The Use of Patent Data for Technological Forecasting: The Diffusion of CNC-Technology in the Machine Tool Industry

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ABSTRACT. In the 1980s, a dramatic change in the competitive structure of the machine tool industry through the development and implementation of CNC-technology occurred. For the individual company, the timely anticipation and forecast of these technological challenges has been of vital importance in order to incorporate these technological changes into its strategic planning process. This paper assesses the suitability of patent data for forecasting technological developments, based on the experience in the case of CNC-technology. Following a general description of the technological life cycle concept and the discussion of possible benefits of patent data as a technological forecasting tool, actual patenting activity in CNC-technology is analysed. It is found that the diffusion of CNC-technology can be appropriately described by means of patent data. Different development stages in the life cycle of CNC-technology can be distinguished, where for each stage strategic R&D investment decisions can be derived. Analysing the impact of CNC-technology on the trade pattern between Japan and Germany clearly reveals that patenting activity causes subsequent and immediate market changes. The strong Japanese patent position in CNC-technology is closely associated with favourable trade changes. Consequently, it is recommended to incorporate the systematic and continuous monitoring of patenting activity into a company's overall competitor monitoring intelligence. Especially for small and medium-sized enterprises, patent data analysis provides a technological forecasting instrument with high potential benefits and relatively low cost.

1. Introduction

In a recent article, Wieandt (1994) analysed the impact of an emerging innovative technology on the competitive structure of an entire industry (Wieandt, 1994, pp. 421–437). For the machine tool industry, Wieandt (1994) showed that Japanese companies had been very successful throughout the 1980s in imploring their competitive position relative to their competitors in the United States of America (U.S.A.) and Germany, through the development and implementation of computerised numerical control (CNC) machine tool technology. This new CNC-technology dramatically changed the basis of competition in that industry, it opened up new markets and simultaneously destroyed established markets. As Wieandt (1994) concluded:

> What caused these changes in market shares? Further analysis suggests that the shifts in market shares have been caused to a large extent by innovation. The Japanese have successfully managed to *create new markets through innovation*. They have found new customers all over the world, many of them in the U.S., for their NC machine tools thereby *destroying most of the domestic markets* of machine tool manufacturers (Wieandt, 1994, p. 429).[1]

For the individual company, the timely anticipation of these technological advances is of vital importance in order to incorporate technological changes into its strategic planning process (Lange, 1994, pp. 3–9). Technological changes can be an early warning signal for subsequent fundamental market shifts and hence for the future competitive position of individual companies (Martino, 1982, p. 77; Pfeiffer *et al*., 1986, pp. 112–113). Therefore, a lot of effort has been devoted to the important issue of technological forecasting in the literature and a variety of forecasting techniques have been developed (Brockhoff, 1994, pp. 132–144; Geschka, 1995, pp. 630–640; Porter *et al*., 1991, pp. 64–66).

In the literature, it is often argued that patent data are a valuable source of information for the

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early detection of technological changes (Campbell, 1983, pp. 137–143; Fendt, 1983, pp. 40–45). The availability of patent data from on-line databases or CD-ROM facilities has greatly enhanced the possibilities for the systematic evaluation of patenting activities. Hence, there is an intensive call for the use of patent information for strategic business planning in a variety of fields (Ashton/Sen, 1988, pp. 42–46; Brockhoff, 1992, pp. 41–58; Fendt, 1988, pp. 72–80; Fendt, 1983, pp. 40–45; Merkle, 1985, pp. 391–418; Mogee, 1991, pp. 43–49; Van der Eerden/Saelens, 1991, pp. 18–25). According to Campbell (1983), patent data can particularly be used in order to forecast technological developments:

> Patent indicators provide a very useful *forecasting tool for decision makers* in the public and private sectors. . . . Patent analysis can indicate the *growth pattern of a technology* (emerging, maturing or declining) and the technological skills that are occurring. It can also indicate *which firms are about to enter or leave a technology*, the *age and type of each firm's technological base*, and the *relative technological strengths of the firms* (Campbell, 1983, p. 137).

The use of patent data for strategic business planning is further stressed by empirical research, where a positive relationship between research and development (R&D) expenditures and subsequent patenting activities has been found (Griliches, 1990, pp. 1701–1702). In addition, latest empirical work establishes a positive impact of patenting activity on a company's economic performance. Using a set of different patenting indicators, Ernst (1995a) identifies four different types of patenting strategies in the German machine tool industry. Companies which show high patenting activity together with a high patenting quality are found to perform significantly better compared to the other companies in the research sample (Ernst, 1995a, pp. 232–236).[2] Thus, patent data are to be considered as an indicator of technological activities, which are transformed into subsequent market success. This result enhances the usefulness and meaningfulness of patent data for strategic planning applications. The outlined business applications and empirical research clearly reveal that possible users of patent information are to be found in top management or strategic planning departments of business firms. It is therefore not surprising that patent issues have become a major aspect on the top management's agenda (Shapiro, 1989, pp. 7–9).

Based on these empirical observations, it becomes highly interesting to examine, whether the fundamental market changes in the machine tool industry through the introduction of new CNC-technologies are mirrored by patent data. This paper picks up this issue and addresses the following main questions:

1. Can the diffusion process (technological life cycle) of CNC-technology in the machine tool industry be described by means of patent data, i.e. do changes in patenting activity reflect different stages in the life cycle of this particular technology?
2. Does patent data indicate international differences in the technological focus, i.e. can the dominant Japanese position in CNC-technology be attributed to strong patent positions?
3. Can a relationship between the international trade pattern and relative patent positions be established, i.e. does the technological position, as measured by patent data, influence the trade pattern between Germany and Japan in the machine tool industry?

If patent data are found to provide the required information, it should not be neglected for technological forecasting and thus for technological decision making purposes. Then, analysing patent data should be included in any competitor technology intelligence (Brockhoff, 1991, p. 91). Large companies have already realised the benefits of patent information for various strategic planning purposes (Naetebusch *et al*., 1994, pp. 198–206; o.V., 1987, pp. 184–188). Since the need for assessing technological developments does not vary according to firm size (Balachandra, 1980, p. 82),[3] it becomes especially valuable for small and medium-sized enterprises (SMEs) to identify a technological forecasting tool, which adequately satisfies their information needs with respect to organisational resource constraints, e.g. a possible lack of financial or personal resources. Patent information would give in particular SMEs an instrument at hand, which offers a high benefit-cost-ratio and could furthermore be easily implemented in the overall strategic planning process (Schmoch, 1990b, pp. 161–162). Since the machine tool industry mainly consists of SMEs,[4] this paper should communicate the value of patent data analysis for technological forecasting purposes especially to SMEs. This seems to be of great relevance, since the value of patent information is barely recognised by SMEs. As Schmoch (1990b) stresses: "First, the concept "patent" is exclusively associated with legal matters. All the problems occurring here are, therefore, immediately delegated to the patent attorney. The high information content of the patent literature is, therefore, seldom recognized (Schmoch, 1990b, p. 159)."

This paper is organised as follows. In ***chapter 2***, the general concept of technological life cycles is discussed. We will first elaborate on the well-known S-curve approach in technological forecasting, since we plan to compare this concept to technological forecasting based on patent data. Second, the use of patent data as a technological forecasting tool is discussed. In ***chapter 3***, Japanese and German patenting activity in the field of CNC-technology is described. In ***chapter 4***, the impact of patenting behaviour on the international trade pattern between Germany and Japan is analysed. This paper closes in ***chapter 5*** with concluding remarks.

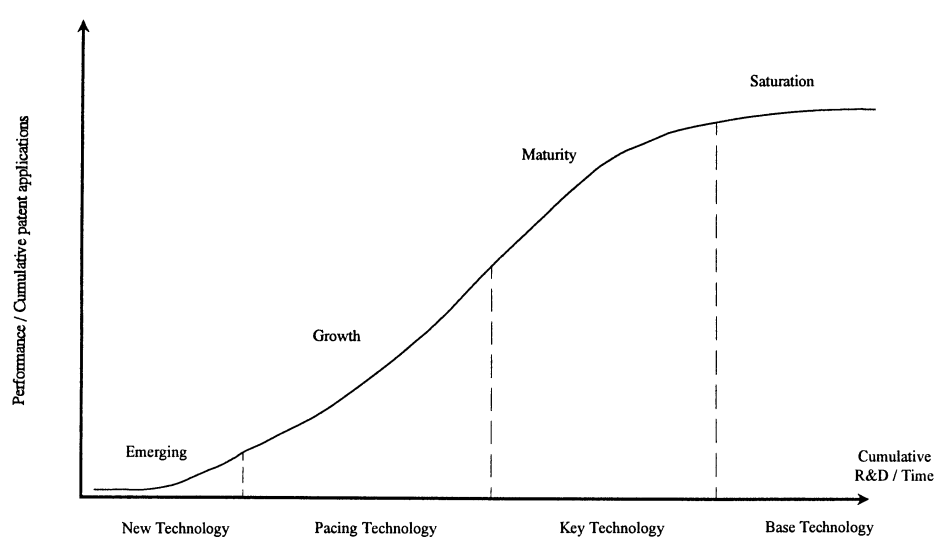
2. Concepts of technological forecasting

2.1. *The concept of technological life cycles*

As it is the case for the concept of product life cycles, technological forecasting basically assumes that technological change follows a certain pattern, where different development stages in a technology's evolution process can be identified. For the respective stage of an individual technology, strategic R&D investment decisions can be formulated (Sommerlatte/Walsh, 1983, pp. 298–321).

A first approach to identify technological life cycles comes from the observation that technological performance data for particular technologies over either time or cumulative R&D expenditures show an S-shaped relationship (Krubasik, 1982, pp. 28–31; Merino, 1990, pp. 275–291). Figure 1 illustrates the S-curve concept of a technological life cycle, where four different development stages can be distinguished.

The *emerging* stage is characterised by a relatively low growth of technological performance compared to the amount of R&D efforts. In the *growth* stage, the marginal technological progress over cumulative R&D expenditures is positive, whereas it is negative in the *maturity* stage. In the *saturation* stage small technological performance



Source: Own Graph.

Fig. 1. The S-curve concept of a technological life cycle.

improvements are only gained through very high R&D efforts. Based on the S-shaped technological development, strategic R&D decisions can be made. In the maturity stage, further investments in the "old" technology are not recommended, since future technological improvements are only marginal. Instead, it should be looked for a "new" technology (S-curve) with a higher future development potential (Brockhoff, 1994, pp. 154–155; Foster, 1982, pp. 22–27).

A major problem associated with the S-curve concept is the selection of an appropriate performance measure (Brockhoff, 1994, pp. 134–140). In technological S-curves, performance is measured in the technological dimension only. The integration of economic performance measures for the evaluation of technological potentials does not take place. As Brockhoff (1994) points out: "Excluded from the illustration are curves that reflect the number of innovations or market shares of technological innovations, which could be indirectly measured through market shares of new products based on the particular technology. . . . The reason for the S-shaped development must not only be attributed to technological performance criteria, since economic effects are plausible (Brockhoff, 1994, p. 134 and p. 139)."[5] The integration of economic aspects into the S-curve concept might be reached by using cumulative patent data. In Figure 1, the development of the cumulative patent stock of a particular technology over time could be plotted. On the one hand, patenting activity reflects the latest state-of-the-art in technological development. It is therefore an appropriate measure for technological performance.[6] On the other hand, patenting activity is oriented towards the commercialisation of a new technology[7] and empirical research shows a positive relationship between patenting activity and subsequent market changes (Ernst, 1995a, pp. 232–236; Ernst, 1995b; Griliches *et al.*, 1991, pp. 183–201, chapter 4). Consequently, it can be argued that aggregate patenting activity in a technological area measures both the technological progress and the market diffusion of a particular technology.

A second approach to assess technological life cycles has been developed in the consulting area. It is more oriented towards the market effects of technologies which can be incorporated into the S-curve illustration. Table I displays the concept of a technological life cycle according to A. D. Little. In this approach, technologies are classified according to two dimensions, i.e. a technology's integration in products or processes and its competitive impact. A *new* technology with low competitive impact and low integration in products or processes is, according to Figure 1, in the emerging stage. Technologies with a high (future) competitive impact, which have not been integrated in new products or processes yet are called *pacing* technologies. They are in the growth stage of the technological life cycle. If a technology becomes integrated in products or processes and maintains its high competitive impact, it turns into a *key* technology. This technology enters the maturity stage. As soon as a technology looses its competitive impact, it becomes a *base* technology. It enters the saturation stage and might be replaced by a new technology. As a major strategic ecommendation, R&D investment ought to be especially undertaken in pacing technologies. Thus, the identification of these technologies gains vital importance (Sommerlatte/Walsh, 1983, pp. 304–307). In this paper, the hypothesis should be tested, whether the development of aggregate patenting activity follows a life cycle pattern and thus helps to identify important technologies.

TABLE I
The concept of a technological life cycle according to A. D. Little.

		Integration in products or processes	
		Low	High
Competitive impact	High	Pacing technology (2)	Key technology (3)
	Low	New technology (1)	Base technology (4)
		Old technology (5)	

Source: Servatius, 1985, p. 117.

2.2. *Patent data as a technological forecasting tool*

The increasing supply of patent information has facilitated the possibilities of large scale patent data retrieval and evaluation. Thus, patent data have become increasingly important as an information source for strategic business planning. The importance of patent information in strategic planning is stressed by Ashton/Sen (1988):

> Patent information provides a *unique planning resource* for managing a firm's *technology or product development* and for *systematically evaluating its competitive position relative to other companies in a market area* (Ashton/Sen, 1988, p. 42).

In principle, six major business applications for patent data analysis have been identified. These are technology competition analysis, new venture evaluation, patent portfolio management, R&D management, product area surveillance and human resource management (Ashton/Sen, 1988, p. 44; Brockhoff, 1992, pp. 53–56). According to Ashton/Sen (1988), technology competition analysis and R&D management basically allow users to assess companies' different technological strategies and to identify their relative technological position in low- and high-growth technologies. This information is believed to improve R&D allocation decisions and to guarantee the best focus on long term product management strategies (Ashton/Sen, 1988, p. 44). A major advantage of patent data is the possibility of breaking it down into different technological fields, which are of particular interest for each individual company. Analysing the technological position of business firms relative to its competitors, Brockhoff (1992) developed a Patent-Portfolio, where the technological position is measured by means of patent data. Since patents are broken down into technological fields, the attractiveness of each technology and the relative patent position of the company under consideration compared to its major competitors in each technology can be judged. This should help the company to identify pacing technologies, to evaluate its technological position relative to major competitors and to redirect its allocation of R&D expenditures if necessary (Brockhoff, 1992, pp. 45–48).

According to Fendt (1983), the use of patent data for technological forecasting purposes and its major benefits can be summarised as follows:

> ***Technological changes*** threatening the ***survival*** of business firms are often recognised too ***late***, especially by those companies which have been ***technological leaders*** in a particular area and thus have enjoyed ***market success***. Early signals of technological change, with a high potential impact on the ***basis of competition*** are often very ***weak***. If suddenly, ***new competitors*** capturing strong positions in promising future markets emerge, it is often too late for effective retaliatory responses. However, there exists a relatively ***simple*** recipe against this scenario. The simple knowledge of the own technological capabilities is to be enhanced by the ***continuous monitoring of new technological developments***. It is of substantial importance to detect the slightest technological changes in ***key- and pacing technologies as early as possible***. Therefore, the ***systematic*** evaluation of information obtained from **patent documents** proves to be very valuable (Fendt, 1983, p. 40).[8]

Some elements of this statement need to be pointed out:

- Technological changes are often tied to subsequent market changes with a major impact on the competitiveness of individual companies or entire industries. They lead to the entrance of potential *new competitors*, change the *basis of competition* and even threat the *survival* of business firms.
- Companies holding strong market positions might be especially exposed to technological changes. *Technological leaders* with *market success* are tempted to overlook basic technological changes and are thus even more endangered to substantially loose well-established market positions.
- Signs of technological changes are often not very clear in a development stage of a new technology. Thus, companies might recognise *weak* technological changes too *late* in order to react to new technological challenges in time. Monitoring technological developments, companies frequently use sources of information, e.g. from trade exhibitions, which do not allow sufficient reaction time, whereas other sources of information, e.g. from databases, with a longer possible lead-time are rarely used (Brockhoff, 1991, p. 97). Companies are often surprised by new technological developments, which could have been seen in *earlier* patenting activity.
- Analysing patent data should not be executed on a temporary basis. The proper evaluation of technological changes requires a *systematic* and *continuous* monitoring of patenting activity.
- As far as the practicability of a forecasting tool is concerned, analysing patent data provides a *simple* monitoring instrument. The easy access

to patent information, the comfortable retrieval of patent information and the relatively low cost of data retrieval account for a high benefit-cost-ratio of patent data analysis for strategic business analyses (Schmoch, 1990b, pp. 161–162).

- It is assumed that patenting activity helps to identify *pacing- or key technologies*. The underlying assumption is the description of a technological life cycle by patent numbers. Based on the respective stage in the technological life cycle, technologies can be evaluated according to their competitive impact, where then strategic decisions can be derived from (paragraph 2.1).

The usefulness of patent data for technological forecasting purposes is affected by differences in the propensity to patent, which may vary among countries, industries, companies and over time (Pavitt, 1988, p. 514). Companies might choose to secure their inventions by other means of protection rather than filing a patent (Brockhoff, 1994, pp. 71–79). In these cases, low or entirely missing patent activity may not be interpreted as a sign of low R&D efforts. This would reduce the meaningfulness of patent data as a measure of R&D activities and hence as a technological forecasting tool. For this paper, three aspects need to be mentioned. First, there is empirical evidence for a positive relationship between patent activity and R&D expenditures at the firm level. This result has been confirmed in the cross-section and time-series dimension (Acs/Audretsch, 1989, pp. 171–180; Bound *et al*., 1984, pp. 21–54; Hall *et al*., 1986, pp. 265–283; Scherer, 1983, pp. 107–128). As Griliches (1990) summarises: “Nevertheless, the evidence is quite strong that when a firm changes its R&D expenditures, parallel changes occur also in its patent numbers (Griliches, 1990, p. 1674).” Second, empirical research shows that the effectiveness of patent protection and hence the propensity to patent largely depends on the particular industry under consideration (Mansfield, 1986, pp. 173–180).[9] This observation is important from a methodical perspective, since Schmoch *et al*. (1988) point out: “Whenever patent activities are analysed in homogeneous areas, all factors determining the propensity to patent are the same for every patent applicant, so that statistical interpretations are methodically correct” (Schmoch *et al*., 1988, p. 53). Since this paper concentrates on the machine tool industry only, this requirement for statistical patent data analysis is fulfilled. In addition, the machine tool industry is characterised by a substantial amount of overall patenting activity, thus implying a generally positive propensity to patent.[10] Furthermore, Ernst (1995a) identified four different types of patenting strategies in the German machine tool industry, where companies following an active and high-quality patenting policy showed the highest economic performance (Ernst, 1995a, pp. 235–236). Thus, there appears to be strong evidence for using patent data as a measure of technological activities in the machine tool industry, which are positively related to subsequent market success. Third, patenting activities are influenced by firm size. Whereas larger firms receive an higher amount of total patents, small firms appear to be more efficient, receiving a larger number of patents per R&D expenditures (Griliches, 1990, p. 1674).[11] Patent protection should therefore not be underestimated as an important competitive tool for SMEs, as it is witnessed by the substantial patenting activity in the machine tool industry (Rothschild, 1987, pp. 24–30).[12] In conclusion, patent data appear to be a suitable indicator for R&D activities, which is a major prerequisite for its use as a technological forecasting tool. However, one need to be aware that the usefulness of patent data as a technological forecasting tool varies according to differences and changes in the propensity to patent, which in turn is affected by various factors, e.g. the industry under consideration. The degree of effective patent protection, as evidenced by a higher propensity to patent, determines the effectiveness of patent data as a technological forecasting tool. Thus it may be highly advisable to add other sources of technological information to the analysis of patent data if necessary. As Brockhoff (1991) points out: “While the observation of patenting activities is not equivalent to a full-scale review of technological trends, it is one of its cornerstones” (Brockhoff, 1991, p. 91).

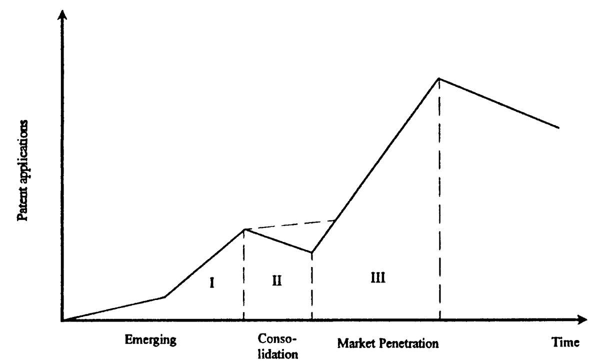
There exist a variety of patenting indicators to be used for strategic planning purposes (Brockhoff, 1992, pp. 41–58; Campbell, 1983, pp. 137–147; Ernst, 1995a, pp. 228–229). For technological forecasting, however, not all patenting indicators seem to be suitable. In this paper, we purposely restrict ourselves to indicators of overall patenting activity, as measured by patent applications. There are three major advantages of this patenting indicator as a technological forecasting tool:

1. ***Relevance***: Patent applications are considered as a fundamental patenting indicator, since they are assumed to reflect overall management commitment to patenting as a competitive tool (Campbell, 1983, p. 139). Patent applications do not differentiate patent documents according to their individual technological or economic quality.[13] However, patent applications are the best available and immediate output measure of R&D activities (Griliches, 1990, pp. 1701–1703; Brockhoff, 1993, p. 184).[14]
2. ***Time***: Patent applications are available for patent data analysis at the earliest possible stage. Patent applications at the European patent office (EPO) or the German patent office (GPO) are accessible 18 months after the priority date.[15] Quality measures of a patent application, e.g. patents granted or patent citations are not available at this early stage.
3. ***Access***: Patent applications can be comfortably retrieved from various suppliers of patent information at relatively low cost. The cost of patent data retrieval has to be seen in relation to potentially high benefits of patent information.

In order to obtain a quality measure of patenting activity, foreign patent applications can be analysed. Foreign patent applications have been found to be of higher economic value (Ernst, 1995a, p. 236). However, early technological developments are often patented first nationally. Therefore, patent applications at the respective national patent offices need to be screened, too.[16]

Figure 2 illustrates the theoretical development of patenting activity, as measured by patent applications, over time. Basically, three different development stages can be distinguished.

Phase I can be called the *emerging* phase of a new technology. Prior stable patenting activity is suddenly interrupted by a substantial increase in patenting activity. The number of patenting companies is rather small at this stage. The first peak of aggregate patenting symbolises the end of the development stage. First products, based on the new technology, are introduced into the market. In phase II, the growth of patenting activity is lower compared to the preceding stage. Here, R&D efforts are newly focused, based on the first experiences with the new technology in the market. One might label this stage *consolidation* phase. Phase III is characterised by a dramatic increase in total patenting activity. In addition to the former patent applicants, new companies start filing patents in the particular technological area. Patenting activity rises up to a new peak, which is substantially higher than the first peak in phase I and thus indicates the final breakthrough of the new technology (Basberg, 1987, p. 134). We label this stage *market penetration* phase. It has to be stressed that this development pattern is entirely based on patent applications, since we concentrate on technological forecasting only. This life cycle concept, however, can retrospectively further be described by other patenting indicators (Campbell, 1983, p. 143). It is for instance reasonable to assume that patent applications in phase III cite former patent applications from phases II or I. In these phases important basic patents had been filed, whereas subsequent patent applications represent further developments.[17] In the following chapter 3 it should be analysed, whether patenting activity in CNC-technology at the GPO follows the previously discussed pattern, where technological forecasts can be based upon.



Source: Own Graph.

Fig. 2. The theoretical development of patenting activity over the technological life cycle.

3. Analysis of patenting activity in CNC-technology

3.1. *Data retrieval*

Prior to the actual data retrieval from patent databases, the relevant international patent classification (IPC) symbols have to be identified, in which patents concerning control-technology in the machine tool industry are filed by the respective patent applicants. There are two major areas in the IPC-classification scheme, where control-technology patents can be found. Control-technology in a wider definition comprehends patents filed in the IPC-classes B23Q015-B23Q027 and G05B019/00-417.[18] In the former IPC-classes primarily mechanical control-technology patents can be found, whereas in the latter IPC-classes mainly patents for electronic control-technology are filed. In the following, we shall concentrate on the narrow definition of CNC-technology, isolating electronic control-technology patents in IPC-classes G05B019/00-417 only.[19]

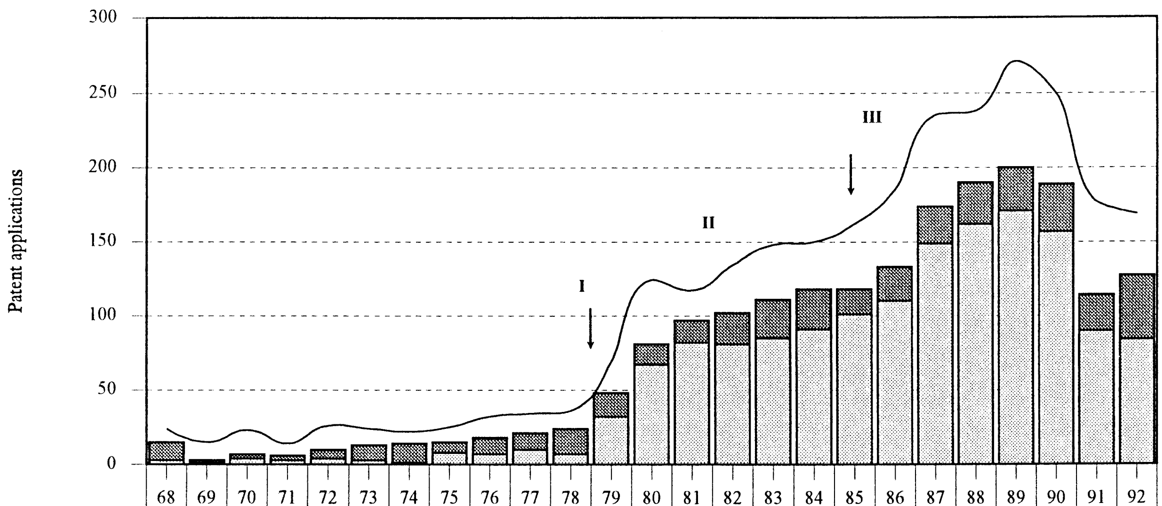
Patent data were then derived from the patent database of the GPO PATDPA. PATDPA comprehends patent documents, which assure legal protection for an invention on German territory since 1968. These patent documents can either consist of patent applications via the Patent Cooperation Treaty (PCT) mechanism, patent applications at the EPO with Germany as a designated state for patent protection, or direct patent applications at the GPO. Since 90% of the overall patent applications at the EPO claim Germany as a designated state, PATDPA provides an almost complete picture of German and European patenting activities (Schmoch *et al*., 1988, p. 81). Since international differences in patenting behaviour exist, a comparison between German and Japanese patenting activity in CNC-technology at the GPO has to be interpreted carefully, due to two reasons. First, German patent applicants enjoy a so-called "In-Country-Advantage", because more inventions are filed nationally (GPO, 1993, pp. 14–17). This possible overestimation of German patenting activity in comparison to foreign patenting in Germany can be reduced by analysing patent data at a "neutral" third patent office, e.g. the EPO (Pavitt, 1988, p. 517). At the outset, it can be assumed that German inventors will show a higher patenting activity at the GPO than their Japanese counterparts. Second, foreign patent applications of Japanese inventors in Germany are presumably of higher quality in comparison to national German patent applications.[20] By looking at patent numbers at the EPO, a more objective picture of patenting activity in CNC-technology can be gained.

3.2. *Japanese and German patenting activity in CNC-technology*

In Figure 3, annual Japanese, German and overall patent applications in CNC-technology between 1968 and 1992 are displayed.

Before 1979, a stable patenting activity can be observed. The number of German patent applications lay above the number of Japanese patent applications. Between 1979 and 1980, the overall number of patent applications substantially increased. It almost quadrupled from 36 patent applications per year in 1979 to 124 in 1980. This increase in total patenting activity was mainly caused by Japanese patent applications. In this period, German patenting activity slightly decreased. Between 1981 and 1984 overall patenting activity remained rather constant. However, annual Japanese patent applications were four times higher than German patent applications. After 1984, patenting activity in CNC-technology dramatically increased. It almost doubled from 150 patent applications per year in 1984 to the peak of 271 patent applications per year in 1989. This sharp increase was again largely determined by Japanese patenting activity. In 1989, annual Japanese patent applications were almost six times higher compared to German patent applications. Since 1990, overall patenting activity has declined. This development has been largely influenced by the decreasing Japanese patenting activity. It is interesting to note that German patenting activity, contrary to the overall patenting trend, substantially increased in 1992. This can be interpreted as the attempt of German machine tool producers to break the strong market position of their Japanese competitors in CNC-technology. However, Japanese annual patent applications were still on a higher level.

Looking at Figure 3, the pattern of patenting activity in CNC-technology basically follows the



	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Germany	12	2	3	3	6	10	13	7	11	11	17	16	14	15	21	26	27	17	23	25	28	29	32	24	43
Japan	3	1	4	3	4	3	1	8	7	10	7	32	67	82	81	85	91	101	110	149	162	171	157	90	84
Total	24	15	23	14	26	24	22	25	32	34	36	69	124	117	134	148	150	162	185	235	238	271	250	177	169

Source: PATDPA.

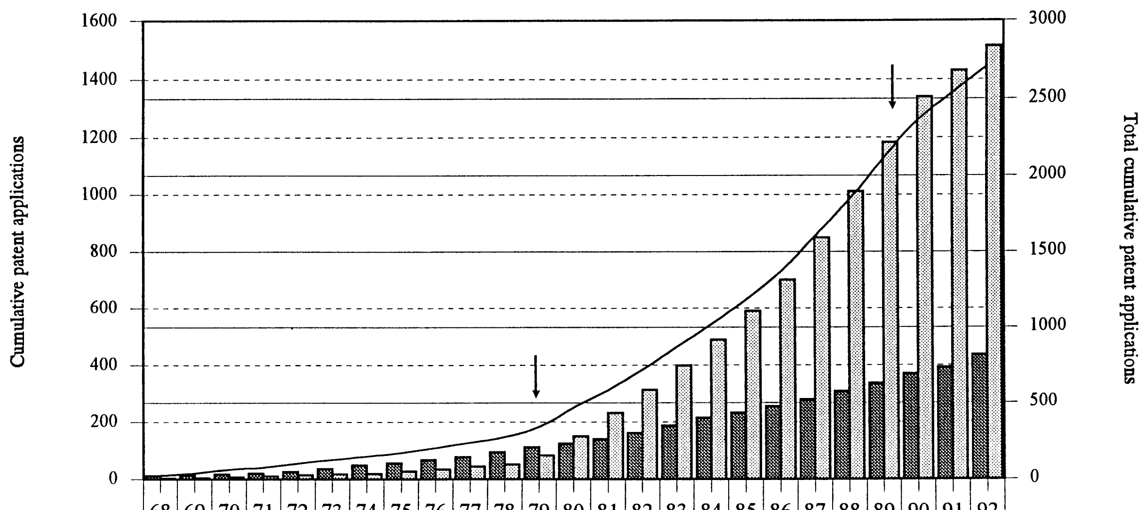
Fig. 3. The development of patent applications at the GPO in CNC-technology (1968–1992).

previously discussed theoretical technology diffusion model based on patents, which is shown in Figure 2. In phase I, prior to 1981, the new technology was developed. The first increase of overall patenting activity between 1979 and 1980 clearly signalised the end of the technological development phase and the upcoming of the new technology in machine tool products. In this period, the number of patent applicants was relatively small. In phase II, between 1980 and 1984, the stable rate of patenting activity might be characterised through the redirection of R&D efforts. Based on first market experiences, development efforts were aimed at the adaptation of the new technology to individual market needs. The result of this consolidation process can be seen in phase III after 1984. The sharp increase of patenting activity up to a second overall patenting peak in 1989, which was almost 2.5 times higher than the first peak of patenting activity in 1980 mirrors the final market breakthrough of the new technology on a broad scale. This is further stressed by an increasing number of new patent applicants in CNC-technology. To sum up, it becomes obvious that patenting activity in CNC-technology has followed a development pattern, which is assumed to symbolise the diffusion process of the new technology. It has to be analysed, whether this argument can be supported by looking at economic indicators for the market diffusion of CNC-technology (chapter 4).

Figure 4 illustrates the cumulative development of Japanese, German and overall patent applications in CNC-technology since 1968.

In 1980, the Japanese cumulative patent stock passed the German position and lay in 1992 almost 3.5 times higher than the German patent stock in CNC-technology. It has to be pointed out that the dominant Japanese patent position is measured at the GPO, which generally tends to overestimate German patenting activity. Looking at the development of overall cumulative patent applications, the shape of an S-curve becomes obvious. Three different stages of technology development occur and can be interpreted according to the diffusion scheme already discussed in Figure 1:

1. Before 1979, the *new* technology had been developed. The *emerging* technology had not



	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Germany	12	14	17	20	26	36	49	56	67	78	95	111	125	140	161	187	214	231	254	279	307	336	368	392	435
Japan	3	4	8	11	15	18	19	27	34	44	51	83	150	232	313	398	489	590	700	849	1011	1182	1339	1429	1513

Source: PATDPA.

Fig. 4. The development of cumulative patent applications at the GPO in CNC-technology (1968–1992).

been integrated in new products yet and the competitive impact had been rather low.

2. In the period between 1979 and 1988, the sharp, exponential increase in cumulative patenting activity indicated the *growth stage* of the new technology. The competitive impact of the technology increased, however, the technology had not been fully incorporated in products yet. At this stage, the technology could be labeled as a *pacing* technology.
3. Since 1989, the overall cumulative patent applications have grown at a much lower rate. Especially the growth of Japanese patent applications has decreased. Thus, it can be argued that the technology has entered the *maturity stage*, in which the marginal growth of technological improvements, as indicated by patenting activity, follows a concave shape. The technology has widely diffused in the market and the competitive impact remains still high. The technology in this phase has become a *key* technology in the machine tool industry.

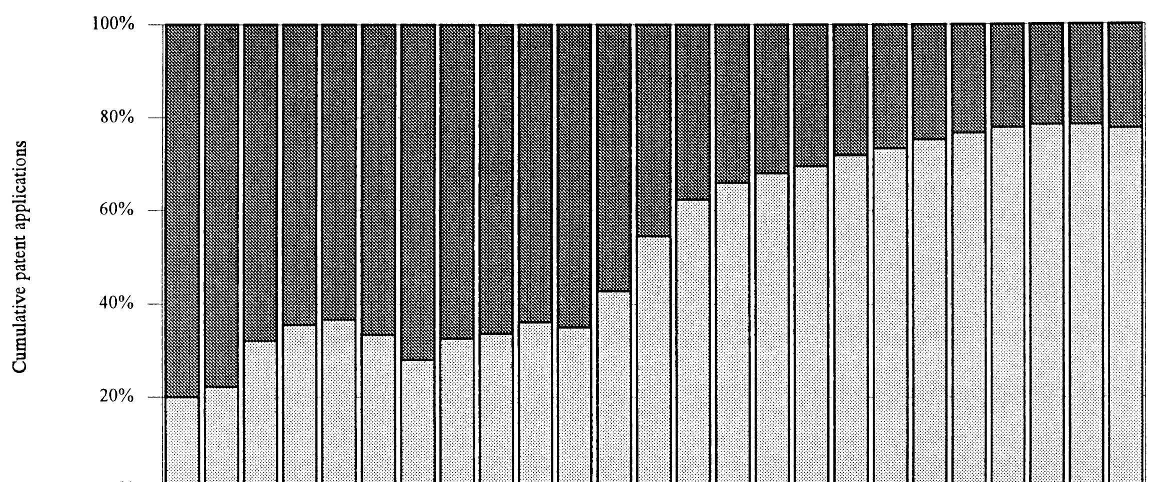
However, one could argue that the decline in overall patenting activity in CNC-technology has to be attributed to the economic slowdown at the beginning of the 1990s in Japan and especially in Germany. This argument can be tested by looking at relative growth rates of patent applications within the overall machine tool industry. It is revealed that, since 1989, the growth rates of patent applications in CNC-technology have been much lower, compared to the average growth rate of patent applications in all other technological areas concerning the production of machine tools (Ernst, 1995b).

4. Following the S-shaped technological development pattern, one might forecast the entrance of CNC-technology into a *saturation stage* in the future. The competitive impact gradually declines and the technology becomes a *base* technology in the industry. This information is of major importance for future R&D investment strategies for machine tool manufacturing companies. According to the information obtained so far, CNC-technology has been found to be in a mature stage, where the potential of further technological progress seems to be restricted. Another important

drawback for future investments in CNC-technology comes from the strong patent position of Japanese companies as a legal obstacle for further developments in CNC-technology (chapter 5).

The different patenting behaviour of Japanese and German inventors is further stressed in Figure 5.

Figure 5 plots the relationship between Japanese and German cumulative patent applications since 1968. Up to 1978, German inventors dominated the field of CNC-technology at the GPO with more than twice the cumulative patent stock compared to Japanese competitors. Thus it is plausible to assume that some German inventors were at that time aware of the upcoming new technology and must have already gained some technological knowledge, as witnessed by the patenting activity in this technology. However, after 1978, German inventors did not react to the technological offensive by their Japanese competitors. An explanation for the passive reaction might be attributed to the dominant market position of German machine tool manufacturing companies at that time. According to Wieandt (1994), German machine tool manufacturing companies in *1975* accounted for 17.6% of total world production, 30.4% of total world exports and had an export-import-ratio of 8.3. Japan on the other hand, accounted for 7.8% of total world production, 5.2% of total world exports and had an export-import-ratio of 2.2 (Wieandt, 1994, p. 428). At this stage, Japanese companies were eager to offensively attack the dominant German market position through the development and introduction of an innovative technology. As the follower in a particular market, the Japanese companies were ready to take the risk of investing into the new technology, whereas the leading German machine tool manufacturing companies could have been tranquillised by their already existing market success. They might have underestimated the impact of the new technology and did not push it to the market, despite basically knowing about the new technology's upcoming.[21] Here, an innovation pattern can be observed, which is often mentioned in the literature, where the market follower successfully attacks the dominant market position of established firms through fundamental innovations, which change the existing basis of compe-



	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Germany	12	14	17	20	26	36	49	56	67	78	95	111	125	140	161	187	214	231	254	279	307	336	368	392	435
Japan	3	4	8	11	15	18	19	27	34	44	51	83	150	232	313	398	489	590	700	849	1011	1182	1339	1429	1513

Japan Germany

Source: PATDPA.

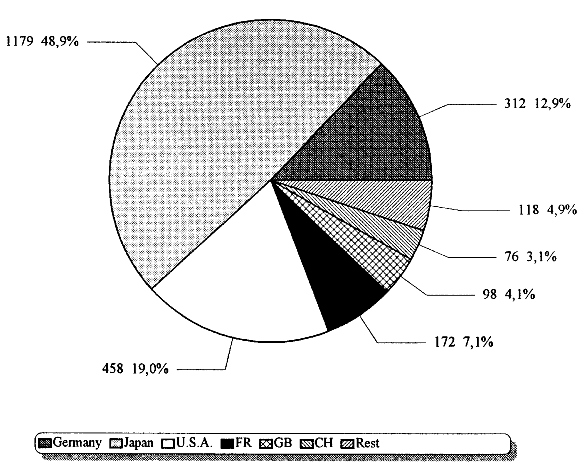
Fig. 5. The Japanese/German share of cumulative patent applications at the GPO in CNC-technology (1968–1992).

tition in an industry. In 1990, the ratio of cumulative Japanese/German patent applications peaked at 80% to 20%. Consequently, market figures in comparison to 1975 changed dramatically. In 1990, the share of German machine tool manufacturing companies of total world production remained stable at 18.9%, whereas the share of total world exports declined to 23.6% and also the export-import-ratio decreased to 2.4. Japan on the other hand, increased its share of total world production to 23.2%, its share of total world exports to 18.3% and had an export-import-ratio of 6.2 (Wieandt, 1994, p. 428).

As already pointed out, analysing patenting activity at the GPO overestimates national, i.e. German patenting activity. Thus, it is advisable to look at the respective patenting figures at a third patent office, which largely eliminates the "In-country-advantage" for German inventors. Figure 6 displays the patent applications at the EPO by country of origin.

Figure 6 clearly reveals the dominant Japanese patent position in CNC-technology. Almost 50% of total patent applications in CNC-technology at the EPO between 1977 and 1992 originated from Japan. The second largest patent stock is held by the U.S.A. with a share of 19%, followed by Germany with 13% in third place.

In chapter 3, we looked at the development of patenting activity in CNC-technology since 1968. It was inferred that changes in patenting activity



Source: ESPACE-Bulletin.

Fig. 6. The distribution of patent applications at the EPO in CNC-technology by country of origin (1977–1992).

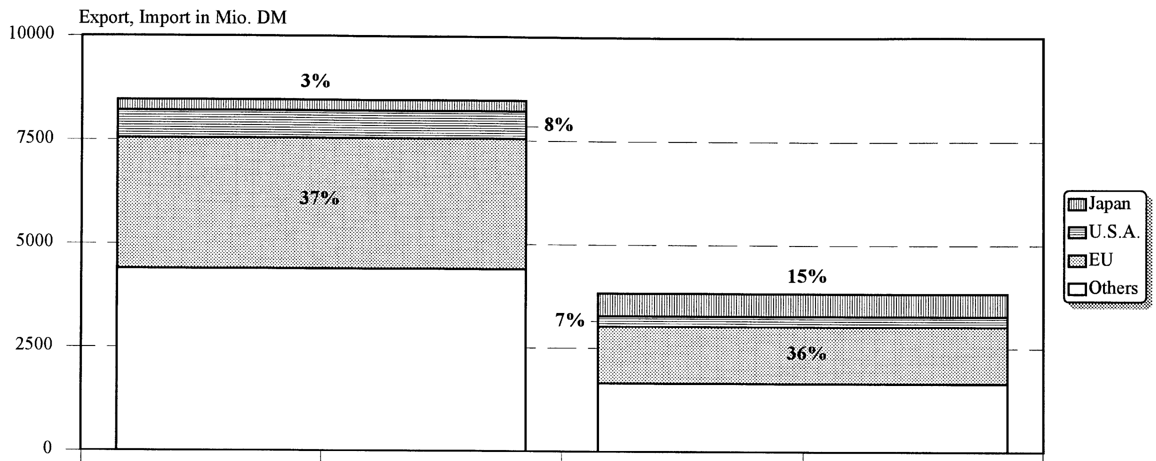
over time described different development stages of CNC-technology. Thus, it can be concluded that patent data provide a useful tool to forecast technological developments. Therefore, the systematic and continuous evaluation of patent data has to be a core element of a company's technology monitoring intelligence. We further showed the dominant position of Japanese companies in CNC-technology.[22] The development and introduction of the new technology into the market changed the basis of competition in the international machine tool industry in favour of Japanese companies. This competitive shift was indicated by the dramatic increase of the Japanese share in world production and world trade throughout the 1980s. The impact of the Japanese dominant patent position in CNC-technology on the trade pattern with Germany is further analysed in chapter 4.

4. The impact of CNC-technology on the machine tool trade pattern between Japan and Germany

In Figure 7, the export-import-structure of German trade with machine tools in 1991 is displayed, where we concentrate on the major trading partners of Germany only.

It becomes obvious that trade is most intensive with other countries of the European Union (EU). Trade with the EU accounts for 37% of total exports and 36% of total imports. In trade with the EU, Germany shows a substantial trade surplus. The U.S.A. are a major trading partner for German machine tool manufacturing companies, with exports at 8% and imports at 7%. As with the EU, the German trade balance is positive. Exports to Japan, however, do not seem to play an important role, since the share of exports to Japan is only 3%. It is interesting to note that market priorities of German companies become also obvious from looking at patent numbers. The majority of foreign patent applications of machine tool manufacturing companies are either filed in other European countries or in the U.S.A. The number of patents filed in Japan is rather low.[23] On the import side, however, Japan accounts for 15% of total German imports in that industry. Consequently, the trade balance with Japan is negative.

Figure 8 differentiates the trade pattern between Japan and Germany according to the underlying



	Export	Import
Japan	259	551
U.S.A.	655	254
EU	3159	1374
Others	4398	1652
Total	8471	3831

Note: % of total export and of total import.

Source: VDMA, 1993, pp. 28–29.

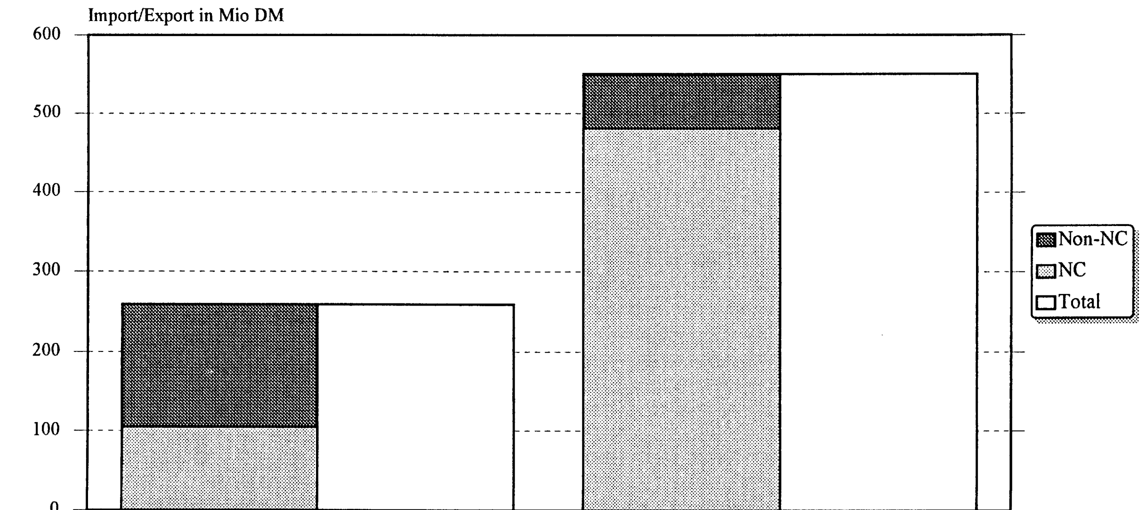
Fig. 7. The export-import-structure of German machine tool trade (1991).

technology, where total exports to Japan and total imports from Japan are classified into NC- or Non-NC-products.[24]

NC-products incorporate innovative CNC-technology. As far as Non-NC-machine tool products are concerned, Germany shows a positive trade balance with Japan. The comparative advantage of German machine tool manufacturing companies obviously lies in the production of conventional machine tools without CNC-technology. On the contrary, imports from Japan overwhelmingly consist of NC-products. Here, Germany's trade balance is negative. It appears that technological factors to a large extent explain the international machine tool trade pattern between Japan and Germany, as already assumed by looking at the different patent positions in CNC-technology.

In Figure 9, we now look at the development of German NC-imports from Japan between 1978 and 1991.

It is shown that NC-imports basically rose in two phases. In phase 1 between 1979 and 1981, imports increased substantially beyond prior import levels. In phase II, beginning in 1984, NC-imports form Japan dramatically increased. From 1984 to 1986 imports more than doubled and had finally tripled until 1990. The almost parallel development of import figures and Japanese patenting activity in CNC-technology at the GPO becomes obvious. A first increase in Japanese patenting activity occurred in 1979 to 1981 and was followed by an even higher patenting activity beginning in the middle of the 1980s. The latter development stage was viewed as the market penetration phase of the new technology. Looking at the import figures clearly supports this argument. However, it could be argued that exchange rate fluctuations might have caused the increase in German NC-imports from Japan, i.e. a possible devaluation of the Japanese currency could have led to a price advantage for Japanese exporters. Thus, we also plot the development of the exchange rate of the Japanese Yen to the German DM in Figure 9. Since 1980, the Japanese currency has basically been appreciated in comparison to the German currency. Thus, one would expect a negative effect on Japanese exports, i.e. on German imports from Japan. Despite the



	Export	Import
Non-NC	154	70
NC	105	481
Total	259	551

Source: VDMA, 1993, p. 29.

Fig. 8. The export-import-structure of German machine tool trade with Japan (1991).

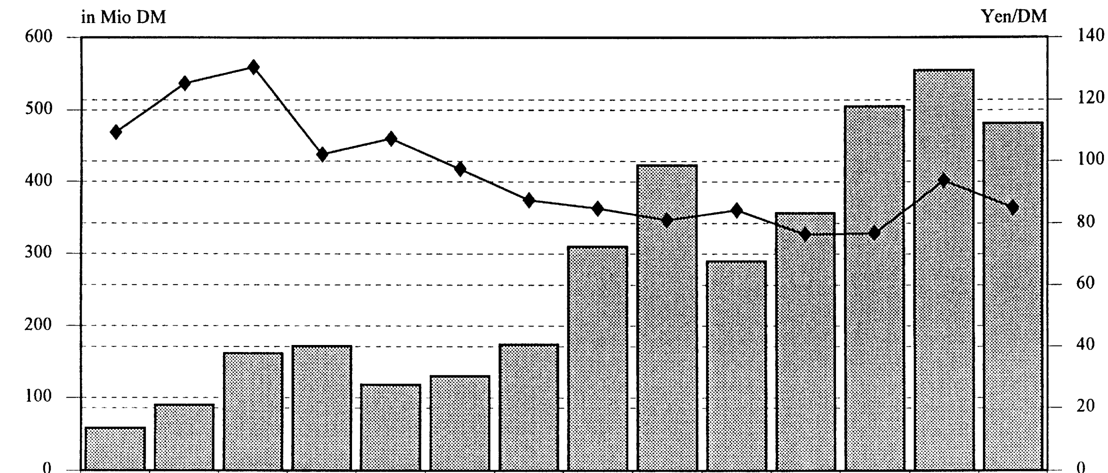
unfavourable currency situation, imports of NC-products from Japan grew rapidly throughout the 1980s. Obviously, comparative technological advantages do influence the international machine tool trade pattern between Japan and Germany.

In order to further analyse the relationship between patenting activity and subsequent trade changes between Germany and Japan, we performed a multiple regression analysis of Japanese patenting activity at the GPO on the change of German NC-imports from Japan. Analysing the impact of patenting activity on import changes has to be undertaken very carefully in order to obtain sensible results:

- Lagged effects between patent applications and market changes have to be taken into account (Brockhoff, 1994, p. 218). Thus, we incorporated a lag structure of two years between patenting activity and import changes. This requirement is captured by three indicators of patenting activity, where PA_t, PA_{t-1}, PA_{t-2} measure Japanese patent applications, which are related to import changes in period *t*.
- The mere interpretation of absolute patenting or import figures may lead to misinterpretations, since a high interdependence between patent applications, import changes and the overall economic development probably exists.[25] Therefore, we calculated relative measures for both independent and dependent variables. As the dependent variable, we used the relative annual growth rate of Japanese NC-imports during the period 1978 to 1991. Growth rates for NC-imports are measured relatively to the growth rates of overall machine tool imports from Japan. For all patenting variables, we also calculated annual growth rates.[26]

The selected output of the multiple regression analysis is summarised in Table II.

There is a positive and statistically significant relationship between patenting activity and increases of Japanese NC-imports to Germany with a lag of one year. The high R^2 of 52% and the highly significant regression coefficient for $LNPA_{t-1}$ stress the substantial impact of technological changes, as measured by patent numbers, on trade changes. Thus it can be concluded that patenting activity is a useful indicator for technological developments and subsequent market changes. The trade pattern between Japan and



	78	79	80	81	82	83	84	85	86	87	88	89	90	91
NC-Imports	58	90	162	172	118	130	174	310	423	290	357	505	555	481
EX-Rate	109,4	125,2	130,5	102,1	107,2	97,4	87,4	84,8	81,1	84,2	76,4	76,8	93,7	85

Note: 1972 = 100.

NC-Imports ◆ EX-Rate

Source: VDW, 1995, Deutsche Bundesbank, 1993, p. 92.

Fig. 9. The development of German NC-imports from Japan and annual exchange rates between Yen and DM (1978–1992).

Germany is highly influenced by technological differences.[27]

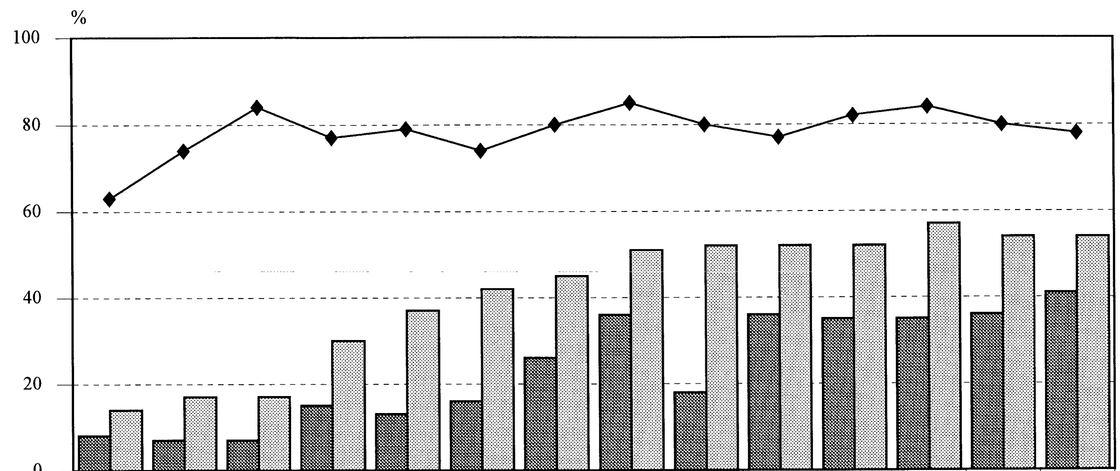
It is further interesting to analyse the diffusion of CNC-technology in the marketplace, since cumulative patent applications have been assumed to mirror the market penetration besides technological developments (paragraph 2.1). Figure 10 illustrates the share of NC-products in German imports from Japan (NC/IMJP), the share of NC-products in German exports to Japan (NC/EXJP) and the share of NC-production in the overall German production of machine tools (NC/PROD).

It is shown that the share of NC-products imported to Germany from Japan substantially increased after 1979. Since then, shares of Japanese NC-imports to Germany have remained high at about 80%. German NC-exports to Japan have increased steadily since 1985 and now account for 40% of total German exports to Japan. The share of NC-products in total German machine tool production climbed up to 57% in 1990. This development illustrates the increasing economic importance and broad market diffusion of NC-machine tools, especially after the mid-1980s.[28] This development is, as already pointed out, closely related to changes in patenting activity (Figure 3).

TABLE II
The relationship between patenting activity and subsequent NC-import changes.

	Dependent Variable: Relative annual growth rates of imports (LNIM)* in NC-technology products from Japan to Germany
R^2	**0.52**
Adjusted R^2	0.48
F-Value	12.146 (0.0051)***
$LNPA_{t-1}$* (T-value)	**0.134 (3.485)*** **

* For both, dependent and independent variable, the natural logarithm (LN) was taken.
*** = Level of significance: < 1%.
No significant results for $LNPA_t/LNPA_{t-2}$.
Kolomogorov-Smirnov-Test for normal distribution of standardized residuals p = 0,6545.
Source: Own calculations.



	79	80	81	82	83	84	85	86	87	88	89	90	91	92
NC/IMJP	63	74	84	77	79	74	80	85	80	77	82	84	80	78
NC/EXJP	8	7	7	15	13	16	26	36	18	36	35	35	36	41
NC/PROD	14	17	17	30	37	42	45	51	52	52	52	57	54	54

NC/IMJP = Share of NC-products in German imports from Japan,
NC/EXJP = Share of NC-products in German exports to Japan,
NC/PROD = Share of NC-products in overall German machine tool production.

Source: VDW, 1995.

Fig. 10. The diffusion of CNC-technology in machine tool production (1979–1992).

5. Conclusions

In this paper, we analysed overall, Japanese and German patenting activity for CNC-technology in the machine tool industry. It was found that the development of patent applications over time followed a certain pattern, describing the technological diffusion process of CNC-technology. The upcoming of CNC-technology in the machine tool industry was first signalised at the end of the 1970s and the beginning of the 1980s. Therefore, German machine tool manufacturers should have been aware of the Japanese technological focus on CNC-technology since the end of the 1970s. However, German companies did not, despite own efforts in this technology, react to the Japanese technological challenge. This passive behaviour might be attributed to the dominant market position at that time. As the market follower, Japanese competitors took the risk of developing the new technology and successfully implementing it into the market. CNC-technology turned into a pacing technology during the 1980s and has now become a key technology in the machine tool industry. This market breakthrough of the new technology on a broad scale was accompanied by high increases in patenting activity of Japanese and other manufacturers since the mid-1980s. It was further shown that technological innovations, as indicated by patent numbers, are transformed into substantial market success. Today the market share of Japanese companies in CNC-technology is estimated to be 65% (VDW, 1993, p. 7). As witnessed by international trade figures, Japanese companies successfully altered the basis of competition in the entire machine tool industry through this basic innovation.[29] This result yields two major managerial implications:

1. As already briefly mentioned in chapter 3, the recent rise in German patent applications in CNC-technology indicates the effort to shorten the Japanese technological advantage. However, it has been argued according to the technological life cycle concept that decreasing overall patenting in CNC-technology and the already strong legal patent position of Japanese

competitors might not favour further investment in CNC-technology. In the light of opportunity cost, R&D investment in other technological areas of machine tool production, which might yield higher future competitive advantages should not be neglected. In this case, CNC-technology should simply be bought from Japanese suppliers.

However, CNC-technology can be viewed as a strategic technology. It is feared that without the development of a competitive own CNC-technology, Japanese machine tool manufacturers would enjoy a sustained future competitive advantage over its German competitors.[30] Consequently, strategic reasons support further R&D investment in CNC-technology in order to avoid a Japanese monopoly in CNC-technology. In this case, it has to be pointed out that other upcoming technological developments should not be overlooked. Looking at patent data, the application of "Laser-technology" in the production of machine tools seems to become increasingly attractive. Since 1990, yearly Japanese patent applications in "Laser-technology" at the EPO lie above German patent applications (Ernst, 1995b).

2. Patent data obviously provide useful information for a company's strategic business planning, especially for R&D investment decisions. Patent data mirror different technological development stages, which allow companies to timely react to technological challenges. It is therefore necessary to continuously monitor the patenting activity of competitors in different technological areas in order to anticipate technological advances and subsequent market shifts. There exist a variety of patenting indicators for strategic patent data analysis (paragraph 2.2).[31] In this paper, we purposely restricted ourselves to indicators of overall patenting activity as measured by patent applications. As far as relevance, time and access are concerned, patent applications are the superior patenting indicator for technological forecasting purposes. In order to obtain quality measures of patenting activity and to assess early foreign national technological moves, foreign patent applications should be analysed. Suppliers of patent information have reacted to the need for complete international patent coverage of potential customers. They provide different databases, which can all be searched using the same retrieval language.[32] Therefore, companies can easily and at relatively low cost implement patent data analysis in their competitor monitoring intelligence. As shown, the incorporation of patent data analysis in the strategic planning process yields high potential benefits. Thus, it seems to be a very suitable and valuable tool for technological forecasting especially for SMEs (Schmoch, 1990b, p. 163).[33]

Recognising the importance of patent information, it becomes important for SMEs to decide on how to perform strategic patent data analysis. There are two basic alternatives. First, strategic patent data analysis can be performed internally within the organisation. In this case, the company needs to devote financial resources to build up own competence for patent information retrieval. Furthermore, it has to be decided who should perform patent data analysis and where this task should be located within the organisational framework. Major advantage of internal patent data analysis is the integration of company expertise in any patent search. This helps to formulate appropriate search objectives, guarantees the alignment of patent searches with the individual company's information needs and allows the direct evaluation of patent information with respect to its impact on the competitive position for the respective company. From an organisational point of view, patent data analysis might reduce interface problems (Brockhoff, 1989), especially between Marketing and R&D, since practical experience shows that the effective and efficient performance of patent data analysis depends on the incorporation of both, market and technological know-how. The costs of patent data analysis are difficult to assess, since they depend on the extent of patent searches performed and the search expertise of the analyst. However, patent data retrieval costs are relatively low compared to other forms of technological information sources (Ashton *et al.*, 1991, p. 102) and have to be judged according to the outlined major benefits for various business applications.[34] Second, it might be interesting for SMEs to make use of external patent information sources.[35] The external acquisition of patent information could be a starting point to get acquainted with the retrieval of patent information and to recognise its usefulness. However, even the use of external suppliers of patent information requires within company expertise to assure an effective and efficient patent search and to facilitate the transfer process of patent information into the strategic planning process within the company.

Summing up, SMEs should treat patent information as a strategic asset rather than associating it with legal aspects only. The continuous and systematic analysis of patent information should become a core element in a company's technology competitor intelligence.[36] This should be realised by SMEs' top management, since its support is crucial to the successful implementation of a patent information system.[37]

Notes

[1] The same problem has been lately addressed in an article by the German business magazine *Manager Magazin* (Schlote/Schwarzer, 1995, pp. 58–66).

[2] The results are based on a sample of 50 companies within the German machine tool industry. Economic performance is analysed for nine years over the period between 1984 and 1992.

[3] Corsten/Lang (1988) report that 70% out of a sample of 1,200 European SMEs monitor technological developments of their competition (Corsten/Lang, 1988, p. 145). However, no information is given on how technological monitoring is performed.

[4] In 1992, 82.7% of German machine tool manufacturing companies had less than 500 employees (VDMA, 1993).

[5] The quotes are translated from German by the author of this paper.

[6] This argument is further supported by the fact that 85% of the overall technological knowledge is assumed to be incorporated in patent documents (Engelhardt, 1989, pp. 9–10; Fendt, 1988, p. 73). An even more appropriate measure of technological performance could be patents granted, since a patent is only granted by the patent office, if it comprehends new elements beyond the already existing technological state-of-the-art (§1 and §3 of the German patent law (PatG)). In this paper, we do not look at patents granted, since they are not available for technological forecasting purposes. However, other indicators as for instance patents granted or patent citations could theoretically be used to describe technological diffusion patterns in retrospect.

[7] The granting of a patent requires its possible commercial application (§1 and §5 of the German patent law (PatG)).

[8] The quote has been translated from German by the author of this paper.

[9] In industries like pharmaceuticals, chemicals, petroleum, machinery and fabricated metal products patent protection seems to play an important role. For these industries 84% of patentable inventions actually were patented (Mansfield, 1986, pp. 176–177).

[10] In 1986, German machine tool manufacturers accounted for 24% of patent applications with two or more designated states, followed by the U.S.A. (22%) and Japan (18%) (Gerstenberger, 1988, p. 7).

[11] In Germany between 1982 and 1991, SMEs with less than 500 employees accounted for 27% of overall patent applications and employed only 10% of the total R&D personnel. In contrast, large companies with more than 10,000 employees accounted for 43% of overall patent applications and employed more than 50% of the total R&D personnel (o.V., 1994, p. 7).

[12] Ernst (1995a) found high rates of valid patents for smaller companies, which hint towards the economic importance of these inventions to the companies (Ernst, 1995a, pp. 229–232).

[13] In the literature, some quality indicators of a patent application have been identified. These are patents granted, international patent applications, valid patents and patent citations (Basberg, 1987, p. 138; Ernst, 1995a, p. 236; Narin *et al*., 1987, pp. 152–153).

[14] Patent applications by the respective company are not influenced by external sources, e.g. patents granted or patent citations by the patent office.

[15] At other patent offices, patent data are published with a higher time delay. E.g. at the American patent and trademark office (USPTO), only patents granted are published, which happens on the average after 3 years. For more details on international publishing procedures see: (Schmoch, 1990a, pp. 25–26).

[16] For a world-wide coverage of patent documents, e.g. the patent database World Patent Index (WPI) could be searched. This approach is very helpful in detecting other international patent applications and in particular early national Japanese patent applications. National Japanese patent documents can also be directly searched in JAPIO, the patent database of the Japanese patent office.

[17] The distribution of basic patents over the technological diffusion process is discussed in: (Basberg, 1987, pp. 134–135). In reality, the distinction of phases in the presented framework of patenting activity might not be as strict as discussed. There are smooth transitions.

[18] This classification was discussed with experts within the industry and from the patent office.

[19] It has to be mentioned that the analysis according to the wider definition of control-technology provided no different results, since the majority of control-technology patents have been filed in the narrow area of electronic control-technology. The patent position of German companies compared to their Japanese competitors slightly improves, but it does not change

the overall picture. Presenting these results would have gone far beyond the scope of this paper. For more details see (Ernst, 1995b). Looking at individual patent documents, while performing a comprehensive case study within the machine tool industry, revealed that the technological content of a patent application could often only be inferred by looking at the supplementary patent classification. Thus, in the following analysis, patent documents are included in which the IPC-classification symbols representing CNC-technology appear either in the main or supplementary patent class. This procedure ensures that patent documents are included in the analysis, which cover new machine tool developments (Main classification: B23) incorporating CNC-technology elements (Supplementary classification: G05B019/00-417). Thus, patenting activities of machine tool manufacturing companies in CNC-technology can be adequately assessed. While only a few machine tool manufacturing companies have developed own control devices, the majority of patent applications in the patent classes G05B019/00-417 are caused by suppliers of CNC-technology. This distinction, however, might be misleading for technological forecasting purposes, where the prime focus lies on the detection of technological changes. Even if the technological invention originates within the supplier industry, it might have a large competitive impact on the user industry, as it has been the case with CNC-technology for the entire machine tool industry. For the individual machine tool manufacturing company, the timely awareness of these technological changes is the essential necessity for the formulation of effective R&D investment decisions. Basically, the potential R&D investment in CNC-technology could have either been undertaken internally or externally (if better know how had been available from external sources, e.g. from suppliers).

[20] This assumption was verified for Japanese competitors in the machine tool industry. Japanese patent applications at the GPO were often filed in the U.S.A. also, received a higher amount of patent citations and were found to be longer valid, i.e. longer used economically (Ernst, 1995b).

[21] It is interesting to note that in patent documents of Japanese companies, references to basic German work in the area of CNC-technology could be found, e.g. PhD-dissertations from the technical university (TU) Berlin in 1968 and 1970 (Ernst, 1995b).

[22] Interesting support for this observation comes from a line of research, where technological fields are mapped by multidimensional scaling (MDS) techniques on the basis of bibliometric (patents, articles) data. Engelsman/van Raan (1994) show the integration of electronic and mechanical technology as a distinctive difference between the Japanese and the European and world-wide technology maps (Engelsman/van Raan, 1994, pp. 12–13).

[23] Only 7% of overall patent applications in a sample of 50 machine tool manufacturing companies are filed in Japan, whereas 40% are filed in the U.S.A. (Ernst, 1995b).

[24] Statistics from the Verein deutscher Werkzeugmaschinenfabriken e.V. (VDW) use the expression NC instead of CNC. The underlying technology, however, remains equal.

[25] This assumption was tested through various exploratory correlation analyses. Very high correlation coefficients were found between all patenting variables, import figures and different measures of overall economic prosperity. These high correlation coefficients would have violated fundamental assumptions of multiple regression analysis (Backhaus *et al.*, 1990, pp. 34–36).

[26] To control for measurement errors, we took the natural logarithm from the annual growth rates. Calculating relative growth rates incorporate overall economic effects in the analysis. We also tested for correlations among the independent variables. No violations of assumptions for multiple regression analysis occurred in the final analysis.

[27] According to Figure 9, the Japanese currency was substantially appreciated in 1988. However, the increase of NC-imports was probably influenced by high prior patenting activity in 1987.

[28] The share of German NC-exports in the overall trade with the U.S.A. and the EC increased at the same rate (VDW, 1995). The economic importance of NC-products in comparison to conventional machine tools is further stressed by a much higher value generation as indicated by high sales-per-piece ratios (VDW, 1995).

[29] This development is almost identical with the scenario presented by Fendt (1983), which was discussed in paragraph 2.2.

[30] It is argued that CNC-technology elements account for 25% of total costs in machine tool production. A Japanese monopoly in CNC-technology would allow them to control prices for CNC-technology and bring German machine tool manufacturers in a dependency position (VDW, 1993, p. 13). It is further said that German companies are reluctant to use Japanese CNC-technology, since they do not want to give away their own conventional know-how in machine tool production (Schlote/Schwarzer, 1995, pp. 65–66).

[31] A useful tool for strategic patent data analysis is the Patent-Portfolio as an alternative R&D planning instrument to the conventional Technology-Portfolio, which has been successfully implemented in a comprehensive case study (Ernst, 1995b).

[32] PATDPA covers German patent applications, the International Patent Documentation Centre (INPADOC) and WPI cover international patent applications and JAPIO covers Japanese patent applications. PATDPA, INPADOC, WPI and JAPIO are all offered by the host Scientific and Technical Information Network (STN), which allows the user of patent information to comfortably search all databases with only one retrieval language and thus combining the different information from each database. An introduction to the use of databases for patent data analyses can be found in: (Engelhardt, 1989; Koschatzky, 1991, pp. 263–268; Krestel, 1991, pp. 236–244; Schmoch, 1990a; Schmoch *et al*., 1988; Wilson, 1987a, pp. 18–26; Wilson, 1987b, pp. 89–99).

[33] Besides technological forecasting, further business applications of strategic patent data analysis were identified (paragraph 2.2). One major aspect for SMEs to be pointed out is that patent data might be very helpful for the identification of possible external sources for acquiring technological know-how, e.g. through R&D joint ventures, R&D cooperations or acquisitions.

[34] In a case study with a medium-sized mechanical engi-

neering company, we established a patent information system. Patent information is systematically and continuously analysed, e.g. prior to the start of any R&D project. The patent information system was especially designed to meet the specific information needs of the company. Judging the net effect of the patent information system on the improvement of decision making processes, company officials verified that the benefits far outweigh the costs of the new information system.

[35] Patent information is for instance provided by the GPO and its regional offices or professional database suppliers like STN. *Schmoch (1990b)* describes an interesting pilot project by the Fraunhofer Institute of Systems and Innovation Research (ISI) and the Federal Minister for Economic Affairs. An information distribution centre has been established with the objective to provide user-friendly patent information especially targeted to SMEs (Schmoch, 1990b, pp. 158–164).

[36] The design of an adequate competitor technology intelligence is discussed in: (Ashton *et al*., 1991, pp. 91–111; Brockhoff, 1991, pp. 91–98; Lange, 1994).

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