees facing this pattern of labour market organization will be extremely reluctant to develop patterns of firm-specific skill development needed to support entrepreneurial strategies relying on the development of high organizational complexity. This discussion suggests that LMEs have a comparative institutional advantage in creating clusters of radically innovative project-based firms, but, on the other hand, have a comparative institutional disadvantage in the governance of entrepreneurial firms where organizational complexity is high.

In the light of this analysis we now examine the performance of three European economies in three radically innovative sub-sectors (standard software, therapeutics biotechnology, middleware software) and two organisationally complex subsectors (enterprise software, and platform biotechnologies). Two economies are governed by institutions that encourage high levels of economic coordination, Germany and Sweden, while the third, the United Kingdom, most resembles the liberal market economy.

Germany and Sweden are paradigmatic examples of coordinated political economies (for a good comparison of the two countries see Thelen, 1993; for Germany see Katzenstein, 1989; for Sweden see Pontusson and Swenson, 1996). Within both countries non-market forms of business coordination are facilitated by the embeddedness of large firms within networks of powerful trade and industry associations, as well as a similar, often legally mandated, organization of labour and other interest organizations within para-public institutions (Katzenstein, 1989). Businesses and other social actors engage in these associations to create important non-market collective goods, such as the apprenticeship system or network of collaborative technology transfer institutes.

Public policy in both countries focuses on neo-corporatist bargaining environments through the legal delegation of specific bargaining rights to unions and other stakeholders within firms (see Streeck, 1984). Strong codetermination laws empower unions and other stakeholders to bargain the terms of industrial change with employer associations. Some differences exist across Sweden and Germany. For example, Sweden's collective bargaining system is far more centralised than Germany's more decentralised model focused on federal *Laender* (Thelen, 1997). Similarly, employers associations and unions, as well as training programmes, are more sectorally organised in Germany than in Sweden. Nonetheless, industrial relations in both countries lock managers and employees into long-term relationships, promoting competence enhancing human resource development within firms. These institutions should advantage the governance of organisationally complex collaborative firms.

In strong contrast, the UK has developed largely LME institutions (see Hall and Soskice, 2001; Wood 2001; King and Wood, 1999). The financial system is strongly capital market based, with total market capitalization as a percentage of GDP at the end of 1997 at 151% exceeding the United States (121%) and far ahead of Germany's still predominately bank-centred system (26%) (*Deutsche Bundesbank,* 1998). Financial and labour markets are largely deregulated, facilitating "hire and fire", while corporate law is primarily enabling in nature and focused on shareholder primacy (see Monks and Minow, 1995). Particularly through the 1980s and 90s, the UK dramatically deregulated markets and weakened the power of collective actors within society, above all unions. This liberal market orientation should encourage the development of radically innovative project-based firms.

Given our characterisation of the five technologically dynamic subsectors we would expect the success of project-based and collaborative entrepreneurial technology firms in each to vary considerably between in Germany, Sweden, and the United Kingdom. In particular, while the first two countries should evince greater success in platform biotechnology and enterprise software, they are likely to be less successful in the other three subsectors. These expectations are summarised in table 1.

Sub-sectoral Distribution of Biotechnology and Software Companies in Germany, Sweden and the UK

To assess the validity of these expectations we examined the distribution of publicly quoted companies in the biotechnology and software industries in these three countries in terms of their preponderance in subsectors with different kinds of technological risks. While the subsectoral specialisation of these firms does not necessarily reflect only national economic performance in new industries, they performed well enough during their initial, usually venture capital financed stages for investment banks and private investors to invest in their further growth through initial public offerings on the stock market. If a country has a high number of public firms specialised in a particular sub-sector this is a good indicator that competences associated with that sub-sector can be efficiently governed within the country's institutional frameworks.

The primary business of each company was classified through an analysis of their web pages. We also drew upon company summaries and sub-sector classifications published on the Internet by financial service companies such as Hoovers On-line and Wright Investment Analysis to verify our classifications.

All biotechnology and software firms listed on technology-oriented stock markets in the UK, Germany, and Sweden were included. As our theoretical analysis rests largely on nation-specific institutional effects on the organization of firms, we checked to ensure that all companies included in our analysis had corporate headquarters in Germany, Sweden, or the UK. This led to the removal of three companies listed on the German *Neuer Markt* that had headquarters outside Germany.

For many biotechnology companies determining whether the primary orientation was towards development of platform technology or therapeutic products was simple. Therapeutic companies presented themselves as specialists within particular therapeutic areas, such as immunology or cardiovascular diseases, and had extensive internal expertise in disease-specific areas. Platform technology companies focused extensively on their technological competencies that are usually presented as applicable across a wide array of therapeutic research areas.

However, some companies, particularly in the genomics area, develop technology platforms that can then be used to generate therapeutic targets (so-called "gene to lead" strategies). For these companies, we examined whether the primary technological orientation was towards the improvement of the technological platform and its licensing to other firms, or towards in-house therapeutic development. A good indicator of this is the stage of development by which in-house therapeutic candidates are sold to pharmaceutical companies. In contrast to therapeutics-based firms, most platform technology companies sell candidate compounds they have discovered at a very early stage of their development, choosing to invest little or no funds into in-house expertise within particular therapeutic disease areas or competences in pre-clinical trials.

A second problem, found with several UK biotechnology companies, is an orientation towards what could be labelled "radically innovative" product innovations that could be sold to mass markets with relatively little customisation. Nine of the UK firms were specialised in drug-delivery products. Examples include powder-based injection devices that remove the need for needles, dermal patch technologies, and compounds used to shield drugs taken orally from strong acids contained in the stomach. While sometimes classified as platform biotechnologies, the drug delivery segment shares strong characteristics with “radically innovative” firms. In each of these areas, competition across firms largely rests on the basis of creating major new technological innovations aimed at capturing large market shares for firms. We decided to classify these companies within our project-based firm category, which was then renamed “therapeutics and product based biotechnologies.” Diagnostic products were also included in this category.

Classifying the software firms was in most cases straightforward. Middleware software firms usually identified themselves by this product category, and were focused on the development of software to improve to aid the efficiency by which different computing systems interfaced within communications networks. To differentiate standard and enterprise software vendors we focused first on well known standard and enterprise software categories (e.g. enterprise resource planning (ERP) and customer relationship management (CRM) products are well-known enterprise software segments, while multi-media, entertainment, and graphics software are well-known standard software segments).

For all other firms, we examined the degree by which the company offers to customise its software for clients. Companies offering extensive consulting, implementation, or systems integration services were classified as enterprise software firms. Standard software companies, on the other hand, generally licensed software “as is” to clients and do not engage in extensive consultancy-related services. These classifications were, when possible, verified by gathering data on the percentage of a company’s earnings generated through software licensing, which is high for most standard software companies and low for enterprise software vendors (available for about half the firms in our database).

While for most cases sub-sectoral classification was not difficult, the problem with investigator bias remains inherent in this type of analysis. Future research could reduce it through identifying structural characteristics of firms within particular sub-sectors that could be captured through more quantitative data (see Casper and Vitols, 2002). As our purpose within the present analysis is to capture broad trends at a macro-level, the more puzzling or interesting of which can then be explored in more detail, we believe simple investigator-led classifications are sufficient. Furthermore, adopting a multiple-methodology approach should help minimise the bias and classification error issues; supplementary data will be used to verify these macro-results for some cases.

Considering first the distribution of biotechnology firms in Germany, Sweden and the UK, summarised in table 2, we can see that the United Kingdom is the only one of these three countries with a well-developed concentration of therapeutics biotechnology firms (34). These data support a number of consulting reports and previous academic studies concluding that the UK has Europe's strongest biotechnology sector (see e.g. Senker, 1996; Ernst and Young, 1999; Cooke, 1999; Casper and Kettler, 2001).

Neither the German nor Swedish sectors have a critical mass of therapeutics biotechnology firms (only three in each country), while each has a larger number of platform biotechnology firms. While supporting our expectations, these results could not be considered conclusive due to the small number of public biotechnology firms existing in Sweden and Germany. We therefore discuss the German biotechnology case in more detail below, drawing on a range of supplementary statistics that strongly suggest that firms in this country have a comparative institutional advantage in platform biotechnologies.

Turning to the software cases summarised in table 3, the German evidence strongly supports our predictions. While a relatively large number of German software firms are traded on the German stock market for growth companies, ninety percent of firms (54 in total) are in enterprise software, while there are only three firms in either standard software or middleware. The UK data are also supportive. The UK has the largest software industry in Europe and 74 percent of these firms are in “radically innovative” segments, standard software or middleware. This combined with the smaller number of enterprise software firms generally supports our predictions. However, the UK case is puzzling in another respect. Why are most of the UK software firms in standard software, with so few in middleware software?

The pattern of Swedish software firm specialisation, on the other hand, is problematic. While a large number of enterprise software firms exist (20, or 44% of the total), over half the Swedish software firms are in radically innovative areas, and Sweden has Europe’s largest concentration of publicly listed middleware firms. As we will discuss in more detail below, the 10 publicly listed middleware firms represent only a small percentage of a much larger population of recent start-ups in this area. The Swedish concentration of middleware software firms poses a strong challenge to the theoretical predictions of this paper; “coordinated market economies” should not have a comparative institutional advantage in this area.

Overall, these statistical data, despite limitations, provide good support for our theoretical analysis. Of the 15 cases, 12 could be interpreted as confirming our expectations (UK middleware, Swedish middleware and standard software being problematic). For these three European economies, the claim that national institutional frameworks influence patterns of competitive advantage, and specialisation, should be taken seriously. To further strengthen our analysis and also investigate the problematic middleware software case, the remainder of the paper examines a smaller number of cases in more detail. Process tracing based on field research, supplemented at times by additional descriptive statistics, can help to examine the link between institutions and firm organizational strategy more sharply.

We focus on two areas. Firstly, we examine recent developments in Germany where the state has, over the last decade, developed an array of technology policies designed to spur German industry into the types of entrepreneurial technology start-ups discussed here. These policies, while generally successful in promoting entrepreneurial start-ups, have convinced few firms to head into "radically innovative" market segments characterised by project-based firms. We examine this case in more detail, providing richer evidence that German entrepreneurial technology firms are almost exclusively clustered in subsectors characterised by collaborative firms, despite substantial government subsidisation of high-risk venture financing.

Secondly, we examine the middleware software case in more detail, focusing on the Swedish case but with comparisons to Germany and the UK. The technological characteristics of middleware software are more complex than standard software due to the importance of technical standard coordination across firms. The activities of large firms capable of developing useful technical standards for firms active in the sector are crucial in this case and help to explain how Swedish firms have become more successful in the middleware software sector than UK ones. We use this case to examine the process by which radically innovative technology start-ups have become sustainable within a coordinated market economy.

Germany's Engagement with the "New Economy"

Beginning in the mid 1990s The German government introduced a range of new technology policies designed to create clusters of entrepreneurial start-up firms. Starting in 1996 the government decided to provide "public venture capital" in the form of "sleeping" or silent equity partnerships from federal sources (see Adelberger 2000). Over the past five years well over one billion DM has been channelled into such investments, with over half of the new firms specialising in information technology, communications, or biotechnology. German public officials have crafted a dense network of support policies for university-centred spin-offs. This includes funding the creation of several technology parks and incubator labs, hiring of consultants to persuade university professors or their students to commercialise their research findings and help them design viable business plans, subsidies to help defray the costs of patenting their intellectual property, and the provision of management consulting and partnering activities once new firms are founded. The programs have concentrated on biotechnology, but recently have been extended into other sectors including software (Lehrer, 2000).

Government support has dramatically reduced the financial risk of founding an entrepreneurial technology firm in Germany. The "public venture capital" program has spurred a dramatic increase in private venture capital. The structure of Germany's venture capital market has dramatically improved over the course of the late 1990s. Total venture funding rose from about 9 billion DM in 1996 to 25 billion available in 1999 (German Venture Capital Association, 1999). At only 400 million DM in 1999, federal funds formed less than five percent of the total sum of venture capital then available in Germany. Private sector investments in new financial markets, coupled with supportive financial regulatory reforms, also help explain the creation of large venture capital markets in Germany. The cornerstone of these initiatives was the creation in 1997 of a new technology oriented stock exchange, the *Neuer Markt*, with substantially less burdensome listing requirements than those that exist for the main stock market. As of December 2000, about 270 firms had taken initial public offerings on the *Neuer Markt*. By providing a viable "exit-option" to investors in technology start-ups, the *Neuer Markt* has created a financial environment more conducive to high-risk venture capital investments despite its recent price falls.

Given the relative ease of obtaining VC finance and, particularly for biotechnology firms, fairly sophisticated infrastructure support within low-rent start-up incubators, it is it not surprising that hundreds of new start-up firms have been founded in Germany. However, the vast majority of these firms are specialised in platform biotechnologies. In an initial survey of over 300 German biotechnology firms conducted in 1998, managers 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." (Schitag Ernst and Young, 1998: 17). A more recent survey published in late 2001 examined the number of therapeutic products developed across European biotechnology companies. This survey found that the UK companies had 128 products in development, compared to only six for Germany (Ernst and Young, 2001).

An analysis of the technological intensity of German biotechnology patents strongly supports the notion that German firms have specialised in sub-sectors with high cumulativeness. Figure 1 examines the average number of scientific journals referenced in German and US patents from 1985 until 1998. This is a rough indicator of technical cumulativeness – the greater the number of basic research citations in a patent application, the "newer" or less cumulative on previous discoveries the innovation may be presumed to be. These figures show that the average number of US scientific references in 1998 (about 24) is about three times as many in Germany (about 8), with the gap widening substantially over the 19990s. This finding complements evidence that German firms have specialised in sub-sectors of biotechnology firms with technological characteristics that are generally more cumulative in nature.

Turning to the software industry, German companies are overwhelmingly specialised in enterprise software markets. Most German software firms were founded during the 1980s to help fuel the corporate enterprise software markets; the average age across the 60 public firms is 15.3 years. Examples of prominent segments include enterprise resource planning (4 of the publicly listed firms), customer relationship management (5 firms), systems integration (7 firms), and a variety of sector-specific enterprise tools in areas such as logistics and supply chain management (9 firms).

There is only one cluster of German publicly traded software firms that is relatively young – a group of 7 firms active in the e-commerce software field (average age 7.4 years as of May 2001; Casper, 2002). This group of firms has received substantial private venture capital funding, facilitating much faster growth before initial public offerings. Rather than relying on "organic" driven growth based on earnings, they have had the opportunity to invest lavishly to create large organizational structures in an attempt to quickly grab substantial market shares. A closer examination of this sub-sector reveals complex organizational structures and relatively incremental innovation patterns characteristic for new technology enterprises in Germany.

E-commerce software is one of the only core Internet infrastructure areas in which German firms have established substantial market share in non-German language markets. While American firms dominate several segments, particularly in the provision of software for "business to business" transactions, German firms are internationally competitive in the provision of software to facilitate on-line retailing ("business to consumer" ecommerce) and are also strong in creating secure-transaction software for on-line financial transactions (see Casper, 2002).

Business concepts underlying e-commerce software resemble those pioneered by the German firm SAP to create the Enterprise Resource Planning market.. E-commerce software firms develop customisable software modules designed to help client firms organise e-commerce platforms. The business model involves the creation and updating of a kernel of e-commerce applications – inventory tracking, accounting, order completion, as well as the creation of visual web-interfaces used by customers – which are typically installed and extensively customised by the software provider or third party software consultancies.

While e-commerce software firms may compete to introduce software with enhanced functionality, especially in the "ease of use" area, the software itself is relatively generic. E-commerce software platforms are proprietary systems completely owned and maintained by the developer. Patenting over core e-commerce processes appears weak; dozens of e-commerce software firms exist, most of which offer relatively similar technologies. To reduce these appropriability concerns, firms invest in a core proprietary library of programs that are then customised for clients during extensive implementation programs. Doing so creates a lock-in effect for the software vendor, and can also help capture rents from periodic “up-grade” cycles as the software is improved.

Germany’s e-commerce software specialists resemble most German firms in developing human resource policies that are broadly competence enhancing in nature. Firms usually organise a group of programmers with advanced degrees who update the core software platform, along with a much larger group of trained technicians and consultants involved in implementation and service issues. Proprietary programming environments tend to keep competence destruction low – new programmers may be added to accommodate inevitable “feature creep”, but existing staff have high job security due to the need to periodically update the code. Relatively complex coordination across teams of programmers and technicians involved in customisation and implementation work is key to competitive success.

In summary, in both biotechnology and software small German growth companies have gravitated away from segments with radical innovation and related competence destroying risks. The German pattern of sub-sector specialisation in the biotechnology and software sectors strongly suggests that, while changing, the German model has not converged to a “liberal market economy” system capable of supporting project-based entrepreneurial technology firms. To some commentators, particularly in the business and consulting community (see e.g. Ernst and Young, 2001), this pattern of specialisation represents a failure of German technology policy to alter the structure of the economy radically.

Indeed, outside the financial area, there have been no major reforms to German labour or company laws. Rapid hiring and firing continues to be difficult in Germany. Long-term employment strategies by large firms limit the development of labour markets for high quality staff. While large German firms can sell entire subsidiaries or business units or send some lower-productivity older employees into early retirement, codetermination law makes it difficult for firms to lay-off individual employees or groups of employees as part of the "normal" course of business (see Becker et. al., 1999 for a discussion of Hoechst's difficulties in this area). Seen in terms of career structure, there is a high risk for senior managers and researchers in moving from an established large company or prestigious university professorship to a start-up firm.

This constraint-based argument ignores the fact that several of Germany's new economy firms have been successful, capturing international markets for important biotechnology platform technologies and specialised e-commerce and related enterprise software. Rather than viewing German developments as a case of failed technology policy in the face of institutional constraints, we would argue that German firms have specialised in areas of the new economy in which they have a comparative institutional advantage.

If the long term development of platform biotechnology and enterprise software firms does create substantial amounts of risk created by a weak appropriability regime, high cumulativeness, and high knowledge complexity, then it is likely that German institutional environments could allow more efficient governance structures to cope with these problems within collaborative firm structures. German national institutional frameworks continue to encourage competence enhancing human resource development through restraints on hire and fire that facilitate long-term employment. Access to a superior institutional environment could lead to German firms eventually outperforming firms located within liberal market economies in areas where complex organizational structures are important.

Sweden's Surprising Performance in Middleware Software

Stylised contrasts between CMEs and LMEs need to be further elaborated when considering sectors where different kinds of knowledge and specifications need to be coordinated in the development of new technological systems. Under some circumstances large firms can act as de facto coordinating agents in CMEs and encourage the development of radically innovative firms in societies that otherwise would not be expected to support them. We now turn to consider firm development in such a sector, middleware software production.

The technological characteristics of middleware software are more complex than standard software, due to the importance of technical standard coordination across firms. This depends upon the resolution of collective action dilemmas that are difficult for numerous small firms to resolve, particularly when distributive issues hinge on the particular constellation of technical knowledge chosen (Shapiro and Varian, 1999). In addition to human resource policy risks created by high competence destruction, middleware software firms face an additional coordination risk created by uncertainty about which emerging standards in a firm's chosen technical field will succeed.

Though governments have at times played important roles within telecommunication standards (see Glimstedt, 2001), within much of the middleware software sector most firms are dependent upon large corporations, typically telecommunication equipment manufacturers and established companies active in network intensive standard software products, for the provision of standards to help products become interoperable (see Casper and Glimstedt 2001). Examples of the former include large network equipment manufacturers such as Cisco Systems, Lucent, or Ericsson, while Microsoft, Sun, or Oracle exemplify the latter. Each of these firms has been involved in the creation of technology platforms for emerging network communication markets. These firms hope to provide technology platforms that function as "club goods" to middleware software companies, enticing them to develop a variety of follow-on technologies aimed at eventually creating new software platforms. Large firms are self-interested when providing these standards – through controlling emerging network communication protocols, they hope to secure large markets for equipment and software using the standards.

Large firms can help stabilise technologies through attracting middleware firms to create applications for their standards. As a result, middleware software firms are most likely to exist within technology clusters dominated by large companies that can entice them to commit to a technical standard, either through a reputation of past success or through other means such as financial incentives or technical support. Through locating within regional economies dominated by such firms, middleware firms can plausibly hope to insert its software engineers into emerging technical communities surrounding new platforms. Privileged access to such communities can provide a competitive advantage for middleware firms, through for example supplementing codified technical knowledge (protocols, languages) with tacit knowledge surrounding their efficiency or, at times, through securing quicker access to emerging technological platforms.

In sum, the existence of a firm that can credibly coordinate technical standards can help lower technical coordination risks, though high levels of technical and market uncertainty remain. This suggests that middleware firms existing with liberal market economies that are home to dominant technology firms should excel in creating clusters of middleware firms. The United States, for example, is a clear example of a country that has both. Large concentrations of middleware firms exist in the Silicon Valley and New Jersey areas, in part due to the existence of several firms dominant in setting network infrastructure standards (e.g. Lucent and Cisco in the telecommunications area, Microsoft, Sun, and Oracle in the recently emerging network services area).

Within the three European economies examined here, our example of a LME, the UK, is not home to a dominant network technology firm (its core telecommunications equipment manufacturer, Marconi, is widely seen as failing to succeed in "broadband" internet equipment markets). This helps to explain why so few UK firms are in middleware technology, but are more successful in standard software.

The UK is home to technology clusters that are embedded within the type of labour markets needed to facilitate flexible forms of human resource coordination but does not have a hegemonic network communications player capable of sponsoring emerging middleware software standards. UK software firms have instead gravitated to standard software segments, for which technical intensity remains high, but inter-firm coordination is low.

Germany is a clearer case. It is also not home to a dominant technology provider (Siemens is strong in some equipment markets, but is not a leader in promoting new telecommunications standards; see Casper, 2002), nor does it have a business system conducive to the creation of flexible labour markets. For this case, it is overdetermined that the governance of middleware software firms should be difficult. More interesting are CMEs that are home to dominant technology firms.

Within Sweden, for instance, Ericsson's current leadership in third generation wireless technologies has helped create a technology hub in the Stockholm area that has a technological intensity far more similar to Silicon Valley than normal patterns of industrial organization in Sweden. Ericsson has become the dominant provider of end-to-end wireless communication systems, and currently has about 40% of all orders for third generation wireless equipment. Other major telecommunications equipment players such as Nokia have set up development centres in Stockholm, and Microsoft recently opened a R&D centre for wireless software. Hundreds of software firms focusing primarily on wireless Internet technologies have developed in the Stockholm area of Sweden. A recent survey showed that around 250 wireless firms are active in Sweden, most in technically intensive middleware technologies (see Glimstedt and Zander, 2002).

We will use this case to examine the interplay between human resource coordination and technology coordination. The key issue here is: what constellation of policies must the large firm take to induce engineers, managers, and financiers to make commitments to projects that are normally extremely risky within their societal contexts? Can dominant actors take actions to "tip" labour market institutions in a direction contrary to "normal" institutional incentives with an economy?

We focus here on two factors: a) the influence of technology standards in fostering a switch from firm specific to more generic, industry-specific technical skill-sets among software engineers, and b) initiatives taken by Ericsson to foster entrepreneurialism surrounding technologies it is sponsoring. From the perspective of human resource coordination, these factors have reduced the career risk of working in a radically innovative technology start-up, and through doing so allow competence destroying firm strategies to become sustainable.

Ericsson through the 1980s and early 1990s in many ways resembled Siemens, Alcatel, and other European telecommunication equipment manufacturers. Operating as a quasi-monopoly equipment provider in a highly regulated domestic telecommunication markets, it developed large systems integration capabilities needed to design early digital switching technologies designed primarily for voice-traffic in-house. As the only significant telecommunications equipment manufacturer in Sweden, it could attract the country's best engineering graduates, who were then offered stable, long-term careers in Ericsson. The company developed proprietary protocols and systems integration languages. The core of Ericsson's programming staff, for example, were experts in Ericsson's in-house systems integration language, Plex, a computer language used nowhere else. While the convergence of data-communication and voice-based digital communication technology has forced Ericsson to adopt new languages for its next generation telecommunications gear, several thousand employees have been retained for their expertise in Plex, which is still used to update legacy equipment.

During the late 1990s data-communication networking devices have begun to converge with traditional telecommunication switching equipment. The increased use of Internet Protocol based switching has forced firms like Ericsson to increasingly adopt connectivity standards developed for data-communications networks. The issue for such firms is how this influences product development and systems integration issues internally. In designing switching equipment, base tower systems, and related artefacts for its internet-compatible wireless equipment, a small group of system engineers within Ericsson developed a new systems integration language, called Erlang. As with Plex, Ericsson's initial strategy was to make this technology proprietary.

However, unlike Plex, Erlang is a systems development language based on relatively standardised object-oriented programming tools with the potential to help firms in a number of industries develops software to manage complex technological systems. Upset at Ericsson's move to keep Erlang proprietary, the chief developer of Erlang along with a group of systems programmers left Ericsson in 1999 to form an independent start-up software company called Bluetail (Glimstedt and Zander, 2002).

Around the same time as this personnel crisis, Ericsson faced important strategic decisions regarding its sponsorship of wireless connectivity standards. Through its strong advocacy of the GSM standard, Ericsson management learned that, in relatively open data-communication network architectures, network externalities play a crucial role in determining which network standards become dominate (see Glimstedt, 2001). Ericsson was a major sponsor and developer of two important new web-based wireless connectivity standards, WAP and Bluetooth. The firm realised that if these standards were to succeed, dozens of other firms would have to work with these standards, creating unique applications software and middleware technology. Through creating large marketplaces for various wireless applications, demand for Ericsson's core end-to-end wireless systems technology would increase. Nurturing nascent wireless technology start-ups in the Stockholm area would help enhance Ericsson's favoured technologies.

To help promote technology spillovers into the Stockholm economy, Ericsson made two strategic moves. First, in decided to make Erlang an "open source" development language, it allowed the founders of Bluetail as well as other firms to use Erlang as a development tool. In this case, using open source development protocols ensures that enhancements to Erlang by third parties would flow back into Ericsson. More importantly, however, it helped to create industry-specific rather than firm-specific skills among engineers involved in large-scale systems integration. Sponsorship of emerging wireless connectivity standards such as Bluetooth and WAP or widely used mobile scripting languages like UML produces a similar effect. Standardisation of development tools, protocols, and connectivity standards dramatically increases the portability of skills across local firms working in wireless technology areas.

Secondly, Ericsson has changed its personnel policy towards engineers who leave to work in start-up firms. It had formerly strongly shunned engineers leaving long-term careers at Ericsson to work elsewhere, signalling that they would not be re-employed by Ericsson in the future. Through creating a corporate venture capital program, it now allows engineers leaving Ericsson to try their hand at technology entrepreneurialism. Given that most wireless start-ups within the Stockholm area are involved in the development of Ericsson-sponsored standards, and in many cases are using its core systems development language, local start-up ventures are working primarily to develop technologies compatible with Ericsson's next generation wireless technologies. If individual firms fail, their managers can now easily return to work within Ericsson, perhaps having developed new managerial skills or career perspectives through working in a start-up. If start-up firms are successful, Ericsson benefits through its sponsorship of key technologies and has close links with the management of the new companies.

In sum, the existence of industry rather than firm-specific standards reduces the career risk for engineers leaving established large firms for start-ups. Industry specific standards ensure that skill and knowledge investments made by programmers and engineers are portable. It allows managers of high-tech firms to successfully recruit highly skilled technical talent knowing that competence destruction and accompanying hire and fire risks are high. This combined with a more open human resource policy at Ericsson helps explain the rapid emergence of numerous radically innovative firms. Within normally conservative Swedish labour markets, this employment insurance is a key catalyst for creating extremely active labour markets necessary to sustain competence destroying technology strategies.

Conclusions

By focusing on the characteristics of different sub-sectors in this paper we have attempted to show how institutional frameworks structure distinctive strategies and organisational capabilities of firms in a more precise manner than much institutional theory. Institutional explanations associated with the "varieties of capitalism" literature strongly predict that the diffusion of entrepreneurial patterns of organising technology firms should differ across European economies. Both descriptive statistics on sub-sector specialisation and more qualitative case analysis suggest that the concept of comparative institutional advantage helps to explain patterns by which new technologies are developing in Europe.

One contribution of this analysis is to demonstrate that European economies can perform well in emerging technology industries such as biotechnology and software. These economies do so, however, not by radically altering institutional frameworks to mimic the US liberal economy model, but by seeking sub-segments within these segments in which firms can embrace long-standing comparative institutional advantage. Evidence presented in this paper has documented the existence of important sub-sectors, such as high quality platform biotechnologies and enterprise software, in which patterns of company organization and related business strategy need to develop complex organizational structures focused on competence enhancing human resource management. Firms within coordinated market economies such as Germany or Sweden have specialised in these technologies not as a "second best" solution, but because the institutional organization of these business systems create institutional advantages in resolving the managerial dilemmas that characterise these sub-sectors.

An implication of this analysis is that trade-offs exist in designing policies intended to foster entrepreneurial technology firms. Because different types of technology firms differ in their core organization, their optimal governance requires their embeddedness in different innovation systems. Thus, while the US has a large lead in fostering new technology firms, as key technological drivers diffuse through the international economy, one can expect that a division of labour will emerge cross nationally. While institutions associated with the US (and UK) innovation systems support business models demanding extreme flexibility (and competence destruction), Germany, Sweden, and other "organised" economies might promote superior innovation dynamics in areas dominated more by business integration and appropriability risks.

The focus on sub-sectors also sheds light on the organization of more "radically innovative" technological segments such as therapeutics biotechnology, standard software, and middleware software. Our analysis chimes with a number of important studies of the institutional organization of high-technology regions such as Silicon Valley (Saxenian, 1994; Kenney, 2000; Almeida and Kogut, 1999). We share with these studies the suggestion that low technological cumulativeness and resulting competence destruction across clusters of new technology start-ups can be facilitated by the creation of extremely fluid labour markets within regional economies. While most studies of Silicon Valley and related technology clusters have a regional focus, we focus primarily on broader national institutional frameworks that structure patterns of coordination across particular sectors and regions within the economy. Doing so helps explain broad differences in technological specialisation across economies, but cannot explain the relatively rare development of regional economies capable of fostering high levels of technological intensity across start-up firms within particular economies. In other words, there are more “degrees of freedom” between the orientation of national institutional frameworks and the ability of managers across groups of firms to develop innovative competencies than is suggested by varieties of capitalism theory.

Linking insights from varieties of capitalism research with the emerging literature on regional technology clusters is an important area for future research. A firm-centred approach, focused on relatively stable constellations of organizational and strategic dilemmas faced by managers across particular sub-sectors, can help push this agenda forward. Our analysis of the Swedish middleware software case is a first step in this direction. This case shows that institutions are not the only mechanism by which human resource coordination across firms can be overcome. In sectors in which external coordination with other firms is important, the activities of large firms might override “normal” institutional framework conditions. Due to a close linkage between standards used to coordinate technological trajectories across firms and the development of particular skill-sets among scientists and engineers, successful standards stewardship by telecommunications giants such as Ericsson has helped to reduce the competence destruction risks faced by personnel choosing to work in middleware software firms in normally conservative labour markets. Exploring this link between institutional environments, large firm strategy, and the development of entrepreneurial technology firms is an important topic for future research.

TABLE 1: EXPECTED SUCCESS OF THREE EUROPEAN ECONOMIES IN FIVE TECHNOLOGICALLY DYNAMIC SUBSECTORS

	Germany	**Sweden**	**United Kingdom**
Platform biotechnology	Successful	Successful	Unsuccessful
Enterprise software	Successful	Successful	Unsuccessful
Standard Software	Unsuccessful	Unsuccessful	Successful
Therapeutics biotechnology	Unsuccessful	Unsuccessful	Successful
Middleware software	Unsuccessful	Unsuccessful	Successful

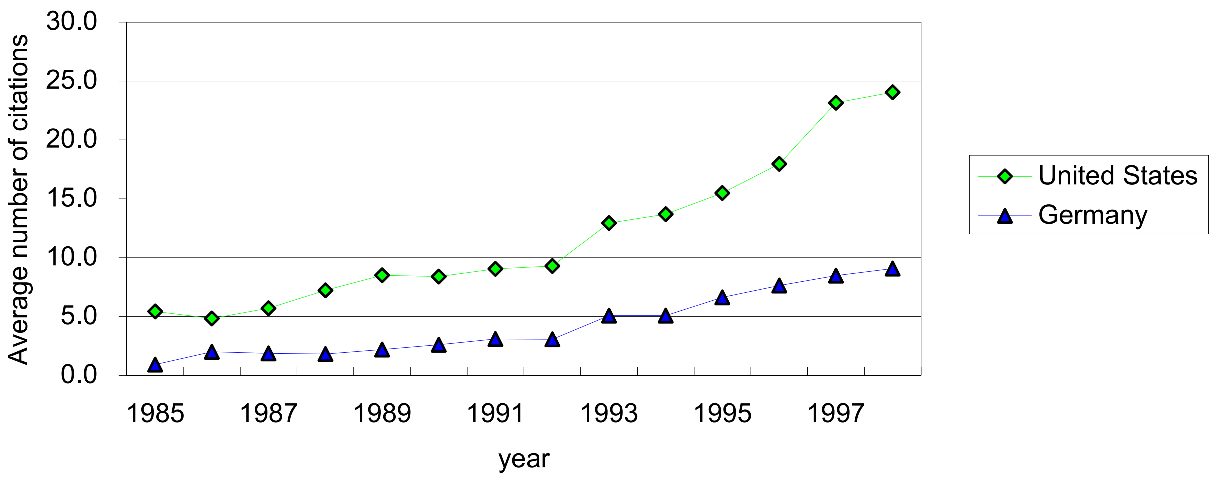
TABLE 2: SUB-SECTOR DISTRIBUTION OF BIOTECHNOLOGY COMPANIES

	Germany		United Kingdom		Sweden	
	Number	Percent	Number	Percent	Number	Percent
Platform Biotechnologies	13	81	6	15	8	73
Therapeutics/ Product based biotechnologies	3	19	34	85	3	37
Total	16	100	40	100	11	100

TABLE 3: SUB-SECTOR DISTRIBUTION OF SOFTWARE COMPANIES

	Germany		United Kingdom		Sweden	
	Number	Percent	Number	Percent	Number	Percent
Enterprise Software	54	90	23	26	20	44
Standard Software	3	5	58	66	16	34
Middleware Software	3	5	7	8	10	22
Total	60	100	88	100	46	100

FIGURE 1: SCIENTIFIC INTENSITY OF BIOTECHNOLOGY PATENTS, 1985-1998



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