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Patent statistics in the age of globalisation: new legal procedures, new analytical methods, new economic interpretation

Hariolf Grupp *, Ulrich Schmoch

Fraunhofer Institute for Systems and Innovation Research (ISI), Breslauer Strasse 48, D-76139 Karlsruhe, Germany

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Abstract

Patent analysis seems to become more difficult in the age of globalisation. Starting from microlevel observations, it is evident that multinational enterprises pursue different technological, marketing and strategic aims. In effect, they cover world markets in a distinctly different manner with patent intellectual property. This article, in good economic tradition, starts with consideration of recent microlevel patent behaviour in telecommunications before new macroeconomic procedures to measure technical change are outlined. The new challenges to patent statistics comprise the assignment of countries to patent documents of multinational firms, the appropriate use of economic 'filters' in comparing patent statistics from various patent offices, the fitting of the new international patent procedures offered by the amended Patent Cooperation Treaty (PCT) to national statistics, the assignment of patent applications in case of withdrawn country destinations and the estimation of time series if most recent data sets are incomplete. We propose consistent, workable adjustments to patent statistics that overcome the above-mentioned biases, which we denote the 'triad patent model', for measuring technical progress in the proper economic sense. First applications deal with the assessment of the pace of technical change in major countries up until 1995. In conclusion we discuss problems for future research. The main policy implication is that macroeconomic patent statistics can correct for the effects of global knowledge production, indeed, as these are not disruptive but rather limited and well accountable.

Keywords: Patent statistics; Measurement of technical change; Global knowledge production; International patent procedures

1. Starting point: patent strategies of a modern multinational enterprise

It is a good tradition in economics, to base macroeconomic analysis on microlevel observations. On this level, for most economists and business administration researchers, a patent is what it is for lawyers, a legal document. It helps a firm in appropriating innovation rents as technology is a (latent) public good (Nelson, 1990). At least, it 'protects' the inventing firm from other firms' appropriation of that technology. What interests us in patent econometrics is the *quality* of the *output of technical change* that finds expression in patents. If in a company two engineers work for a year on a defined project funded from internal sources (cash flow), and if they are successful and invent something new, then we eventually have a document emerging from this lab which tells us that two engineers worked for

* Corresponding author. Tel.: +49-721-68-09-156; Fax: +49-721-68-09-176; E-mail: gru@isi.fhg.de

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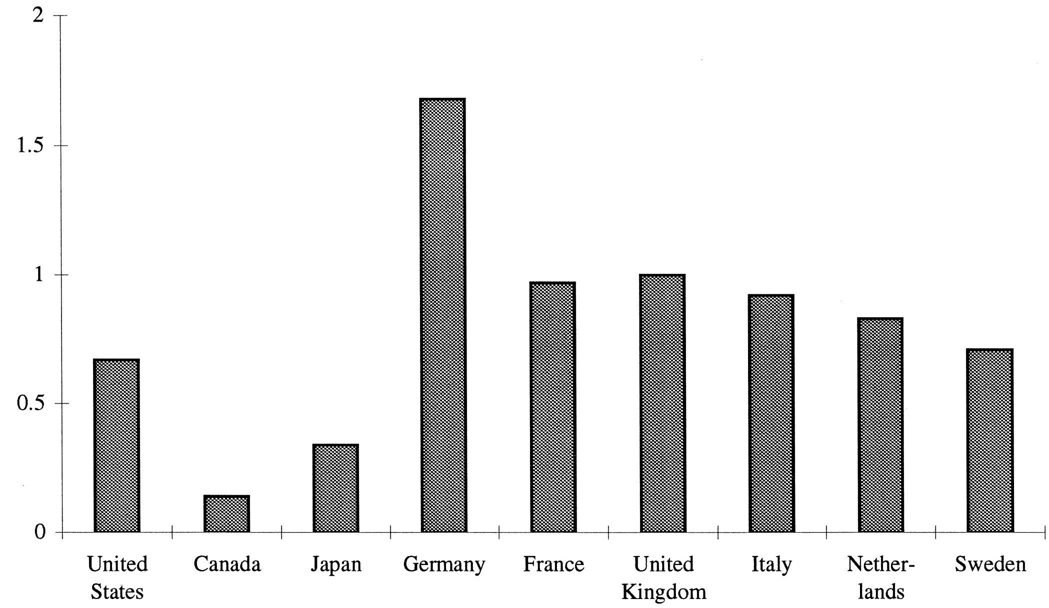

Fig. 1. Destination countries of telecommunications-related patent applications by Siemens (consolidated) 1987–1989 (source: Schmoch, 1996; the index is set as 1 for the foreign country that attracts the most patents applied for, in this case the UK).

a while on a certain invention, described very precisely. We can read from the document, as we read from scientific publications, that this company has deliberately brought about a certain inventive step, now documented and codified. So patent documents point to those areas of activity in which a company has invested research and development (R&D) labour and resources. When patent examiners (in most countries civil servants at patent offices) discover that the idea is not new—but is already known—it matters to patent attorneys, but little to us, because the fact remains that the company invested, say, two person–years in R&D.

The fact that our world is divided into national territories and that intellectual property rights are protected by national patent offices within national borders, means that a patent protects an idea in *one* country and in *one* market. Territorial coverage of patent protection must be deliberately decided by a company. So when one invention, one patent application, is filed at home, it is a sign that a company intends to market it in the domestic market only. When patents are filed in seven or eight countries, it either shows the company intends to manufacture or market the product in these countries, i.e., in many markets. [1] An alternative interpretation would be that in decades of growing globalisation this heralds a substantial and growing number of international strategic alliances of large firms in many countries that have adopted a cross-licensing policy or other network agreements on the generation and use of new technology.

Patent analysis is difficult. We must treat the data with care. A few years ago, the OECD secretariat in Paris published a *manual*, a guideline, one should observe in working with patent documents (OECD, 1994). [2] It provides the relevant definitions for a statistical patent analysis.

Let us introduce some microlevel problems of patent statistics in the age of globalisation by the example of telecommunication *manufacturing*. Our objective is to examine the marketing information inherent in patent statistics. Let us examine the

[1] In cases when the subject of the invention is a process, this normally has implications for some kind of machine or apparatus, e.g., for innovative investment goods of other firms. Then the given argument is about the same as for product innovation.

[2] A rich bibliography on patent analysis is included in this source.

Table 1
Destination countries for telecommunications-related patent applications for selected companies 1987–1989 (source and index as in Fig. 1)

Destination country									
Corporation (consolidated)	USA	CND	JPN	DEU	FRA	GBR	ITA	NLD	SWE
Alcatel NV	0.71	0.71	0.49	1.28	1.09	1	0.97	0.92	0.89
Bosch	0.40	0.11	0.39	1.98	1	0.95	0.92	0.69	0.58
Ericsson	0.88	0.37	0.71	0.92	0.85	1	0.69	0.76	1.02
GEC	0.66	0.37	0.73	1	0.99	1.3	0.91	0.81	0.81
STET/Italtel	0.63	0.34	0.50	1	1	1	0.89	1	0.97
Nokia	0.28	0.06	0.32	0.95	0.94	1	0.81	0.71	0.82
Philips	0.92	0.19	0.85	1.10	0.98	1	0.69	0.44	0.59
Siemens	0.67	0.14	0.34	1.68	0.97	1	0.92	0.83	0.71
Thomson	0.97	0.13	0.48	0.99	1.23	1	0.76	0.52	0.43
AT&T	1.96	0.84	0.98	0.93	0.93	1	0.65	0.54	0.51
IBM	1.11	0.10	0.85	1	1	1	0.32	0.10	0.08
Motorola	1.51	0.44	0.94	0.95	0.95	1	0.90	0.92	0.90
NorTel	1	0.48	0.38	0.36	0.36	0.38	0.20	0.35	0.34
Fujitsu	0.9	0.69	31.46	1	0.93	0.99	0.25	0.11	0.23
Hitachi	1	0.11	12.19	0.54	0.33	0.39	0.07	0.06	0.05
Matsushita	1	0.12	3.2	0.66	0.53	0.70	0.13	0.27	0.26
NEC	1	0.50	3.81	0.58	0.43	0.69	0.11	0.29	0.26
NTT	1	0.50	44.8	0.87	0.51	0.79	0.14	0.27	0.52
OKI	1	0.19	20.95	0.53	0.47	0.57	0.15	0.04	0.19
Sony	1	0.27	5.25	0.85	0.78	0.89	0.11	0.34	0.04
Toshiba	1	0.32	13.34	0.54	0.33	0.47	0.05	0.08	0.13

German-owned multinational firm Siemens first. Fig. 1 shows the number of patent documents originating with Siemens (this includes a number of affiliated companies), somewhere in the world, and we first look at the domestic market. The number of patents filed is the largest in Germany. Many of them remain *only* in the domestic market. But a considerable share of all inventions is designated to the UK; they do not necessarily originate from there. So out of all countries in the world, the UK is the *most preferred foreign market* for Siemens in terms of protection of inventions. This is explained by Siemens' serious effort to enter the British market, protected through patenting, in the late 1980s. Other large European countries are nearly equally covered with patents. For smaller countries, the number of patent applications declines. [3]

The number of intellectual property rights in the domestic market is less than twice of those abroad—so the company is quite international in its perspective. In the US, though it is the single largest market in the world, the number of duplicated patents remains low despite the affiliated company Rolm which was acquired there and produces some inventions of its own. Siemens has neglected this country in comparison with Europe, and neglected Japan as well, for whatever reason (quality selection, lesser exchange agreements with US-based firms, etc.).

Table 1 provides similar information for some other telecom companies. In this table, the number of patents filed in the foreign country with the most patents applied for is taken as the benchmark (indexed to 1.0).

It is evident from Table 1 that GEC is the mirror image of Siemens—a British firm filing heavily in Germany; GEC and Siemens run a joint subsidiary, originating from the Plessey group. Note the behaviour of Japanese companies. Here we observe a statistical artefact. The patent law and conventions in Japan are such that they cannot easily accumulate and combine several claims to be protected in one document. In practice (though not by law and in theory) each claim requires its *own* document. Expe-

[3] Data sources for patent statistics of (consolidated) company affiliations are in the paper of Schmoch and Schnöring (1994) and lengthier data annexes cited therein (from 1992).

Table 2
Typical patent strategies of selected companies on foreign markets (source: Schmoch and Schnöring, 1994)

Feature	Examples
Average share of foreign patents, broad coverage	Alcatel, AT&T, Philips, Siemens
Generally, little foreign patenting, but broad coverage	Ericsson, GEC, Motorola, many network operators
Selective strategy	Hitachi, Oki, Matsushita, NorTel
Special focus on the American market	Matsushita, Hitachi, NEC, Thomson, Philips
Special focus on the Japanese market	AT&T, IBM, Motorola, NorTel, Philips
Low presence on the Japanese market	Bosch, Nokia, Siemens, STET, Thomson

rienced patent lawyers provide a rule of thumb: divide the number of Japanese domestic patent applications by four or so to arrive at roughly comparable numbers to the West. So we cannot surmise that the patenting activity in Japan is as fast and furious as the numbers indicate, and we have to find better yardsticks.

To this point, the strategic marketing aspect of innovation, as revealed in patent applications by protected national markets, has been analysed. It has been shown that potential strategic initiatives of companies in foreign markets can be traced. In analysing these data, one arrives at the conclusion, that in the telecom industry there are several, very different strategic behaviors of companies at the end of the 1980s (see Table 2). There is a group of companies from various 'home' countries, which have a medium share of patents abroad. We have another group of companies, selective in patenting their inventions abroad among them some Japanese manufacturers. Then we may discern a group of companies with a special focus on the American market. Finally, there are companies with special focus on the Japanese market. Another group of companies—among them newcomers in that market—does little strategic marketing on the Japanese market as evidenced by external patents. Coverage of European markets is a special case in patent strategy. [4]

To further set the agenda of this article, let us conclude this microeconomic introduction by giving special attention to the Canadian firm Northern Telecom (NorTel). The overwhelming share of patents from this company originates in Canada, as Canada is the domestic market and the location of the headquarters. However, different to most other telecom companies, this firm has a clear preference for the much larger neighbouring US market. Thus, only half of the 'external' patent applications in the US is also protected at home. Nearly as important as the domestic market are apparently Japan or the UK. At least for this company, the notion of 'national' in distinction to 'global' activities in technology seem to become quite fuzzy. [5] From these observations the

[4] The European coverage is most frequently achieved via European patent applications. Patenting in one European signatory country does not automatically confer a patent in all other countries of the European Union, as is sometimes mistakenly believed, since the EPO has come into being in 1978. But it works as follows: you send your invention document to the EPO. You specify for which member countries you seek patent protection. Note that the EPO member states are not synonymous with the European Union. They include Switzerland, Liechtenstein and Monaco—some 18 member states are involved, in contrast with 15 for the EU members. EPO makes a joint examination, which is costly (about 5 times more expensive than a single national application, see, i.e., Straus, 1997, p. 33), but once done and when successful, it is handed over to the national patent offices, and without further investigation, it is accepted. If one chooses this route, then this document appears in a multiple way in national patent statistics, for all designated countries. What the company or patent applicant saves, is simply the examination and attorneys' fees for several national procedures; however, the final document has to be translated for its transfer to the destination countries. Ultimately, the patent protection only applies at the national level of the designated countries. In contrast to the procedure at the EPO with central application, examination and grant, the international procedure according to the PCT solely comprises a central application and optionally a provisional examination; the legally binding examination and grant remains at the regional or national level.

[5] Seventy-one percent of the inventors of NorTel reside within Canada and 14% in other countries. Around 15% of the inventions originate from cooperation of inventors in Canada with those in other countries.

paper sets out to systematically discuss the problems and opportunities of macroeconomic patent statistics in the age of globalisation.

The goal of this article is to get at an acceptable indicator of the technological strength of nations on international markets. In the section to follow, Section 2, we introduce a typology for macroeconomic assignment of patent documents by countries and in Section 3 we deal with economic 'filters' to arrive at valid statistical comparisons between patent data of various countries (patent offices). We attempt to show that globalisation and new patenting procedures are making obsolete the approach of counting patents from the classical priority country USA. EPO data [4] have also their limits if taken alone. Section 4 answers the question in how far the international patent procedures (PCT) deserve special attention in patent statistics and bring in new biases. Evidence will be provided that the international procedures represent a strong challenge for the econometrics of patenting and are thus of greatest importance for the validity of such statistics. We propose finally an indicator based on patents from the trial (US, Europe, Japan) complemented by the estimated transferred PCT applications. Section 5 outlines an important application of the new methods suggested: We analyse the pace of technical progress in the 1990s and thus reconsider earlier empirical work (and its misinterpretations). In Section 6, we conclude by discussing policy issues and remaining problems for future research.

2. Macroeconomic assignment of patents by countries

In Section 1, it has been shown by way of introduction that because of the increasing role of globalisation in particular by multinational enterprises (MNEs) the assignment of 'countries of invention' is no more a trivial task. In the literature, three different theoretical foundations for assignment of data may be found.

2.1. Three classical methods of patent counting for macroeconomic analysis

The first and still most common concept originates directly from the legal patent system and classifies by *priority countries*. For any given invention, the priority filing is the first application. According to the OECD patent manual (OECD, loc. cit., para. 83), it is 'generally filed with the patent office of the country in which the invention was produced'. While the priority certainly is the first application (by definition), the quoted statement establishes a hypothesis on the meaning of 'generally' which may be tested empirically (see below). For retrieval purposes, the first filed application receives a code number, the 'priority number'. The priority number may be reconstructed from subsequent external applications and is the common feature of *patent families*, the set of patent documents centering around one and the same invention for which protection in various countries is strived for.

A second theoretical notion is that of *national innovation systems* or *inventor countries*. In the discussion on ongoing globalisation, it is argued that national and regional systems of innovation remain an essential domain of economic analysis. While external international connections are certainly of growing importance, the influence of the national education system, industrial relations, technical and scientific institutions, government policies, cultural traditions and many other national institutions is fundamental (Freeman, 1995). The notion of national systems of innovation originated in the late 1980s, but actually goes back at least to Friedrich List's conception of 'The National System of Political Economy' from 1841, expressing concern that one country 'overtakes' another one and that policies should be in place how to learn about new technology and applying it (ibid., p. 5). Within the boundaries of this concept, the principle for classification should be the country of residence of the inventors as the residence denotes most closely the historical and cultural background of the inventors, their education system, tax and other policy specificities.

The assumption that the R&D establishment and the residence can in most cases not be too distant and with special care for commuters across national borders, we arrive at a second assignment classification for countries. The OECD patent manual notes that the country of invention can be ascertained from the fact that every patent application has to give the names and addresses of the inventor and of the person, firm or institution filing the patent, whereby the inventor and the filer may be the same person (OECD, 1994, para. 82).

Another economic concept is that of *shareholder value* or *country of control*. If we imprint this notion on patent statistics as our third approach, we need to assign countries by the location of firms' headquarters. To give an example, inventions originating in laboratories of European affiliations of, say, US-owned corporations will be assigned to the US. The reason behind this concept is that the headquarters of the corporation controls the technology strategically and may make it effective elsewhere than where it was generated. Such counting demands that all assignees are characterised in terms of the industrial groups they are a subsidiary of.

The official statistics of the United States Patent and Trademark Office (USPTO) publish data based on the national innovation principle and assigns inventions according to the residence of the first-named person (US Department of Commerce, 1992, p. 1, fn 2). EUROSTAT recently suggested for regional innovation analysis to take as the basis for the attribution of a patent application to a region the private address of the inventor and to estimate, in cases of doubt, a commuter matrix (EUROSTAT, 1995, p. 40). In case of inventor teams with addresses in different regions or countries, the office advocates fractional counting and thus deviates from the USPTO practice to select first-named addresses.

In earlier work (Gehrke and Grupp, 1994, p. 51; Grupp, 1995) and in this paper from the next section onwards, we also assign patent statistics by countries of invention without further notice. In case of cross-border inventor-teams multiple, but not fractional counting is preferred. This gives the few internationally cooperative inventions greater weight in overall statistics. It does justice to the fact that the basic idea of national systems of innovation points to the importance of historical and educational factors in *each* of the countries. For the remainder of this Section 2, however, we compare the three concepts.

2.2. Comparison and limits of the classical methods

In Fig. 2, country performance under the common headline 'Canada' is compared using the different macroeconomic assignment principles discussed here.

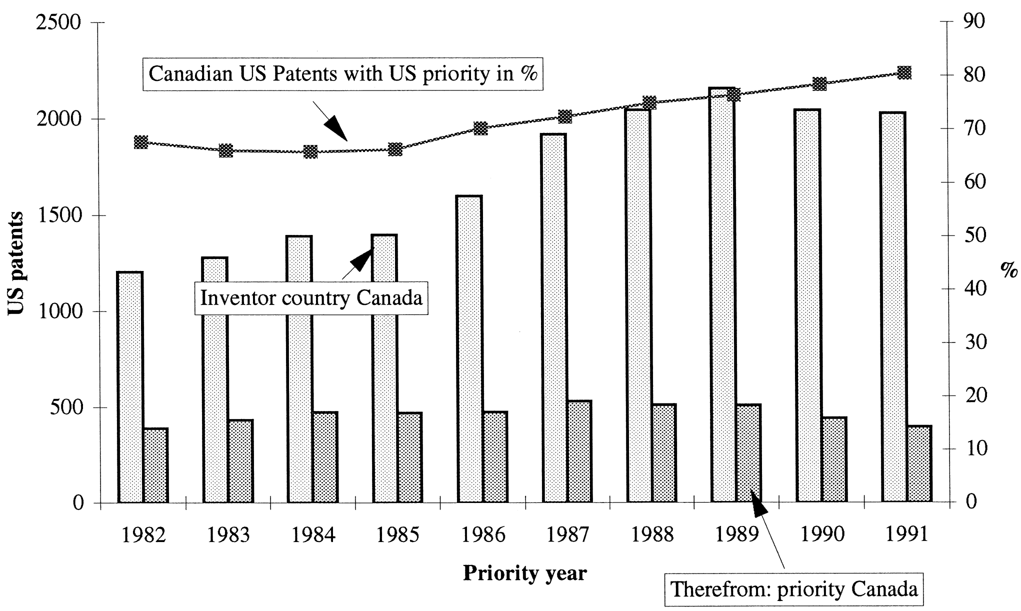

Fig. 2. Analysis of country demarcation concepts in patents statistics for Canadians by US patents 1982–1991 (data base sources: PCTPAT, EPIDOS/INPADOC).

This country was selected in correspondence to the case of NorTel mentioned in Section 1 (compare Table 1). Here we study aggregated statistics, i.e., all patent applications sorted by priority years.

In Fig. 2, at first glance a large disparity between the priority and the inventor country concepts is obvious. A great number of scientists and engineers working in Canada produced a growing number of inventions surpassing 2000 in the year 1989 (by US patent statistics). A minority of these is first filed at the Canadian Patent Office and, up to 1 year later, also applied for at the USPTO (external application), claiming priority in Canada. A majority of Canadian-invented patents, however, is directly filed in the US and claims priority at the USPTO. The share of Canadian US patents with US priority was about 70% in the first half of the 1980s and increased steadily up to 80% in 1991. [6]

Econometrically speaking, patent data is count data and thus Poisson or negative binomial distributions should be embarked upon (Hausman et al., 1984; Ronning, 1991, Chapter 4; König and Licht, 1995; Grupp et al., 1998). However, for a simple check of the relevance of this trend, OLS regression analysis should suffice. Indeed, Canadian scientists and engineers increasingly prefer the USPTO as priority office for their inventions, or, respectively, the company headquarters or patent attorneys of firms decide so. [7] From this observation, we may infer that the first of the above-mentioned theoretical concepts, the one by legal priority countries, is no more valid for macroeconomic country assignment. In other words, priority country counting is no more a good proxy for national comparable statistics on technological strength. This refers to Canada, but also to other such countries being located in the neighborhood of a very large and attractive market for technology (as is also the case for Switzerland in relation to Germany, for South Korea in relation to Japan and for Belgium). [8]

In Fig. 3, one may analyse the corresponding situation viewed from the US. In this analysis, we include the shareholder approach and show the respective statistics following the demarcation of assignees by countries. All US priorities increased in the 1980s with a considerable share of patents with US inventors. However, about 20% of all US priorities have no US inventor, among them certainly the Canadian US priorities discussed above in addition to US priorities from many other countries. The macroeconomic patent sample by priorities (legal patent concept) and by the countries of invention (innovation system concept) would differ by about 20% which is certainly not a disruptive order of magnitude, but seems not to be negligible. As this share varies over the years, intertemporal or dynamic patent statistics may be affected.

An interesting trend is discerned with respect to the shareholder concept (assignment by assignees' headquarters addresses). Most, but not all inventors of US patents in the 1980s are employed by US firms, including cases where the inventor and the filer is one and the same person. On the other hand a certain part of scientists and engineers residing in the US are employed by companies with a headquarter or principle address outside of the US. From Fig. 3, we do not know how large this share really is, but we do know the net balance. As US assignees may file patents exclusively with non-US inventors, this share might even be larger. The net balance of US inventors working for non-US companies vanishes at around 1990 probably due to the fact that, in the course of increasing globalisation, non-US companies handed over their patent and license business to subsidiaries in the US.

From both cases studied above, we can conclude that the distinctions between macroeconomic con-

[6] One has to note that US patents are published on the occasion of being granted, an event which may occur 3 or more years after priority. Whereas most patent offices of the world publish the respective documents strictly 18 months after priority, the USPTO does not. This makes most recent patent statistics difficult if the documents are sorted by priority years and not by patent years. To avoid any problems from missing data, the sample was deliberately truncated at the priority year 1991. The on-line data base searches where performed March 4, 1996.

[7] Statistical parameters are as follows: $R^2_{adj} = 0.89$, $t = 8.49$, $\alpha \ll 0.1\%$, coefficient = 1.7% p.a.; if we limit the analysis to the years 1985–1991, all parameters will improve, e.g., $t = 16.1$, coefficient = 2.2% p.a. No auto-correlation is observed.

[8] For Belgium, in particular, and for other countries compare Patel and Pavitt (1991).

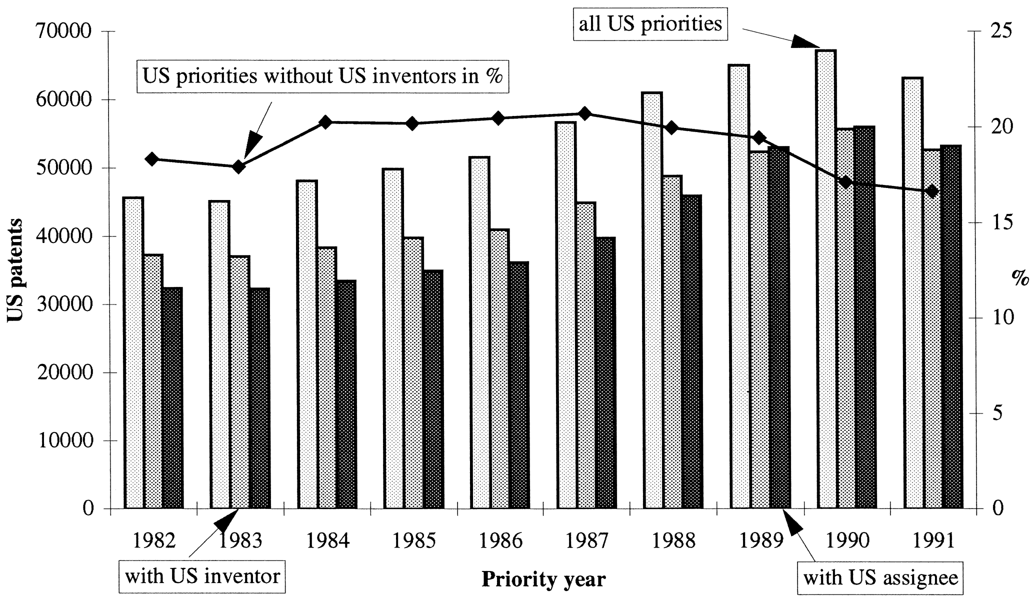

Fig. 3. Analysis of country demarcation concepts in patents statistics for the US by priorities 1982–1991 (data base sources as in Fig. 2).

cepts of the assignment of patent statistics to countries matter and are econometrically relevant. In the age of globalisation, structural changes are observed on a low level as of now which nevertheless make intertemporal comparisons particularly difficult if one is not sure about the country demarcation. Existing literature on the econometrics of innovation and patenting is not always explicit in this respect.

3. Economic 'filters' in comparative patent statistics

Private or corporate research generally produces patents rather than academic publications. Patent statistics are an accepted output indicator for codified knowledge from strategic and applied research and industrial development. However, the economic value of any one patent is difficult to determine [9] and, what is more problematic, the *average* patent value differs considerably between countries (because of different patent values (see Harhoff et al., 1998) but also serious differences concern patent law; see the remarks on Japan in Section 1). Therefore, we need economic filters.

3.1. Four possible filters

(1) One of the most widely used filters is to rely *only* on USPTO data (Dosi et al., 1990). The patents granted in the US may serve as a benchmark for an analysis of the bilateral strength in technology between any one non-US and non-Canadian group of nations in the US markets for technology. It is questionable, however, whether *international* relations (also within the EU and between the EU and Japan) should be reflected in foreign intellectual property rights in the US. From a theoretical perspective this is an insufficient condition. Therefore, another demarcation of filters for intellectual property rights with significance for international technology comparison was looked for.

(2) As duplications of patents in several countries can be traced and matched to each other, so-called patent families may be defined centering around one invention (priority) and bringing together the related property rights in all countries of the world. A major

[9] For a review, see the section on 'Patents Rights and Patent Values' in the paper of Griliches (1990).

improvement was suggested by Faust and collaborators early in the 1980s that, instead of counting external patents in a given third country, a country's total patenting should be grouped into patent families and only the priority patents of such families should be counted (Faust and Schedl, 1982; Faust, 1990). This group of authors argues that in this way double counting of specific innovations is excluded worldwide and patenting biases resulting from special bilateral relationships between countries are eliminated. These authors further suggested that one should exclude the 'one-member' families, i.e. domestic patent applications in any one country, having no foreign equivalent. The threshold requirement are thus patent families with at least two members. This definitely excludes the large number of exclusively domestic Japanese patent applications with usually only one claim (for a review, see Pavitt, 1985).

The 'two-member patent families' approach represents an *economic threshold* criterion. As external patent applications require higher costs on the side of the applicant company, the firm will only be prepared to go abroad if expectations in the commercial value of the invention justify this. The additional costs do not only arise from fees at the external patent offices, but more so from the necessity to translate the documents and to pay the external patent attorneys. Thus, the approach to base econometric patent analysis on priorities with one (or more) external applications sorts out the economically more relevant inventions from all inventions and provides a more balanced subset for statistical inference.

Patent protection establishes market access barriers and, as a result, creates a temporary monopoly on product availability or facilitates a head start in application of technology. However, not every technological innovation is patentable and a patent application is not filed for every patentable innovation. One major reason for filing an external patent application and thus giving birth to a further member of the patent family may be to safeguard export business: Applications are filed in those countries that are targeted for export. Therefore, if intensive bilateral trade relations exist between two countries, their propensity for mutual or one-sided external patent applications might be much higher than for remote countries without close trade relations. Thus, the geo-economic vicinity of any two countries may affect the threshold or filter effect.

Consider the case of Canada in relation to the US (and of Switzerland in relation to Germany and so forth; compare also Fig. 1). The economic incentive to have at least one external patent application is in reality much higher than for countries such as the US with large domestic markets or isolated countries like Japan. This is indeed observed when one works with the filter 'one external application' only.

(3) A further improvement results from the establishment of the EPO. For details of the related procedures see footnote 4. The EPO is a regional patent body with the consequence that patent applications there quasi automatically fulfill the criterion of at least one external application. If the European application refers to a national priority, then the EPO filing *establishes* the second patent family member right away. Indeed, if priority is claimed at the European Patent Office (EPO) the destination normally exceeds one member country. Fees at the EPO are so high that a filing is cost-effective only if about four national external applications are aimed at (Straus, 1997). Thus, the economic filter has narrower stitches than the Faust approach.

Using EPO data has other advantages: The examination procedures are of high quality and—as it is a single office—all underlay the same legal framework. The EPO accepts three languages (English, French and German) which can be attractive for many firms in the world. The EPO filter ultimately defines a subset of all patents which is slightly biased towards European nations and in particular to the disadvantage of countries like Japan. The single most active nation at the EPO is, however, the US, and not any European country.

(4) A fourth and last suggestion for economic filtering is the *triad model* (Grupp, 1998). The economic threshold is set as in the proposal with 'two-member patent families', starting from a sample extrapolation of patent families, but now an additional threshold is introduced to cope with geo-economic factors and to match world trade structures. In so doing, for each country only patent families with external applications in the *two foreign* triad continents (North America, Western Europe or Japan) are considered, and thus external applications in neighbour countries would not be considered sufficient.

3.2. Comparing the utility of the filters

In order to test the usefulness of the various filter concepts, we examine the world market share for all manufactured products in relation to eight sets of patent data, among them the EPO and triad patents (TP). [10] Further, we assigned the US patents by inventors' countries (residence of inventors) as well as by assignees' countries (shareholder principle) to get an impression of the significance of globalisation effects. The first set (USINV) represents the country of origin, the second the firm/country (by assignee) controlling the technology (USASS). Next, we selected Japanese patent applications (at the Japanese office Tokyo Cho, TC) and patent applications at the German Patent Office (DPA) to represent national patent statistics not discussed here in detail.

From these data sets, we constructed two more patent samples (all sets being adjusted to 1986–1988 priority years also for granted US patents in order to avoid any form of incomplete data; we did not use patent publication or grant dates). We merged all domestic patent applications for the OECD countries (DOM) and also added the EPO patents with designation Germany to the national DPA data (and denote this set as DPA/EPO), as legal protection on the German territory is warranted both ways (duplications excluded).

Annual averages for the priority years 1986 through 1988 have been selected. These patents may be regarded as proxies for corporate attempts to protect their goods produced in the early 1990s. Among others, Legler et al. (1992) and Amendola et al. (1993) found in different types of investigations that patent statistics, because of the cumulative nature of innovation, proceeds international trade by about 3 years. Accordingly, the trade data from 1990 are selected. [11]

By linear regression of the data samples (in each case the world patent share per set) with the world export share in manufactured goods, we found the results as compiled in Table 3. [12] Two sets of patents are highly significantly correlated with the export performance, the TP (as expected), but also the European data. Due to the considerably higher fees at the EPO, there seems to be a similar filtering process of the most important patents with relevance for world markets as by the triad model. Yet, rank correlations show the problem of EPO comparative statistics: Japan is largely underestimated but has only one weight in the cross-section sample, whereas the many European countries have more weight taken together.

Table 3
Regression results for world export share (1990) of 17 countries and seven patent samples (priority dates 1986–1988)

Patent sample	Coefficient (t)		Constant (t)	
USINV	0.26	(4.0)[b]	4.23	(4.5)[a]
USASS	0.25	(4.0)[b]	4.34	(4.6)[a]
TC	0.02	(0.7)	10.9	(8.3)[a]
EPO	0.57	(7.3)[a]	2.33	(4.5)[a]
DOM	0.16	(3.2)[c]	3.83	(4.4)[a]
DPA/EPO	0.35	(4.7)[a]	5.41	(5.2)[a]
TP	0.37	(5.6)[a]	3.60	(5.0)[a]

[a] Highly significant at the 0.1% level (heteroscedasticity-robust errors).
[b] Significant at the 0.5% level (heteroscedasticity-robust errors).
[c] Significant at the 1% level (heteroscedasticity-robust errors).

The US patent data explain the trade advantages reasonably well (significant correlation) and there is nearly no difference between the inventors' countries and the assignees' countries which *downplays* a strong distortion effect from *globalisation* (but, of course, the disparities discussed in Section 2 remain). Similarly good is the correlation when all patents with protection in Germany are taken together (DPA/EPO). Patent documents for the German territory, not neglecting the European access to protection, are similar to European patterns. Domestic patents (DOM) can also explain world trade, but not patents in Japan. [13]

From this, we conclude that higher levels on certain world market segments, i.e., manufactured

[10] Unfortunately, patent statistics specified accordingly on the basis of 'priority with one external application' is not available for most countries.
[11] Sensitivity analyses with different years did not change much.
[12] Similar calculations were first published by Grupp et al. (1996).
[13] Note that Belgium and Luxembourg which form an economic and monetary union are treated as a single country. Note also that all German data are for West Germany only.

goods, fall together with higher levels of technological activity as evidenced by patent output. But due to the limitation of patent property to national markets, the analysis of high technology advantage should be filtered and based either on European patents or on TP.

The filter instruments introduced in this paper seem to be well suited for broader application in the analysis of technical change as well as in economic policy. *National* technology production seems to be a major component of market success at least for the markets of manufactured goods despite increasing intra-firm flows of knowledge around the world.

4. Fitting the international patent procedures

4.1. Growing popularity of delayed patent decisions

The latest 'innovation' in patent procedures is the establishment of an international access to protection by the PCT in 1978. The World Intellectual Property Organisation (WIPO) enables firms with international marketing expectations to proceed as follows (Schmoch, 1998). First, a single document is filed in the PCT system and at this moment no translation nor the payment of national fees is required. The firm *designates* in which of the PCT signatory states patent application shall be made effective later on. The PCT procedure in the first phase (so-called 'Chapter I') does not automatically yield a valid national application in analogy to the EPO in the area of EPO member states. Rather it offers an opportunity to delay the decision on effective national coverage including payment of translation and attorney costs and national fees in most cases by more than 18 months. In the meantime the international office provides an international search which is transmitted to the assignee about 16 months after priority. If the assignee so wishes a preliminary examination is performed and a non-binding report is transmitted to the assignee about 28 months after priority (so-called 'Chapter II').

The firm now can make up its mind whether the invention is worth being applied for in several countries of the world. Either, in the 31st month after priority, it provides translations, pays the bills of the foreign attorneys and the fees of the patent offices which were designated in the international phase, then the various national applications go on as usual. Or, the firm does not make the payment after the extended term in some or all of the designated states, then the consequence is that in these states the international designation is regarded as withdrawn and there will be no legal impact of any form. [14]

As Fig. 4 shows the PCT procedure got very popular in the age of globalisation: The total number of international patent application in the designation phase (i.e., before opening the national application phase, or, in case of the EPO, the regional application) increased by a factor of 60 between 1985 and 1995. [15] The largest share of these originates from the US. If one considers the absolute numbers which are now well above 40,000 per year it becomes obvious that omission of the PCT procedures in econometric patent analysis would cause a serious validity problem. [16]

4.2. Consequences for patent analysis

But do the above regulations matter? Is the distinction between an international designation and an effective national application meaningful? And if so, are the numbers of statistical relevance or negligible? The quite complicated regulations and in particular the extended terms of payment are apparently a good opportunity in strategic business planning. From business administration analysis, we should expect that firms will probably exploit the favorable regulations of the international patent procedures. Therefrom, we arrive at the hypothesis that firms will take a deliberate decision on future national markets of technology protection, and will arrive at a tradeoff between fullest coverage and cost.

[14] PCT 900, article 39 (2). The firm gets a prompt note in due time, in order to take such a decision timely.

[15] The PCT procedure was introduced already in 1978. However, the enormous increase began but in 1985 due to an extension of the delay period of the preliminary examination reports. Instead of 18 months, firms have now 31 months to decide on cost-intensive national or regional filings.

[16] The difference between the two curves in Fig. 4 is primarily due to the fact that WIPO reports PCT application years. In most cases, there is a lag between the national priority and the PCT application of 1 year (priority year). If we shift one of the curves by 1 year, they coincide.

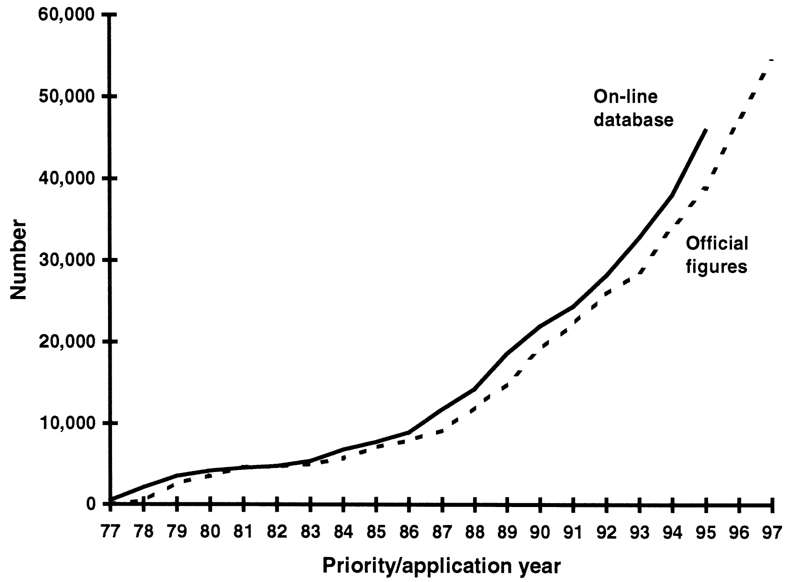

Fig. 4. Total number of worldwide PCT applications in the international phase according to official WIPO (1997) figures (application years) and on-line searches of priority years (sources: PCTPAT, host Questel, February 17, 1998).

The number of US inventions on the international patent route well exceeds the number of 11,000 in 1991 (compare this to Fig. 4). Nearly all of them carry a designation for the EPO and the TC (Japanese Patent Office) and thus are designated to cover the triad areas outside the domestic country (designation Europe is true in more than 97% of all cases, the one in Japan in 93%).

However, when the extended term of payment is over, cost-effective *transfer* into the national (or regional) phase is only decided for 63% (EPO) and 50.5% (TC), respectively. This means, that nearly half (40%, resp.) of the international designations from the US are withdrawn in the case of Japan (and Europe, respectively). In Fig. 5, [17] we analyse US priorities in detail, but the findings for the other countries are very similar (for details, see Schmoch, 1998). For smaller countries with few but important global companies, the relations can even be more extreme.

In econometric patent analysis, how do we cope with any selectivity biases? First of all, initial PCT designations do not meet the *economic filter criterion* in many cases. The withdrawn PCT applications are deliberately those which we should not keep in the analysis; they have the quality of a national patent application.

But also the content of the non-transferred PCT designations is different. We can assess this by asking the question how would the success rate (i.e., the granting of the patent) of non-transferred relate to transferred PCT applications. As we have to keep granting procedures per patent office constant, from all possible PCT applications we only chose those with an EPO designation. If we take full samples of direct EPO applications, transferred Euro-PCT and non-transferred Euro-PCT designations from priority years 1985 to 1993, we arrive at Fig. 6. Whereas the transferred PCT applications come close to the success rates of direct EPO applications, the initial Euro-PCT designations, comprising transferred and non-transferred Euro-PCT designations, rank considerably lower. Thus, we conclude, only transferred PCT applications are of comparable quality to EPO applications. [18]

Secondly, as the withdrawal by non-payment can

[17] The basic samples are all US-invented priorities of 1991 in the international PCT phase.

[18] The decline of success rates in more recent years is explained by the fact that the granting procedures are not yet concluded.

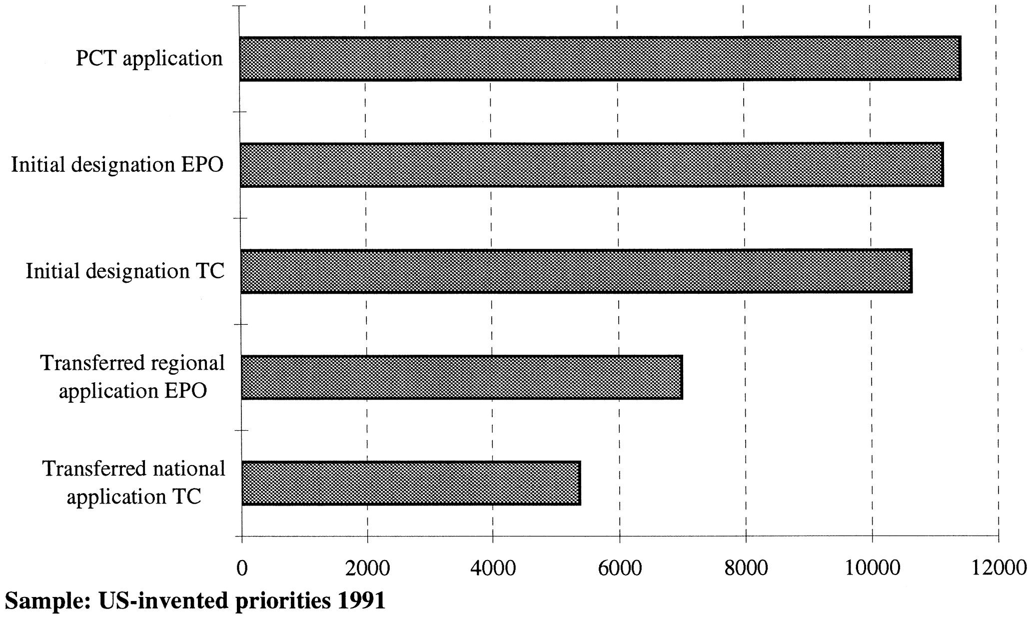

Fig. 5. Breakdown of US inventions in the international PCT phase with respect to designation in the triad (sources: PCTPAT, EPIDOS/INPADOC, EPAT).

occur after 31 months, analysis in *recent years* is affected and intertemporal comparisons may be biased. With the exception of the USPTO, patent data samples are complete 18 months after priority, but this is not true for the part channelled through the international procedures.

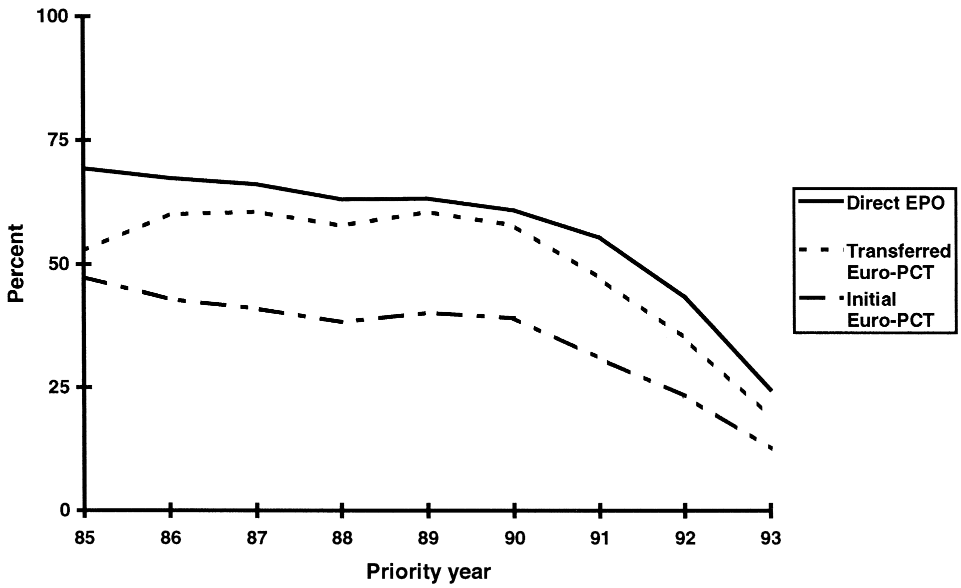

Fig. 6. Comparison of success rates (quality) of various patent sets for the priority period 1985–1993 (in percent) (sources: PCTPAT, EPAT, host Questel, January 29, 1998).

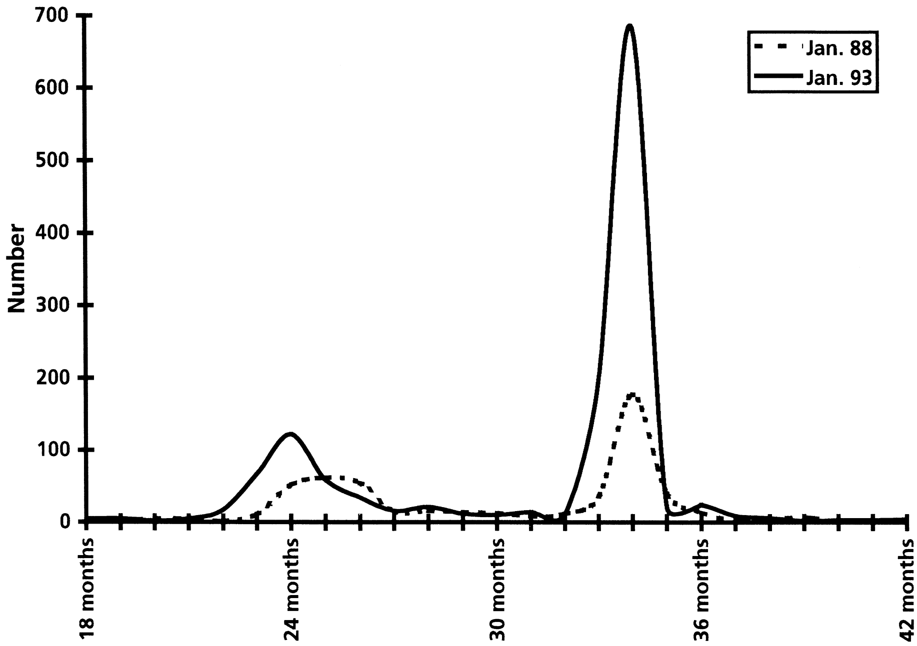

Fig. 7. Publication periods for two samples of transferred Euro-PCT applications of the priority months January 1988 and January 1993 with reference to the priority date, respectively (sources: EPAT, host Questel, January 27, 1998).

Fig. 7 shows that the publication of transferred Euro-PCT applications takes place in the 34th or so month after priority, i.e., *one and a half years after a national publication* would occur (except in the case of the US). Thus, we know about the mere existence (but not about the later territorial validity) of a PCT application 18 months after the priority date, as it is published at that time by the WIPO. However, the effective transfer to the EPO or a national office is confirmed 3 years after priority.

These developments certainly have introduced some new complexity in counting and interpreting the numbers of external applications made by a particular country. If one would not apply the economic filter and keep all PCT applications from the international phase in the analysis, this can seriously *inflate* technology performance comparisons and distort country rankings as the national share of PCT documents differs considerably. The excessive use of a particular application route by residents of firms of a certain country may create statistical artifacts. [19]

[19] This assessment follows Bryant and Lombardo (1996).

4.3. Remedies through estimation—a new proposal

It is suggestive to introduce *extrapolations* to get an unbiased coverage of the more recent years of the analysis. One way to arrive at a reasonable compromise between actuality and non-selectivity consists in a data base search of all initial PCT designations including the (later) withdrawn ones. If one extracts a cohort from these data ‘older’ than 30 months and derives from this the conversion ratios from the international designation to the transferred national application for any one national patent office, then—with the additional assumption that these conversion ratio remains stable for the younger cohorts —one may estimate the share of withdrawals. Of course, this is a challenge for microeconometric analysis as count data, hazard rate and in general time dependent models have to be combined in an appropriate manner (Ronning, 1991, Chapter 4).

The estimation we propose here (and use in Section 5) thus reads

$$\mathrm{PCT}_{\mathrm{tic}}(t_1) = \alpha_{\mathrm{ic}}(t_1)\mathrm{PCT}_{\mathrm{dic}}(t_1)$$

with PCT_{tic}: transferred PCT applications (from country c to office i (i = EPO, USPTO or TC for the triad model); PCT_{dic}: initially PCT designations; t_1: any recent year with data missing; whereby the transfer ratio α is

$$\alpha_{ic}(t_1) = PCT_{tic}(t_0)/PCT_{dic}(t_0)$$

with the above notation. t_0 denotes a year with no data missing; this must be—in accordance with Fig. 7—at least 3 years (36 months) behind the actual year of analysis (Table 4). Alternatively, α_{ic} can be defined by a time series regression up to t_0 extrapolating the ratio to t_1. Of course, direct national or, in the European case, regional applications have to be added to PCT_{tic} without use of α (or $\alpha_{ic} = 1$).

5. The pace of technical progress up to the 1990s: the empirical evidence reconsidered

In the following analysis, an attempt is made to estimate the rate of technical progress by looking at patterns and trends across the three patenting systems: EPO, USPTO and TC. The analysis presents the evolution of those, usually technologically very important, patents filed simultaneously under all three systems. Thus, we try to reconsider the empirical evidence in an unbiased way using the triad 'filter' from Section 3.

Fig. 8 shows the evolution of TP per million employees during the period 1980–1995 for the European Union (EU-12, Germany, France and the UK, and the total EU-15), the US and Japan. In Fig. 8, we

Table 4
$\alpha_{ic}(t_i)$ ratios for transferred PCT applications to the i = EPO by priority years t_1 and countries c in percent (sources: EPAT, host Questel, update 13th January 1998)

c	t_1									
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Australia	67	64	57	66	70	75	79	82	85	86
Austria	16	16	15	19	18	22	28	29	33	40
Belgium	9	7	8	12	18	25	23	31	30	37
Canada	7	9	10	10	40	44	55	58	65	70
Czech Rep.	0	0	0	2	0	17	53	58	67	62
Denmark	50	38	43	58	70	70	68	75	81	79
Finland	58	52	49	45	43	50	51	60	61	68
France	10	8	8	8	11	15	18	21	25	27
Germany	9	8	9	12	16	18	19	23	28	31
Great Britain	19	15	18	20	30	42	44	51	56	61
Greece	22	18	0	10	37	34	59	37	67	63
Hungary	47	46	44	42	48	39	55	58	58	57
Iceland	17	0	100	50	33	33	56	17	22	33
Japan	7	9	10	9	10	11	11	13	16	19
Luxembourg	9	11	11	14	9	7	16	17	17	53
Mexico	25	23	22	13	24	33	13	40	52	68
Netherlands	4	3	3	5	10	15	15	24	31	55
New Zealand	2	5	13	15	15	46	47	85	84	91
Norway	58	37	43	58	65	72	68	70	78	87
Poland	5	6	7	3	22	27	59	33	68	69
Portugal	14	0	23	17	25	20	29	23	55	44
South Korea	62	69	32	25	13	12	24	26	25	28
Spain	7	4	4	5	15	21	20	30	23	35
Sweden	47	44	46	50	57	60	63	68	75	83
Switzerland	13	10	11	12	13	16	18	23	25	29
Turkey	0	0	0	50	20	14	14	50	55	43
USA	22	19	22	23	27	34	38	43	49	53
Total	16	13	15	16	19	23	26	31	35	40

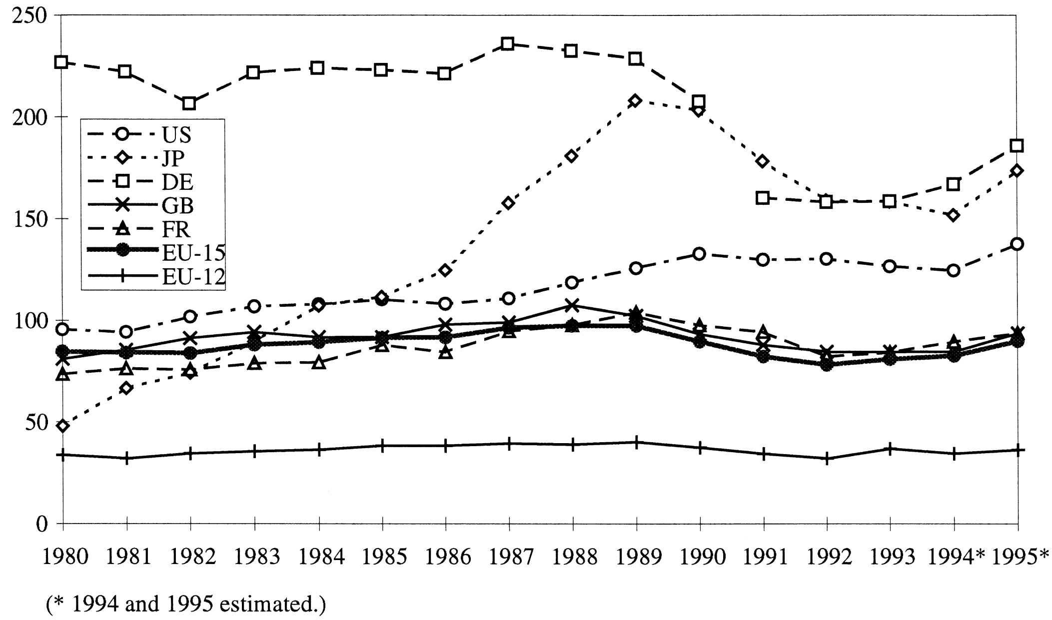

Fig. 8. TP output 1980–1995 by priority years (sources: PCTPAT, EPIDOS/INPADOC, EPAT, EUROSTAT, September 18, 1997; note that 'Germany' denotes West Germany until 1990 and unified Germany since 1991; data are in patent numbers per million employees).

estimated the transferred PCT applications with priority years 1994 and 1995 according to the α ratio defined in Section 4.3. As the data compilation was done in the autumn of 1997, and the '36-month rule' derived from Fig. 7 applies, the 1993 priority data were complete, but the later annual cohorts were not. In addition to the transferred PCT applications, the direct applications at the USPTO, the EPO and the TC were added to the data pool. Only patent families with three members were taken and they were counted as one each, following the triad model. The assignment of these to nation states (or the EU) was done by residence of inventor(s). So all the methodological improvements to patent statistics introduced in the paper were applied.

Japan's triad patenting output was a considerable way behind that of both the leading nations, the US, and the European Union at the beginning of the 1980s. However, in a dramatic catching up, Japan overtook Europe around 1983, and the US around 1986, and its patent productivity continued to rise until about 1989. Perhaps as a result of the incipient worldwide recession at this time, and in view of the costs of maintaining foreign patent applications, Japanese firms appear to have reduced their patent productivity, while still remaining ahead of Europe and the US. Since about 1992 they maintained a very high flat level, which is about three times that of the beginning of the 1980s.

Thus, the US, from the leading position of the 1980s, are now in second place in the triad although not too far behind Japanese patent productivity. The US increase throughout the 1980s reached a peak in 1990, at nearly 50% above the level of a decade before. Since then a leveling-off has occurred, recently a further improvement (compare also European Commission, 1997, p. 93).

Since the early 1980s Europe [20] has been lagging well behind the US and Japan, and at the beginning of the 1990s its position even deteriorated. Since 1993 a slight increase is observed, but overall, the EU is in essentially the same position in 1995 as in 1980. Within the EU there is a strong disparity between countries like Sweden, the Netherlands and Germany being above EU average, France and the UK representing the EU average, and countries be-

[20] Artificially taken together as EU-15 irrespective of the year each of the member countries actually joined.

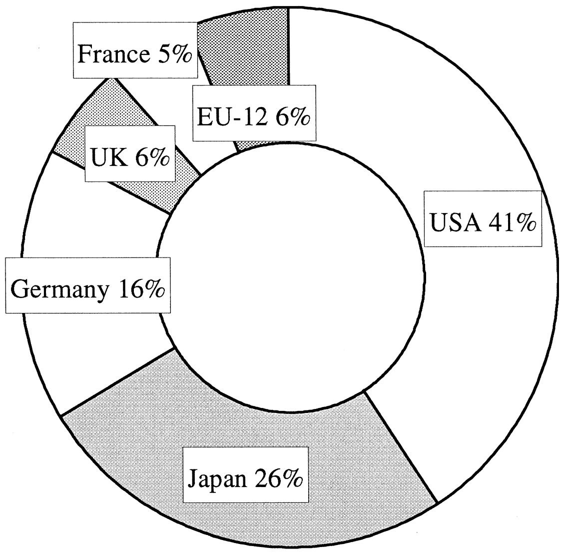

Fig. 9. Relative shares of TP of the triad countries in 1995 (sources: as in Fig. 8, data estimated as described in Section 4.3).

low.[21] The three large EU members and EU-12 are also included in Fig. 8. For all three of them, on different levels, the pace of technical change was lower in the beginning of the 1990s, and accelerated in France and the UK since 1993, in (unified) Germany in 1994.

For comparison with other reports on this matter, e.g., the indicator reports in the US (National Science Board, 1998) or France (Observatoire des Sciences et des Technologie, 1998), the relative shares of TP are also given in Fig. 9 without further discussion. One observes differences in the assessment of countries' technological strength, depending on the method of measurement. This brings the issue of the policy relevance of patent methodology on the agenda.

6. Discussion of the policy relevance of refined patent statistics

We close this article by providing an example that points to the *policy relevance* of non-compensation of selectivity. In several recent publications on overall trends in technology dynamics it was argued that since about 1988 innovation dynamics in US enterprises developed extra-ordinarily positively whereas in about the same time period there was stagnation in Germany and a decline in Japan.[22] In our analysis of the technological competitiveness, on the contrary it was found, that while Japanese innovation dynamics is somewhat declining and the innovation dynamics of European firms and in particular German firms is stagnating, US enterprises experienced innovation growth only up until 1990 and since then remained flat on a high level with no further increase up to 1994.

In order to reconcile the diverging statements on innovation dynamics in the triad regions, the following issues deserve attention. In the macroeconomic studies claiming an acceleration of technical change in the US in the 1990s, for the sake of actuality all the initial PCT designations were accounted for by priority countries. In this article (Fig. 8), on the other hand, the inventor country principle was applied and by extrapolation in recent years and the cohort approach described in Section 5 the withdrawn PCT designations were removed from the sample, and only the transferred ones accounted for. If one would use the (total) number of initial PCT applications and the country of priority principle, then one could reconstruct the ever increasing innovation trends in the US with utmost significance.[23]

The very positive innovation dynamics of US enterprises is thus an effect of increasing numbers on the international patent route and negative investment decisions after the delayed term of 31 months. Many companies with US inventors seem to make the best use of this new opportunity for patent protection, more so than companies in other countries of the world, or companies with US priorities but non-US inventors. They are very selective with the economic decision to protect their technology world-wide and therefore 'inflate' international statistics more than others. This inflation has been

[21] In EU-12, Sweden and the Netherlands are included, but the average of EU-12 is dominated by large countries like Spain and Italy.

[22] See Ifo, 1995, p. 175; Bryant and Lombardo, 1996; Kortum and Lerner, 1998, among others.

[23] We did so in a simple simulation model not reported here in detail. Error probability for growing US trends was below 0.1%.

measured in the papers quoted whereas, if we keep the economic filter constant for the intertemporal comparison, no such effect can be found. This seems to be an important distinction for economic policy. The issue is *not* which of the data samples is 'correct' and which one is 'wrong', but rather which economic filter is more adequate for policy analysis. [24]

Macroeconomic patent statistics in the age of globalisation is facing challenges. Multinational enterprises allocate resources for R&D world-wide. Direct investments abroad, the acquisition of laboratories and a network of subsidiaries or holdings makes best use of mobile sources of technology. The 'absorptive capacity' draws on the science base in several national systems of innovation. The macroeconomic assignment of technological achievements as measured by patents gets more complicated. Fortunately, econometric patent analysis has choices between various models which do not necessarily contradict each other but offer opportunities for more refined statistics.

Of greatest importance is the use of economic filters in cross section country or intertemporal comparisons as the value of single patents and the average value in national patent statistics are at variance. In this respect, a number of good alternatives was developed in recent years. Among them the EPO model and the triad model seems to bear best prospects for future use (see also European Commission, 1997). The rocketing importance of the international patent procedures deserves special attention in order to avoid selectivity.

Despite the methodological progress achieved in recent years, important research questions remain open. As we witness a growing importance of international patent procedures which make estimations and extrapolations extremely difficult, the question remains, whether there will be a stabilisation of trends after the attraction of this route settles down on a high level. If the share of international vs. national patent procedures would level off, extrapolations could be based on more stable estimators and the analysis of cohort effects can be abandoned.

Another methodological question is whether standard extrapolation practices will happen in the community of researchers studying innovation and patents. The α ratio method introduced in this paper could be a generally acceptable method. Related to this is the peculiarity of the USPTO, not publishing patents filed strictly after 18 months even if they are not granted later on. After Canada switched to the standard OECD scheme with a publication period of 18 months in the 1980s, the US patent system is on the legislative way to adapt as well probably within the next years. [25]

On the other hand, patent offices are feeling competition between each other as their attractiveness to firms is relevant for their income and employment. One might conjecture that some national offices could prefer to offer similar extended terms of payment as the International Office does. This again would initiate more structural change between the competing ways to arrive at technology protection and would probably make observations in recent patent statistics more difficult than it now already is.

To sum up, facing challenges from globalisation, patent econometrics develops better methods, more refined tests and new insights into technology development and diffusion over future markets. Obeying reasonable confidence limits, actuality of macroeconomic patent statistics is not hampered, but validity, accuracy and cohort effects become top measurement issues.

Acknowledgements

The authors are grateful for the financial support of the Federal German Ministry of Education and

[24] In econometrics, issues of adequation, i.e., of correspondence between operational statistical and theoretical constructs such as 'pace of technical change' must be well considered. For a general discussion of statistical adequation of mental constructs, see Menges (1974), pp. 3–49. A discussion of 'operational concepts' and 'constructs' can be found in the paper of Machlup (1960).

[25] The House of Representatives is moving quickly on H.R. 400, a bill to amend title 35 of the US Code to authorize publication of US patent applications 18 months after filing (except in the case that the invention disclosed has and will not be the subject of an application filed in a country other than the US, i.e., for domestic, one-member families; 21st Century Patent System Improvement Act, etc.).

Research (BMBF), Bonn, and to Mr. E. Beyer personally, Section Head of Economic Affairs, for the opportunity to work on technology performance indicators and to annually produce a related report. In this framework, it has been possible to elaborate the new patent methods introduced in this article to an international audience. We are also grateful for quite detailed comments of two referees and discussion remarks by participants at the conference on the 'Econometrics of innovation: patents' organized by the Applied Econometrics Association (AEA), Luxembourg, November 1996, to whom we outlined our new ideas. Last, but not least, we have to thank the OECD, and Mr. D. Guellec in particular, for the permission to use some of the data being provided to the Directorate for Science, Technology and Industry as part of our consultancy.

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