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From Factor of Production to Autonomous Industry: The Transformation of Germany's Software Sector

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Summary

In recent months the German software industry has gained extensive public prominence for manifesting a phenomenon not seen on this scale in Germany for decades: a dire labor shortage. As even the general public has been made aware by the Bündnis für Arbeit, Germany's information technology (IT) industries currently suffer a shortfall of about 75,000 software specialists.[1] However, the focus of this article is not on the labor problems, but on the comparative characteristics of Germany's software industry. Difficult though it is to delimit the exact boundaries and segments of the software industry in an age of widespread technological convergence and digitalization, what follows is an attempt to assess the comparative national profile of Germany's software sector in three ways: first, by looking at the business segments that German software firms specialize in; second, by examining the nature of their various business strategies; and third, by considering the components of Germany's "national system of innovation" in regard to software: education and training, government policy, and organized interest formations. All three aspects of the German software industry are in a state of rapid transformation, as reflected in the current German high-tech boom and the growth of the Neuer Markt. Hence the following characterization of the German software sector is very much that of an industry in transition.

1. The German Software Industry: Size, Strengths, Weaknesses

1.1 Overview

In 1999 the market turnover of Germany's information technology and telecommunications (ITC) sector totaled DM 214.6 billion, about 22.5% of the total Western European market. According to the European Information Technology Observatory (EITO), of the Western European ITC market (1999 value: 435 billion Euro), software and software services account for fully 71%: 58% of the information technology segment and an astounding 84% of the telecommunications market. Continual increases since the 1980s in the importance of software and software services have come at the expense of hardware (EITO, 2000). However, most statistics, including many statistics cited below on the German software industry, actually underestimate the true total economic value of software and software services in national economies. This is because information technology (IT) services are usually tallied separately from telecommunications services, yet only IT services are counted as software services in the normal sense. On top of this, embedded software constitutes an increasing proportion of the value-added of most electronics hardware and is likewise excluded from most aggregate statistics.

Before attempting to analyze the relative strengths and weaknesses of Germany's software industry and the way these strengths and weaknesses have evolved over time, a few basic statistics help to provide an overview of Germany's comparative position in the global ITC industry. First, the percentage of gross domestic product devoted to ITC in Germany is at 5.3% well below the average of industrialized nations and even below the average for Western Europe (5.8%):

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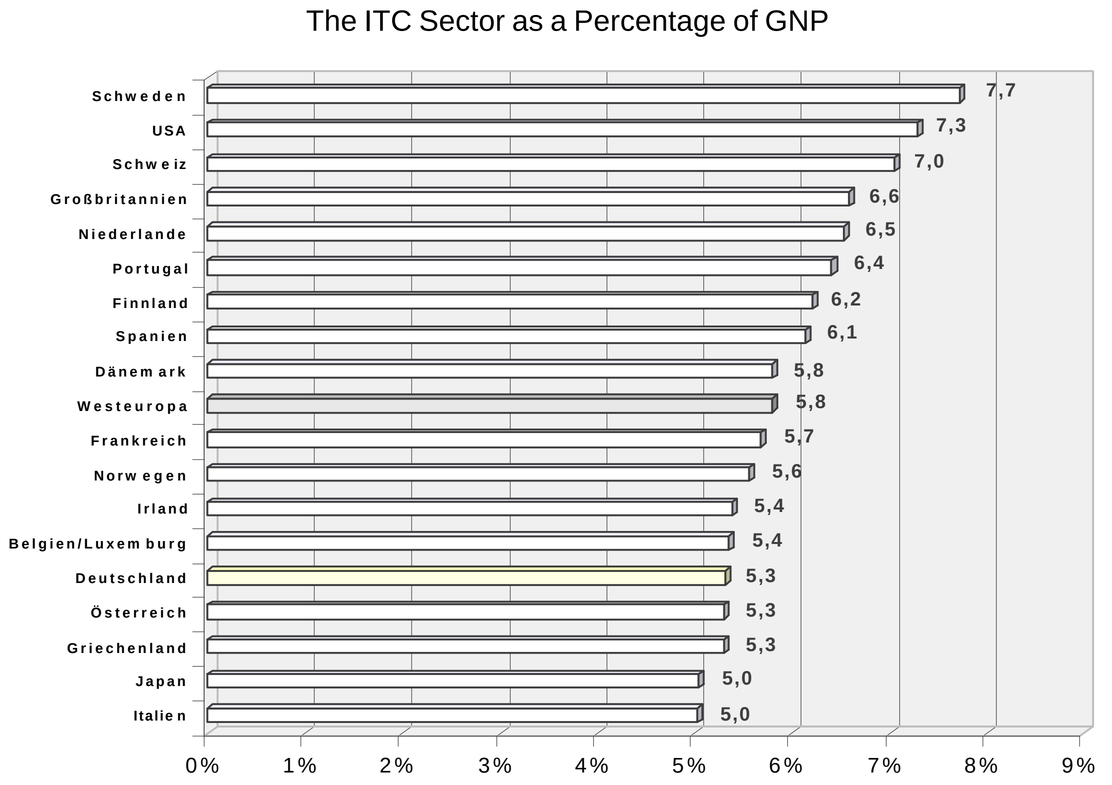
[1] Estimates vary between 50,000 and 100,000. The figure of 75,000 is cited by BITKOM, the industry association mentioned below (Jung, 1999). Since the estimated figure for the whole European Union is 367,000 unfilled positions in software programming, the problem is not unique to Germany but reflects the worldwide boom in unanticipated demand for software products and services unleashed by new technologies.

Figure 1



Source: Bitcom; Basis: EITO.

Further, Germany's revealed comparative advantage in ITC patents, as in most high-tech sectors, is negative, reflecting the traditional predominance of medium-tech industries in German patenting (BMBF, 1999). In sum, ITC is not a large sector of the German economy by international standards, even a bit disappointing in light of Germany's historical strengths in electronics and telecommunications.

As for the software industry *per se* (that is, excluding embedded software and telecommunications services), this is by far the fastest growing segment of Germany's ITC sector, with recent growth rates of approximately 15% annually. This is reflected also in the explosion of employment in software, leading to the drastic shortage of qualified personnel:

Table 1

Employment in the German ITC sector

Segment	Employment			Annual Change	
	1997	1998	1999	1997/98	1998/99
Information Technology	379,000	396,000	433,160	4%	9%
• Hardware	147,000	128,000	135,680	–13%	6%
• Software and software services	232,000	268,000	297,480	16%	11%
Telecommunications	322,000	338,000	338,000	5%	0%
• Hardware	101,000	101,000	101,000	0%	0%
• Telecommunications services	221,000	237,000	237,000	7%	0%
TOTAL	701,000	734,000	771,160	5%	5%

Source: BITKOM (2000).

The software industry (software and software services) is composed of some 5000 firms of various sizes active in Germany. The breakdown of firm size is estimated as shown in Figure 2 below.

These figures reflect an industry that is not only fragmented, but also consists of a high artisan component of freelance programmers. Much computer programming in industry is still performed in a rather unstructured way, notwithstanding the many methodologies for systematic software engineering that have developed in past decades and are discussed below.

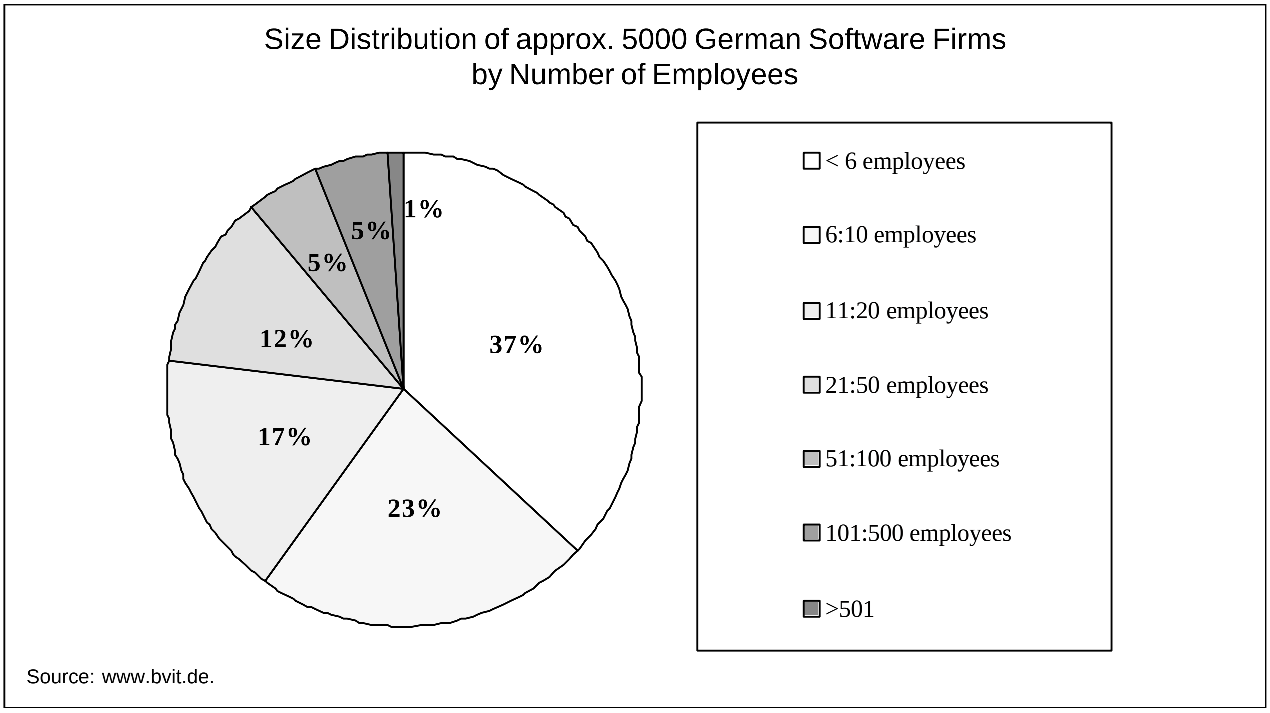
The software industry involves both a product segment and a service segment, which however are so intertwined that the distinction is somewhat artificial. The activities of many information technology (IT) firms involve both services and software products, provided either separately or together in the form of products which are customized to the needs of particular customers through services rendered by programmers. Still, it is useful to conceive of IT firms in areas like systems integration (e. g. Debis Systemhaus or Andersen Consulting) as belonging mainly to the software service segment, while software houses selling mass-produced "products" (such as SAP's R/3 business application suite or Software AG's ADABAS database) can be considered to constitute the product segment of the software and software services industry. Hence we will consider software products and software services separately in the following sections.

Before embarking on the analysis, however, it is worth reviewing the conventional wisdom concerning Germany's software industry. Traditionally, Germany and other European countries have been considered naturally handicapped in the mass product segment by being deprived of the large homogeneous domestic markets that US software producers have enjoyed (Malerba and Torrisi, 1996; Torrisi, 1998). Yet even by European standards, demands conditions in Germany have been considered unfavorable for the emergence of large software companies in either products *or* services. Most users of software in Germany were firms with a traditional preference for developing their software internally, much more so especially than France where large IT service providers like Cap Gemini Sogeti and Sema emerged. In sum, by international standards software in Germany was practiced more as an occupation than as a distinct industry. The German software industry was commonly depicted as strong in the production of technically sophisticated customized software and weak in more standardized software products. A publication of Germany's Federal Ministry of Education and Research (BMBF) on *Innovation in the Knowledge Society* declared: "In the Federal Republic of Germany the strong point and competence of software development lies in the area of application software, especially of customer-specific customized software and software-based services" (BMBF, 1998, 65-66).

1.2 Software Products

The structure of the market for standardized software products has changed dramatically in the past 15 years. As recently as the mid-1980s, both in Germany and world-

Figure 2



Source: www.bvit.de.

Table 2

Largest Providers of Standard Software, 1984

Rank 1984	*Firm*	*Turnover ($ Mio.)*	*Nation*	*Rank 1996*
1	IBM	3197	USA	1
2	Hewlett-Packard	500	USA	13
3	Unisys	408	USA	—
4	NEC	300	J	6
5–6	Digital	200	USA	10
5–6	Fujitsu	200	J	4
7	**Nixdorf**	**160**	**D**	**—**
8	Lotus	157	USA	—
9	Management Science	142	USA	—
10	Microsoft	125	USA	2
11	Computer Associates	116	USA	5
12–13	Hitachi	100	J	3
12–13	Bull	100	F	—
14	Olivetti	96	I	14
15	Ashton Tate	82	USA	—
16	**Siemens**	**39**	**D**	**12**
17	Oracle	13	USA	7
—	Novell	—	USA	9
—	**SAP**	**—**	**D**	**8**
—	Martin Lockheed	—	USA	11

Source: Torrisi (1998, 54).

Table 3

Largest Providers of Standard Software, 1995

Rank	*Firm*	*Turnover ($ Mio.)*	*Country*
1	Microsoft	7419	USA
2	Oracle	3777	USA
3	Computer Associates	3196	USA
4	Novell	1986	USA
5	**SAP**	**1887**	**D**
6	Sybase	957	USA
7	Adobe Systems	762	USA
8	Informix	709	USA
9	American Management Systems	632	USA
10	Sterling Software	610	USA
11	Compuware	580	USA
12	SAS Institute	562	USA
13	**Software AG**	**552**	**D**
14	Cadence Design Systems	548	USA
15	Autodesk	544	USA
16	Sunguard Data Systems	533	USA
17	Computervision	507	USA
18	HBO & Co	496	USA
19	Intuit	490	USA
20	Parametric Technology	441	USA

Note: This list excludes standard software produced by makers of computer hardware.

Source: Broadway Associates, from: The Economist, 25 May 1996.

wide, the leading producers of hardware (such as Siemens and Nixdorf) were also the leading producers of software (see Table 2).

The PC revolution and the emergence of client/server architectures, however, created an entirely new market for software. Liberated from the proprietary standards of mainframe manufacturers, software could be developed for compatibility with either open operating systems like Unix and Linux or with the *de facto* global standards of Microsoft. While mainframe producers, including Siemens and Nixdorf, lost market share in hardware and consequently also in software (see Table 2, 1996 rank**)**, an increasingly global market for standardized software products and software modules emerged. As discussed later, this ultimately led to an enlarged market for IT services, especially "systems integrators," to integrate the different hardware and software components offered on the computer market. Thus software products (and software services) constitute an increasingly global, autonomous industry.

Germany's computer industry did not fare well in the PC and client/server revolution (Siemens and Nixdorf first merged, then more or less disappeared from both computer hardware *and* software), prompting perhaps some of the common conceptions about Germany's relative weakness in standardized computer products and services. Despite such conceptions, some indicators suggest that the production of standardized software in Germany is high compared to any country other than the US. A list of the 20 largest standardized software vendors in 1995 makes this plain:

The prominent position of SAP and Software AG among global software companies was due to their offering complex business applications involving high switching costs for customers and hence assisting in the lengthy retention of customers. Indeed, Software AG (now no longer in the top 20 global software firms) has exported its standard database software since the late 1960s, when standardized software was an entirely novel concept. Both Software AG and SAP were actually global first-movers. Software AG developed and marketed the first so-called network databases (a superior product concept at the time, but now superseded by the relational databases offered by firms like Oracle and Informix).[2] SAP was the first firm to offer an integrated package of business applications (R/3) capable of unifying the information systems used across different functional areas of user companies.

Like other national industries, Germany's software industry is fairly *specialized in the production of capital goods*. This is not only true of SAP, Software AG, and other large German software companies,[3] but also of

[2] The author wishes to thank Prof. Dr. Oliver Guenther of the Humboldt University for providing background information on the matter.

[3] A list of the 25 largest German software companies is published each year by Lünendonk, accessible on the Web at URL: http://www.luenendonk.de. In the list of the top 25 companies, seven are German subsidiaries of US companies (Microsoft,

most recent start-ups on the *Neuer Markt*, in which application domains such as enterprise resource planning (ERP), computer-assisted software engineering (CASE) tools, production planning and work-flow, graphics, encryption, electronic commerce, and document management predominate. Even Germany's most celebrated e-commerce start-up, Intershop, produces Internet software applications for businesses, not for households. In the production of software products for household consumers Germany is not a global player of any note. For example, Germany is hardly a maker of video games, while both the US and Japan field a number of active producers. Here Germany is handicapped by the lagging diffusion of PCs and Internet usage in Germany compared to many other Western countries (EITO, 2000).

Not surprisingly, Germany's standardized software producers are most competitive globally in segments subject to especially *high domestic standards on the demand side*. The stringent demands of German industrial users of software account for much of the competitiveness of industrial business application software. Exacting German standards for building construction helps account for the sophistication of the architectural graphics software of Nemetschek AG, Germany's fourth largest producer of standardized software after SAP and Software AG.[4] Finally, particularly high security concerns in Germany extending above and beyond just *Datenschutz* regulations explain Germany's strong domestic base in suppliers of encryption and other security-related software products; BROKAT is one well-known firm in this area (Salama, 1997).[5]

In spite of many strengths, the commonly heard criticism is probably justified that the German software industry could have performed even better. Aside from Software AG and SAP, the bulk of German software companies in the standardized product segment made little effort to market their products abroad. German software companies have traditionally lacked the capital, marketing know-how, and will to market their products in foreign countries. Ultimately, this made the German software industry more vulnerable to foreign competition. A large number of once-prominent German software companies were bought out by foreign firms, heavily downsized, or outright folded (Dietz, 1995). This inward-lookingness has definitely changed recently. To avoid a repetition of past mistakes, a number of German software companies have announced plans to expand into foreign markets. Taking advantage of the *Neuer Markt,* many stock market floatations by established software companies (PSI, Beta Systems, BROKAT, etc.) involved the goal of raising enough capital to market their products on a global basis.

The simultaneous take-off of both the *Neuer Markt* and Internet has spawned a multitude of start-up companies. Of some 200 *Neuer Markt* companies listed by early 2000, at least 47 can be categorized as developing software products. An overview of their specialization is provided by the following tabulation:

Table 4

Breakdown of 47 Neuer Markt Software Firms

Enterprise Resource Planning	6
Document Management Systems	5
Graphics	3
Finance Software	4
Internet Software	12
Sundry Software Development	17

Source: Tabulations by The Economic Change and Employment Department, Social Science Center Berlin (WZB).

It is too early, at this point, to speculate on where new German strengths in software will develop in the near to medium-term future. Most observers are hopeful; never has Germany had so many domestic producers of packaged software with global ambitions and such a good capital base.

1.3 Software Services

Whereas Germany could arguably boast of a certain international presence in the area of standardized products, the services segment has historically been far less

Oracle, CA, Novell, Autodesk, SAS Institute, Informix). However, the exclusive focus of this article is on German-based companies.

4 Source of this information: interviews with the founder and two top executives of Nemetschek. Size rankings refer to the aforementioned Lünendonk list, exclusive of German subsidiaries of foreign-based software companies.

5 Another factor assisting German producers in this area lies in the rigid US regulations on the use and export of encryption algorithms. See Salama (1997).

Table 5

Largest IT Service Providers in West Europe 1991

Rank	*Firm*	*Market Share*	*Country*
1	Microsoft	7 419	USA
1	IBM	20.2	USA
2	Cap Gemini Sogeti	6.1	F
3	BT Customer Systems	6.0	UK
4	DEC	4.5	USA
5	Andersen Consulting	4.3	USA
6	Sema Group	4.0	F
7	Logica	3.0	UK
8	Thomsen CSF (BSI)	2.6	F
9	Data Sciences	2.4	UK
10	**Siemens Nixdorf**	**2.1**	**D**
11	Olivetti	2.1	I
12	ACT Group	2.0	USA
-	Other	40.7	-

Source: Pierre Audoin Conseil (1992).

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developed. As noted, German companies have in the past demonstrated an above-average propensity to perform their computing activities in-house rather than to rely on external providers. Until very recently, Germany has therefore lacked the large internationally operating IT service companies found in the US and France. For example, as recently as the early 1990s German companies were weakly represented in the European IT services market (see Table 5, previous page).

Nonetheless, despite institutional disincentives (discussed below), outsourcing in Germany has made way in recent years, while large corporations like Debis (of Daimler-Chrysler) and Siemens have discovered that IT service provision can be successfully developed as a business by large industrial conglomerates. The IT services business of both companies grew dramatically in the 1990s, to the point of joining the ranks of the largest European IT service firms:

Table 6

Largest IT Service Providers in West Europe 1997

Rank	*Firm (Mio Euro)*	*Turnover*	*Country*
1	IBM	5 500	USA
2	EDS	3 230	USA
3	Cap Gemini Sogeti	2 530	F
4	Andersen Consulting	2 040	USA
5	**Debis Systemhaus**	**1 600**	**D**
6	Computer Sciences	1 560	USA
7	**Siemens Nixdorf**	**1 490**	**D**
8	Sema Group	1 410	F
9	Bull	1 280	F
10	Compaq/Digital	1 050	USA
11	Finsiel	1 010	I
12	Origin	970	NE
13	Oracle	950	USA
14	Atos	930	F
15	ICL	830	UK/J

Source: Pierre Audoin Conseil (1998).

German IT service providers have only recently begun to manifest an international presence outside of Germany. Some service providers, such as CSC Ploenzke and Plaut, have been buoyed by the SAP boom in recent years and have expanded in foreign countries by offering SAP services. The SAP services divisions of Debis and Siemens-Nixdorf have likewise expanded rapidly, including abroad.[6]

These recent developments have helped push certain painful industry memories into the background. In the early 1990s the growth of server/client networks, the rapid drop in overall hardware costs, and the concomitant growth of standardized software products created overwhelming turbulence for the traditional German computer companies like Siemens and Nixdorf. While it was customary in the press to view the experience of the German computer industry in the 1990s as indicative of *Standort* deficiency, statistics on industry leadership present a more nuanced picture. Of the top 50 software and computer science companies in Europe, 20 are American-owned, compared with 12 a few years ago. Meanwhile, the number of German-owned firms has held steady, whereas European firms have generally held faltered: the number of French companies in the top 50 has fallen from 13 to 7, for example (Pierre Audoin Conseil, 1998). Once again, the aggregate performance of the German software sector seems mediocre compared with the US, but appears satisfactory when judged by any other standard.

2. Basic Strategies of German Software Companies: A Work-Organizational Framework of Software Development

2.1 Specialization Strategies

The issue of how to deploy programmers in an economically efficient manner leads us now to consider the basic economics and organizational patterns of innovative software activity. The further analysis requires a certain general understanding of the different ways in which certain scarce and expensive resources — namely, software programmers — can be organized and deployed to produce a valuable output, namely software products. As a first step toward developing a taxonomy of software development methods, three basic approaches for organizing software production may be distinguished:

- a customized service approach (customer-oriented)
- an entrepreneurial approach (product-oriented)
- a scientific approach (process-oriented)

Each of these approaches entails a different type of firm strategy. Let us consider each in turn.

The *customized service approach* involves close interaction between the software developer and the user with a view to developing a solution tailored to the customer's specific requirements (*Individualsoftware*). Often the user requirements cannot be specified in advance, thus necessitating an iterative sequence of designs proposed by the developer and modifications requested by the customer. This is the dominant approach to software development in Germany. IT service providers can be very small (as little as a single freelance programmer) or a very large company like Debis or Siemens Business Systems.

[6] Indeed, a difficulty in evaluating the overall strength of the German software industry *qua* industry in the recent years is that many of its recently growing firms, including Ixos Software AG and IDS Prof. Scheer, ride on the coattails of a single firm, SAP.

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In contrast, the *entrepreneurial approach* aims at developing a reproducible software product that can be sold in the market place to many users. The focus of this approach is on producing standard software, often with a system architecture that allows users to adjust certain features of the product to fit their particular individual requirements. The more adjustable settings a standard software product features, the greater the flexibility of the product — but also the greater the complexity for the user and the cost of development for the developing firm.

Unlike IT service provision, highly innovative standardized software seldom thrives in a large-firm environment. Siemens-Nixdorf, for precisely this reason, sold the bulk of its software business in 1997 to Baan, a Dutch software company.[7] Successful software companies in the standardized product segment of the industry, in Germany as well as in the US, generally have the following characteristics:

1) They begin as small start-up companies
2) They focus their energies on a very small product niche
3) They grow very rapidly once they create a blockbuster product
4) Further growth revolves around improvements of this one product

Standardized software development usually follows a hit-and-miss pattern of market success requiring a high level of risk, speed, and product focus. Such requirements are best met by small start-up firms guided by "high-powered" market incentives.[8] With the singular exception of Microsoft, few software companies have proven successful as multi-product companies. (Software AG was therefore rather unusual in being able to follow up the success of its ADABAS database ten years later with the introduction of a second successful product, its NATURAL software development environment.)

Finally, the *scientific approach* attempts to inject systematic procedures and scientific methods into the software development process. As in the customized service approach, the end product is *Individualsoftware*; the scientific approach, however, seeks to reduce the time-consuming iterative loops of customer-developer interaction by use of more structured techniques relying on a codified methodology. The use of structured software engineering techniques, comparatively slow to develop in Europe compared to the US and Japan, is correlated positively with firm size and found most especially in large integrated hardware-software companies (Torrisi, 1998, Chapter 5). In Germany, the chief exponent of the scientific approach is Herbert Weber, director of the Fraunhofer Institute for Software and Systems Engineering (ISST) in Berlin.

Each of these three approaches involves different ways of organizing work in the software firm or department concerned:

- The *customized service approach* utilizes a project team which often works on the premises of the customer. A software firm using this approach is usually organized like a consultancy. It may be as small as one or two people, but if it is large, a three-level hierarchy will be the rule: at the top, partners or senior managers who obtain the business, under them a corps of project managers who coordinate the work on each customer project, and finally the programmers who work as team members on individual projects.
- In software firms that have opted for the *entrepreneurial approach*, the hierarchies may be even flatter, with just one or more entrepreneurial owners who supervise the work of tightly-knit development teams. Software firms in this category are legendary for the variable working hours, individualized and often quite idiosyncratic working habits, and the unorthodox compensation schemes of their programmers. The management methods for controlling and disciplining such employees are both psychological (the personal dedication of programmers to their project teams) and pecuniary (stock options).
- Finally, the *scientific approach* seeks to impose a systematic division of labor on the software development process, both on the individuals involved and on the tasks they perform. A guiding principle is to avoid the unstructured type of work patterns that are characteristic of the software industry, patterns that make software development work seem akin to the "industrial stone-age" (Weber, 1992, 76) in comparison with the organization of work in other branches of industry. Rationalization of the work process is the keystone of this approach; however, Torrisi (1998, 164) points out that a greater internal division of labor could also potentially be conducive to a greater absorptive capacity by large software companies, that is, an enhanced ability to capture knowledge spillovers from outside the firm.

While the first two approaches are widespread among firms in the software industry, use of the scientific approach has usually been restricted to large firms with a size-related need to control and synchronize work processes. Industrial work methods of programming have progressed farthest in Japan, known for the high level of work and process standardization achieved in its so-called "software factories" (Cusumano, 1991). In Europe, an attempt to apply the scientific method was undertaken in the Eureka Software Factory Project, discussed below. As an alternative to rationalizing work processes, many Western software firms have relied on new programming

[7] Interview with the former General Manager of Siemens Nixdorf, Gerhard Schulmeyer. See Casper, Lehrer, and Soskice (1999).

[8] Many thanks to José Encarnacao, Director of the Fraunhofer Institute for Computer Graphics (Darmstadt), for pointing out this dynamic aspect of software firms.

techniques such as object-oriented and CASE (computer assisted software engineering) tools in order to improve speed, reliability, and output efficiency.

2.2 Growth Strategies

Regardless of which software development approach is adopted, software firms invariably have a strong incentive to seek scale economies. Since software code is reproducible virtually for free, the marginal cost of producing a given type of software product sinks dramatically once the first unit has been produced: the cost of manufacturing software is more or less identical with cost of the development phase. Entrepreneurial producers of standard software are of course enticed precisely by these economic conditions. But even service-oriented producers of customized software have an enormous economic incentive to specialize on a particular kind of customer application that will enable them to reproduce their previously accumulated know-how, algorithms, and even sections of their computer code. SAP was not alone among packaged software firms in starting out as a service company: it focused on a very narrow niche, enabling the company to resell essentially the same product to multiple customers, naturally with incremental improvements and specially customized features at each additional installation. SAP did not begin selling a standardized product until seven years after the firm was founded. As for the scientific approach, a specialized division of labor and serial production are precisely the goal of introducing more methodical working techniques.

Taken together, the marginal cost curves implied by each of these three software development approaches can be depicted as showu in Figure 3 below.

While the entrepreneurial approach offers the greatest perspective of profit if it succeeds in producing a successful product, it also entails the greatest risk, since extensive development costs must be sunk before the first unit of the new product is sold. Whereas the business strategy of the entrepreneurial approach is to come up with a blockbuster product, the business strategy of the customized service and the scientific approach is to build up a customer base that provides a steady steam of orders and throughput.

In all cases, the economic incentive to increase the volume of business remains, and this can be represented in the following diagram that distinguishes between low- and high-volume production for each of the aforementioned approaches (Figure 4, next page).

We consider each of the three columns in turn. The entrepreneurial approach (left column) in the start-up phase is mainly focused on product development. Once (and if) it has successfully developed and sold a blockbuster prod-

Figure 3

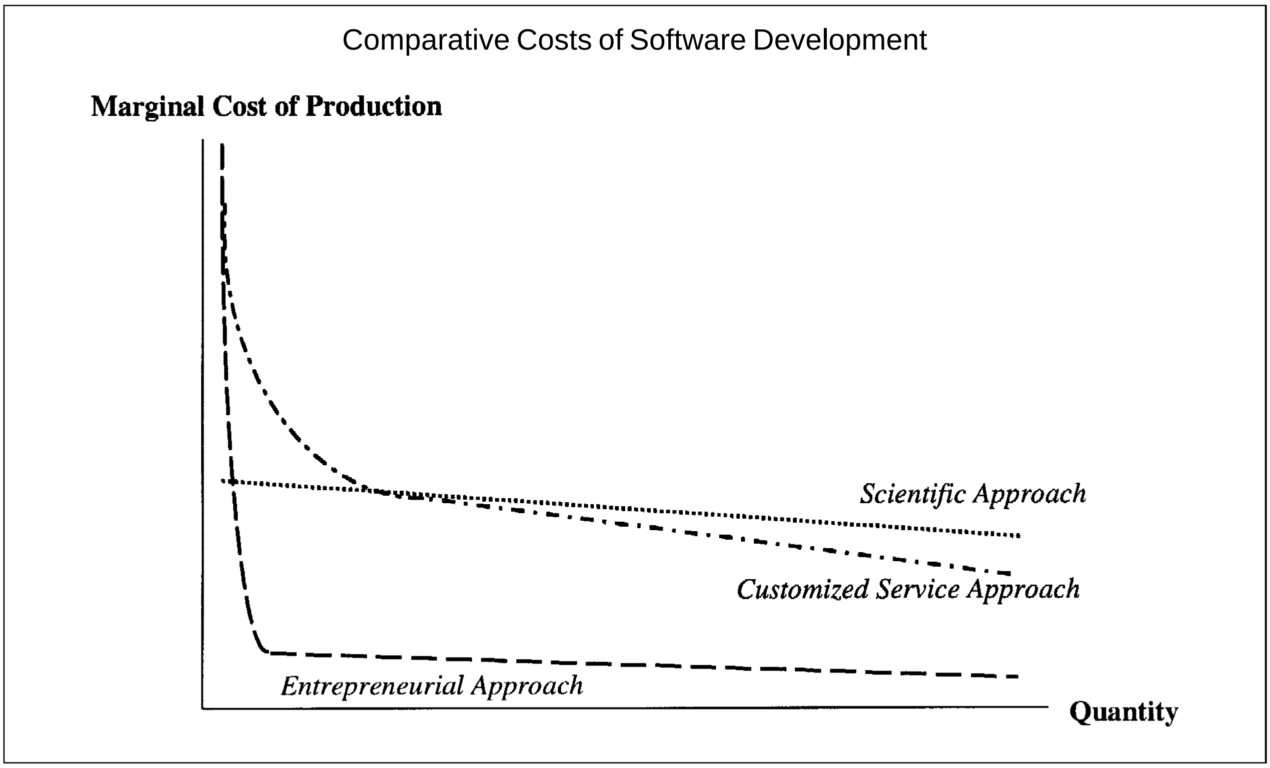

Figure 4

Six Modes of Software Development

	ENTREPRENEURIAL	CUSTOMIZED	SCIENTIFIC
Initial Development Phase	1 Entrepreneurial Start-Up	2 Freelance Artisan	3 Structured Work or Modeling Process
Higher-Volume Production Phase	4 Blockbuster Producer	5 Consultancy/Niche Service Provider	6 Industrial-Strength Software Factory
Approach: Competitive Advantage:	Market-Based Economies of Scale	Service-Based Economies of Experience	Engineering-Based Economies of Specialization
Focus:	Product	User	Work Process

uct, however, resources will be quickly channeled to sales and marketing activities. Concerning the customized approach (central column), the lament of Weber (1992) and others is that the German software sector has long remained too fragmented and dominated by small freelance firms to build a cost-effective and internationally competitive industry. We have already noted that more than 60% of German software firms have ten or less employees, though we leave open whether or not this is an undesirable state of affairs. In any case, the emergence of a few large German software companies with an international presence is a very recent phenomenon.

With respect to the scientific approach, it is useful to distinguish between small-scale and large-scale efforts. Essentially, much of German government support for the software sector has involved sponsorship of small-scale efforts to exploit more systematic software development procedures, either through structuring the work in certain ways or in supplying analytic tools to model the processes involved. One might say that the implicit or explicit rationale of some of the BMBF support programs (discussed below) was to help move German software activity out of cell 2 and into cell 3.

A more ambitious goal along these lines, however, is to try to direct software activity into cell 6: the industrial-strength software factory. The factory approach to software production — the devising of technical, organizational, and social methods to facilitate large-scale code-writing enterprises — has been employed with mixed results in Japan (Cusumano, 1991; Baba, Takai, and Mizuta, 1996) as well as in a European pilot project, the Eureka Software Factory (ESF). The ESF was set up by a group of European firms and universities with generous funding from the European Community's ESPRIT program. Running from 1987 to 1993, this experimental project attempted to devise standards and interfaces to facilitate factory-like software production (Weber, 1997). In the process, the ESF project helped to push out the frontiers of software development tools like computer assisted software engineering (CASE).[9]

Of course, the policy alternative of choice at the current time is to encourage the channeling of more software activity into the entrepreneurial approach (left-hand column) with the medium-term goal of building Germany's share of the world market in standardized software. The proportion of standardized to customized software installations has grown dramatically in recent years, as user firms have found customized software expensive to maintain and increasingly unable to keep pace with new technological developments. Meanwhile, the range of tasks capable of being performed by standardized software has expanded at a rapid rate. Add to this the emergence of global standards for software platforms and proliferating technological and market-driven demand for software inputs and it becomes apparent why vastly more venture capital and young entrepreneurial talent in Germany has become available for entrepreneurial software start-ups through the *Neuer Markt* and other funding sources.

The foregoing framework of software development activity departs from the usual market segment categories of software: operating systems, applications, application tools, etc. This framework can be used as an aid in charting various trajectories of software firm evolution. There are, in particular, different paths of organizational evolution by which a firm can become a major producer of standardized software. To illustrate this point, Germany's largest two vendors, Software AG and SAP, reached their respective market positions by following very different paths. Software AG was founded on the basis of an innovative product idea: the network database, which was rapidly developed upon founding of the company and then marketed worldwide. SAP followed a very different path of evolution. It started out as a niche service provider of business applications for individual customers. Only after the

9 A challenge with which ESF and, for that matter, all large-scale software enterprises have had to contend is the rapid rate of technological change in the industry, making it difficult to stabilize the technical standards and interfaces used in large-scale production.

firm had acquired a broad grasp of possible user needs on the basis of accumulated experience did it develop a standardized product. These contrasting paths can be depicted as shown in Figure 5 below.

Interestingly, the real model for *Neuer Markt* start-ups from this perspective is not SAP, but Software AG, which was founded expressly as a producer of packagable software.

3. Germany's National System of Innovation in Software

3.1 Educational Infrastructure

From a technical and scientific point of view, Germany's educational and research infrastructure in computer science is highly developed. Computer science departments in German universities and technical colleges, additional software development activity conducted by research institutes at all levels (Fraunhofer Institutes, regional and local research centers) and as well as some 150-200 smaller institutes connected with universities, results in a high scientific level of software expertise in Germany, reflected in an above-average level of scientific publications and citations (Abramson et al., 1997, 341). A peculiarity of German universities and technical colleges appears to be the comparatively high profile of the field of Management Information Systems (*Wirtschaftsinformatik*); in other countries (including the US, UK, and France) this field does not enjoy the same prestige and academic weight as in Germany. Nonetheless, reflecting a perennial debate between industrialists and academics, German industry views the university curriculum in computer science as providing excessive theoretical depth and insufficient orientation to business applications (even in *Wirtschaftsinformatik*).[10]

Germany has been exceptional among European countries in having long-standing industry-university links in the software field (Malerba and Torrisi, 1996, 168). Government policy to promote software development through industry-university joint projects, as discussed below, has long been predicated on the view of computer science expertise as a public good worthy of state subsidies. What has been less realized until recently is that Germany's strong industry-university links are favorable to a different approach: to spawn entrepreneurial start-ups to compete in the standardized segment of the software industry. Universities with industry links are breeding grounds for software set-ups because, more than in most industries, the main barriers to the founding of a software company are knowledge barriers. In earlier years German software start-ups clustered around universities because the latter allowed open access to precious mainframe facilities; today they do so because of the access to young talent and social networks carrying new ideas and impulses.

Whereas Germany's apprenticeship system is of very minor importance for the software industry, universities are an important source of both ideas and people. The basic commercial ideas of Software AG, which for nearly two decades was Europe's largest producer of standardized software, were incubated in the research institutions of Darmstadt. While SAP's founders were breakaway IBM programmers, SAP's second generation of programmers in the 1980s consisted of a good dozen PhDs hired directly from the university. A significant number of German software companies, both the earliest software companies in the late 1960s and 1970s (AIV, GEI, IKOSS) and more recent software start-ups, were incubated within Germany's system of universities and technical colleges. Indeed, virtually all major German software companies cultivate significant relations to the universities in order to keep abreast of emerging industry trends and techniques and to recruit young programmers familiar with the latest hardware and programming tools.

Germany's comparatively strong university-industry links help compensate for other handicaps with respect to competing in standardized software. First, in complementary segments of the computer industry, especially hard-

[10] This emerges fairly clearly from *Stellungnahmen* issued by BITKOM (the industry association discussed below) and the Fachverband Informationstechnik of VDMA. These associations advocate the introduction of curricula such as Bachelor Degrees involving shorter lengths of university study.

Figure 5

Alternative Paths of Software Firm Evolution

	ENTREPRENEURIAL	CUSTOMIZED	SCIENTIFIC
Initial Develpoment Phase	Entrepreneurial Start-Up **Software AG**	Freelance Artisan **SAP**	Structured Work or Modeling Process
Higher-Volume Production Phase	Blockbuster Producer	Consultancy/Niche Service Provider	Industrial-Strength Software Factory

ware and semiconductors, Germany is not a leading global player. Historically, German producers of standardized software did not enjoy the same access to newly emerging hardware specifications as Silicon Valley producers; recently, some firms have set up units in California in order to monitor emerging sectoral trends. Second, German producers contend with a highly heterogeneous market on the European Continent, with different languages, different software market characteristics, and geographical fragmentation of business practices in user industries (e. g. German banking functions differently from Italian banking).

Germany's national system of innovation (NSI) extends beyond just the universities, however, and embraces a variety of further research institutions that also engage in software development. Research centers include a Helmholtz Center (*Gesellschaft für Mathematik und Datenverarbeitung)*, a Max-Planck-Gesellschaft institute for computer science, and seven Fraunhofer institutes which are partly or fully active in various segments of information technology, including a newly opened institute in Berlin. Altogether, over 600 employees work in these institutes (Abramson et al., 1997, 341). The contract work conducted by these institutes (especially the Fraunhofer institutes) lends itself more to satisfying the needs of specific users (customized software) than the exploration and exploitation of mass market opportunities (standardized software).

It is also on the basis of these structures that Germany's NSI is sometimes portrayed as especially geared to the production of technically sophisticated, customized software solutions using state-of-the-art scientific techniques (BMBF/DLR, 1996; Abramson et al., 1997; BMBF, 1998). Germany's NSI, in particular the role and special competence of its research institutes, is considered more oriented toward collaborative software projects to satisfy the specific IT needs of contracting companies than toward the design of software products for the global market. In other words, Germany's NSI is considered by some to have an inherent bias toward customized rather than standardized software production. Seen from this standpoint, one objective of government policy has been to assist German computer scientists in developing new techniques to improve the speed, quality, and cost-efficiency of custom software development. This point is discussed next.

3.2 Government Policy

With respect to the effects of government policy, Germany's software sector has benefited from policies that differed in kind from the state support programs for software development that were attempted in France, Britain, and Japan. France (with its Plan pour la Filière Electronique in the 1980s and Plan Calcul in decades prior), Britain (with its Alvey Program of 1983-88), and Japan (with its Fifth-Generation Computer Project) enacted "mission-oriented" policies that aimed at improving their national software industries through targeted government support either for specific firms (France) or specific high-visibility projects (Britain, Japan). Such mission-oriented state support, relying on pre-defined industrial goals and concentrated resources, have been largely unsuccessful (Mowery, 1996). The rapid rate of technological change in computing and the *ex ante* highly uncertain knowledge of market demand for software products make it difficult for mission-oriented support programs to channel resources into commercially valuable efforts.

In contrast, the more "diffusion-oriented" government support policies for software in Germany are generally credited as more effective (Malerba and Torrisi, 1996). These policies have focused more at stimulating the development of software competence at the level of universities and research institutes and at inducing the sharing of this competence with commercial users. Instead of "picking winners," German software support programs have reflected the institutional and historical features of German public policy: decentralized reliance on structured consultation and cascading initiatives, emphasis on education and human capital, and making the provision of public resources contingent on interorganizational cooperation on specific research projects.

The Federal Ministry of Education and Research (BMBF) has granted financial support of approximately 400 million DM since 1980 (figure extrapolated from BMBF/DLR, 1996). In the 1990s, the BMBF became aware of two trends: 1) the growing importance of software as opposed to hardware; 2) the gap between the techniques pursued in basic software R&D and the actual practices and needs of industry. The most recent BMBF-sponsored program in software was the Sponsorship Initiative for Software Technologies in the Economy, Science, and Technology (*Initiative zur Förderung der Softwaretechnologie in Wirtschaft, Wissenschaft und Technik*). In the years 1995-98, 27 software projects aiming to incorporate new software techniques into application software were sponsored (BMBF/DLR, 1996). These projects involved 95 partner firms (including many small- to medium sized ones) and research institutes (including universities and technical colleges). The program's explicit goal was to transfer into commercial practice some of the extensive basic scientific research that had been conducted in academia, with three main areas of endeavor:

- New techniques for modeling organizational and technical systems and processes;
- Methods and tools for the update and re-use of pre-existing user applications;
- Development of methods for improving the security and reliability of complex software systems.

As a sign of commitment to technology transfer rather than basic research, the participating firms rather than the scientific partners were charged with the writing up (*Federführung*) of the final reports (BMBF/DLR, 1998).

While still actively interested in supporting Germany's software industry, the BMBF remains concerned about the overall benefits of this type of sponsorship and is now actively considering alternative approaches (BMBF/DLR, 1998: 263-5). Recent consultation with experts has led the BMBF to consider the strategy of "strengthening clearly existing strengths" in German software, namely in the areas of "application-related" and of "sophisticated high-quality" software (BMBF/DLR, 1998: 266). Areas of possible future sponsorship include software development in embedded systems, complex integrated application systems, and Internet-based standards and tools.

Most government policy has essentially treated software as a *factor of production* and endeavored to enhance the cost/quality ratio of this production factor for German user companies. Yet with the emergence of global open systems and platforms and the ensuing liberation of software from particular hardware systems, software has become an increasingly autonomous industry whose development is shaped by market processes. Reflecting the obvious importance of global software markets, an entirely different approach to software sponsorship is (implicitly) embedded in the BMBF's (and the Economics Ministry's) recent initiative EXIST-*Existenzgründer aus Hochschulen*, launched in December 1997. The EXIST competition sought applications for the establishment of university-based regional networks to foster entrepreneurial ventures, particularly in high-tech. The excellent response rate amounted to 109 proposals involving about 200 of Germany's 326 universities and colleges. Of 12 finalists, five proposals were funded with 45 million DM. The EXIST initiative represents an ongoing government effort to encourage academically-trained people to start their own business, especially in the high-tech area. Although not specifically mentioned, the software sector clearly constitutes one of the most attractive areas for such entrepreneurial endeavor (Casper, Lehrer, and Soskice, 1999).

In summary, there exist two main types of government policy for supporting the software sector. The more traditional form of policy aims to strengthen the basic scientific competence of software development in a decentralized, cascading way. The more recent supplementary approach seeks to encourage entrepreneurship and start-up ventures. Both approaches to software support revolve around universities and research institutes (decentralized diffusion-oriented policies) rather than around national strategic goals or national champion firms (centralized missions-oriented policies). Given the high market uncertainty and rapid rate of technological evolution in the software industry, these kinds of policies are fundamentally sound. Clearly, the more recent efforts by the government in favor of entrepreneurship and start-ups dovetail with the emergence of the *Neuer Markt* and the general high-tech boom in Germany (Lehrer, 2000).

3.3 Interest Representation

It was not only German government policy-makers who were slow to adapt to the evolution of software from a factor of production within companies to an increasingly autonomous industry. German industry was slow to organize accordingly. Until the end of 1999, the German software industry was less organized than other major German industries. Over 20 fragmented software associations like the Bundesverband Informationstechnologien (BVIT), the Verband der deutschen Softwareindustrie (VSI), the Bundesverband Informations- und Kommunikations-Systeme and the IT sections (*Fachverbände*) in the VDMA (the German mechanical engineering association) and ZVEI (the German electric and electronics association) represented only a fraction of the software and software services company in an industry having neither employers' associations nor real unions. This meant that the industry was in a poor position to lobby government for policy changes. As this author wrote in 1998: "This industry requires an effective representation of its interests in order to promote urgently needed reforms, not least of all in the education system. Unlike certain other organized interests which demand traineeships in economic sectors where there hardly exist opportunities for more employment, the software sector watches helplessly as the number of unfilled positions skyrockets due to an insufficient supply of qualified personnel" (Lehrer, 1998).

In 1999, major changes did, at last, take place. In the summer, the largest software associations (BVIT, the IT sections of the VDMA and ZVEI, plus the BVB Bundesverband Informations- und Kommunikations-Systeme) began talks to create a single large association for information technology and telecommunications (ITC). This led to the founding on October 28 of the Bundesverband Informationswirtschaft, Telekommunikation und neue Medien (BITKOM), with headquarters in Berlin. BITKOM joined the BDI (to which previously only the larger ITC companies in the VDMA and ZVEI belonged) and was formed just in time to join the newly formed European ITC association, EICTA (European Information and Communications Technology Information Association, founded on 16 November 1999 in Brussels). Volker Jung of Siemens AG was elected both President of BITKOM and Vice-President of EICTA within a three-week period. With some 75,000 unfilled IT positions in Germany and 367,000 in the European Union, the rationale for a bundling of interest representation hardly needs explanation.

With its original four founding associations, BITKOM boasts representation of about 95% of the ITC industry:

1000 companies, 200 billion DM in annual revenues, and about 700,000 employees. The clear goal of BITKOM, however, is to induce all other associations and companies to merge with it. BITKOM's policy is for all companies to have but one single vote in the general assembly, whether a large industrial firm or a small IT consultant's firm with two employees (Jung, 1999). Beyond lobbying for specific measures to assist the German IT industry, BITKOM advocates a restructuring of ministerial offices in the federal and state governments to enable tighter coordination of IT policy: "It cannot be that responsibilities for agriculture are bundled in a single powerful ministry while information and communication are taken care of by a few ministry officials scattered across several ministries. Our topics are too important as to allow according them anything other than top political priority" (Jung, 1999). From a macroeconomic standpoint, it is hard to disagree with this view. The German government's surprisingly speedy decision to distribute IT green cards to foreigners in 2000 is a sign that the macroeconomic significance of information technology is at last gaining widespread acknowledgment in Germany.

4. Conclusion

In the traditional world of mainframe computers, German software development was largely carried out by user companies themselves without recourse to external software markets. Government programs to support software development regarded software engineering largely as a technological factor of production and was little concerned about influencing the software industry *qua* industry, as an arena of competing firms. This was reasonable for as long as software development was accomplished without market transactions. In the meantime, however, Germany's software sector is organizing itself increasingly according to market principles — including the market for political influence (lobbying). As the IT *Fachverband* of the VDMA put it: "Our core business is politics" (www.fvit-eurobit.de).[11] For policy-makers this means putting a greater emphasis on improving the efficiency of market mechanisms for creating and disseminating software know-how alongside the traditional emphasis on funding software R&D as a public good.

The diffusion-orientation of Germany's public support programs deserves to be continued. But in the future it will no longer be only a question of creating the conditions for new knowledge creation, but of nurturing *innovation markets* in the area of software (which increasingly overlaps with the entire information and telecommunications sector). Software innovations in Germany will not only arise at universities, technical colleges, and the typical joint industry-university research projects subsidized by government, but will also emerge out of interactive market processes and the dynamics of competition. If Germany can position itself as the world's second most important national innovation market for software and software services — a goal that is eminently reachable and perhaps already attained —, then global software players will see Germany not only as a market to sell to, but as a strategically important market for innovating in and for developing next-generation products and services.

With respect to the three general approaches to software development outlined earlier, this means that future public policy for software should rest on multiple pillars so as to be equally attentive to the needs of scientific, entrepreneurial, and service-oriented developers of software. The increasing importance of *software markets* implies the need for institutions of higher learning and research to position their educational curricula and contract research in a more strategic way. *In fine*, dynamic market processes will lead to an increasing differentiation and specialization of software knowledge requiring an analogous differentiation and specialization of such knowledge in Germany's public institutions.

11 "Unser Kerngeschäft ist Politik"

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Zusammenfassung

**Vom Produktionsfaktor zur eigenständigen Industrie:
Die Transformation der Softwarebranche in Deutschland**

Wenngleich es heutzutage im Zeitalter der technologischen Konvergenz und Digitalisierung schwer ist, die Grenzen der Softwareindustrie genau festzulegen, soll im vorliegenden Beitrag versucht werden, das Profil des deutschen Softwaresektors unter drei verschiedenen Gesichtspunkten zu bestimmen: (1) hinsichtlich der Geschäftsfelder, auf die sich deutsche Softwarefirmen vornehmlich spezialisieren; (2) hinsichtlich der verschiedenen Unternehmensmodelle und -strategien im Softwaresektor, und (3) hinsichtlich der Komponenten des „nationalen Innovationssystems" im Bereich der Softwareproduktion. Diese drei Aspekte der deutschen Softwareindustrie befinden sich in einem rapiden Umwandlungsprozess. Daher beschreibt die folgende Charakterisierung des deutschen Softwaresektors durchaus eine Industrie im Übergang.