# Trade Balance of Patent Rights: Who Gains What from International Patent Harmonization, and Why?*

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**Abstract**

The economic implications of international patent harmonization have attracted little empirical scrutiny. Based on patent application and renewal data in major European countries since the early 1980s, this paper examines the empirical relationship between international patenting, R&D, and "trade flows" of patent rights across national borders. The analysis reveals a substantial patent "trade imbalance" among European countries, with size comparable to regular trade balance. Difference among individual countries' ability in rent appropriation through international patent harmonization is primarily related to countrywise differences in R&D intensity and efficiency, as well as institutional differences in enforcing patent rights.

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## 1. Introduction

Technological spillovers and the transfer of intellectual property rights are becoming key factors in international trade and development, and are shaping the world economic geography in the new century. As an increasing share of international economic activities have shifted from physically based to knowledge based, international patent harmonization has received increasing attention from both academia and policymakers. The signing of the TRIPS (Trade-Related aspects of Intellectual Property Rights) Agreement — albeit controversial — in the Uruguay round, for instance, signaled an important milestone in the progress of patent harmonization; whereas the recent collapse of the Doha Development Round negotiations reflected severe disputes over intellectual property issues. All these new developments in the global economy call for quantitative analyses of the economic consequences of international patent harmonization.

Most of the existing literature, however, focuses on theoretical analysis of the welfare gains and losses in international patent harmonization, and few tackle on the empirical side of the issue. This is not surprising, given the fact that patent rights are rarely traded and their values are unobservable. Even for traded patents, in most cases the details of transactions including prices are not revealed to the public. This difficulty seems insurmountable for any empirical studies of patent rights, including welfare analyses over international patent harmonization.

In this paper I address this problem by computing patent values from information available on international patent application and renewal behavior. Based on data collected from patent offices in major European countries since the early 1980s, I estimate the private value of patent rights in these countries, and calculate "implicit R&D subsidy" that the patent system of individual countries provides for inventors around the world, across various technological fields. I then estimate the volumes of net flows of patent rights across national borders within Europe, and draw a broad picture of the balance (or imbalance) of the private value of patent protection each member country offers and receives under the European Patent Convention. Finally, a series of simulation exercises are conducted to explore the determinants of the significant patent trade imbalance that our analysis reveals.

The estimates of patent value are derived from a modified version of the joint patent application-renewal model developed in Deng (2006a). The basic framework relates the expected value of patent right to inventor's patenting behavior in an international setting: which countries to seek patent protection, and how long to keep the patent right alive in each country.

In particular, such decisions are modeled as made by a profit maximizing inventor, where a patent is sought only in countries where expected returns exceed associated patenting costs, and will be kept alive until net returns becomes negative. Estimation of this structural model not only generates quantitative estimates of patent value and the implied patent trade imbalance, but also enables the counterfactual experiments that explore the sources of such an imbalance.

The main empirical results are summarized as follows:

First, patent system in European countries provides sizable implicit subsidy to R&D activities. The total patent value in major European countries is equivalent to an R&D cash subsidy rate of around 31% on average, ranging from 24% for mechanical industries to 47% for the pharmaceutical industry.

Secondly, the economic rents appropriated by inventors in individual countries through European patent system exhibit significant differences. Within the ten European Patent Convention (EPC) member countries in our analysis, there is significant imbalance on the amount of net patent protection received by each country. For instance, out of patent cohorts 1980 to 1985, German inventors received a total of $36 billion (in 2000 U.S. dollar value) worth of patent protection from the EPC, whereas Germany provided $26 billion worth of patent protection to EPC inventors as a whole, thus generated a net patent "trade surplus" of around $10 billion, which amounts to 15% of its annual regular (goods and services) trade surplus. On the other hand, inventors from the U.K. received less than $10 billion worth of patent protection from the EPC, whereas it awarded $21 billion worth of patent rights to EPC inventors, generating a net patent "trade deficit" of about $11 billion, or 44% of its annual regular trade deficits.

Thirdly, simulation studies reveal that such substantial patent "trade imbalance" is primarily caused by country differences in R&D intensity and R&D efficiency. Germany and Switzerland had the highest R&D intensity and efficiency and enjoyed a disproportionately larger share of EPC patent protection, while Italy had the least. On the other hand, there are substantial institutional differences in enforcing patent rights across individual countries, which tend to offset the effects of country differences in R&D intensity and efficiency and diminish the observed patent "trade imbalance," as countries with weaker degree of patent protection tend to have lower R&D input and efficiency. Country differences in patenting costs and technological composition of their pool of inventions only have modest effects on explaining the observed patent trade imbalance.

The outline of the paper is as follows. Section 2 gives a brief introduction of patent harmonization in Europe and discusses the patent sample that will be used. Section 3 presents a patent evaluation model based on patent application and renewal analysis. Section 4 simulates the patent value distribution and calculates "implicit R&D subsidy" the European Patent Convention implies. Section 5 calculates the "trade flows" of patent rights within Europe, and Section 6 explores the determination of patent "trade imbalance" through a series of sequential simulations. Section 7 concludes.

## 2. International Patent Harmonization in Europe

Patent system in Europe has undergone major changes since the 1970s. The signing of European Patent Convention (EPC) in 1973 marked an important milestone toward a unified patent system in Europe. The EPC provides a legal framework for the granting of European patents, via a single, harmonized procedure through the European Patent Office (EPO), its executive branch. Under this framework, a patent applicant only needs to file a single application and, upon payment of a per-country designation fee, designates multiple EPC member countries to seek patent protection. Once the application is approved, he can then transfer it to the countries he initially designated and obtain a set of national patents or a European patent family.[1]

Over the past three decades, the European Patent Convention has become the most successful regional patent organization. Most patents in European countries are now granted by the EPO, and by the late 1990s the EPO had already "almost entirely replaced direct applications to national patent offices" in Europe (Eaton, Kortum, and Lerner 2003). The following study is based on a sample of 757,808 patents awarded by ten EPC member countries, derived from the universe of all 121,069 patent applications submitted to the EPO during 1980 to 1985 (referred to as cohorts 1980 to 1985, same below) and finally approved.

Table 1 summarizes characteristics of this sample. Among the ten EPC member countries, Germany is the largest patent granter, awarding 113,308 patents to applicants around the world, or 15 % of the total European patents obtained through the EPO during 1980 to 1985. The second largest patent granter is the U.K. (14.6%), followed by France (14%), Italy (11%), and

[1] Although the term European patent is often used in the literature to refer to patents granted by the EPO, one should realize that, such "patent" is not a unitary right, but a group of essentially independent, nationally enforceable, nationally revocable patents. Currently there is no single, centrally enforceable, European Union-wide patent.

Netherlands (10%). The ranking of patent numbers is consistent with the relative economic importance of these countries. However, they do not exhibit substantial difference as their size of economy would have implied. For instance, during 1980 to 1985, Luxemburg, the smallest EPC member country by then, granted 29,012 patents, or 26% of the number of patents awarded by Germany, the largest EPC member country, although Luxemburg's GDP is on average only less than 1% of the German GDP.

The number of patents received by different countries, on the other hand, exhibits substantial differences. Germany and the U.S. are the largest patent source countries, owning 194,490 and 186,871 patents through the EPO during 1980 to 1985, respectively, whereas the smallest patent source country, Luxembourg, only owns 1,582 patents. More than 60% of the patents were issued to inventors in the EPC member countries, followed by inventors in the U.S. (25%), Japan (11.4%). Inventors from the rest of the world only own a small fraction of the patents — less than 3%.

A noteworthy feature of the nationality composition of EPO patents is that there is no indication of "home bias." Previous literature on national patenting practices often record a tendency for domestic inventors to apply for disproportionately large number of patents in their home countries, for instance, Eaton and Kortum (1999) find that domestic inventors are the single most important source of patent applications in the U.S., Japan, Germany, France, and the U.K. However, we do not observe any significant pattern of "home bias" in Table 1a. As a matter of fact, in almost every destination country, German inventors are the single most important source, and the number of German patents owned by French and the U.K. inventors is considerably larger than the number of patents they obtain in their home countries. "Home bias" in international patenting is often attributed by the literature to the higher implicit costs when patenting abroad.[2] The disappearance of "home bias" in EPO patenting suggests that patent harmonization in Europe has significantly reduced implicit patenting costs for foreign inventors, at least for European inventors.

Table 1b reports the technological composition of these patents. Here I classify my sample according to their international patent classification (IPC) code into five groups: pharmaceutical, chemical, electronics, mechanical, and other miscellaneous industries. Among these five groups,

[2] As a consequence, the average quality or value of patents held by domestic inventors tends to be lower compared with those held by foreigners, as such patents include more low-quality patents which would not be worth patenting if facing higher patenting costs.

mechanical patents are the largest group, accounting for 30% of all patents in total; electronics are the second largest (26%), and pharmaceutical are the smallest group (less than 6%).

All 757,808 patents are derived from the 121,069 patent applications that were successfully approved by the EPO, out of the 174,966 patent applications submitted to the EPO during 1980 to 1985. As the last column of Table 1b indicates, the grant rates across different technology fields are quite close, all around 70%. On the other hand, even though all ten EPC member countries were available for patent applicants to designate, the average number of patents in a patent family (based on the same invention) is not very high, at only 4.33 patents. Moreover, most patents do not live up to the maximal age allowed (20 years), because all EPC member countries charge an annual patent renewal fee, which increases as the patent becomes older (Figure 1). This suggests that patenting behavior (including choosing both the designation countries and optimal length of patent life) is an optimizing process based on patent applicant's analysis of costs and expected returns from obtaining and maintaining a patent. Such application and renewal decisions will be explicitly analyzed in the structural model in the next section.

## 3. A Joint Patent Application-Renewal Model

To obtain patent protection in an EPC member country $j$, $j = 1, 2, ..., J$, a patent applicant must have designated the country when the initial application is submitted to the EPO, by paying a per-country designation fee $C_0$. Once the patent application is approved by the EPO, the applicant can then transfer the approved application to the national patent offices in countries he designated and obtain national patents in those countries. As long as the annual renewal fees $c_{jt}$ are paid in country $j$ in time, the patent will be kept in force in that country until the statutory limit of the maximal length of patent protection (20 years after the patent application). Thus the decision problem for a representative patent applicant $i$ is to maximize the discounted value of expected net returns by choosing which countries to designate at the initial filing, and how long the granted patents are to be kept alive in each designated country.

The expected net present value of invention $i$ in country $j$ equals

$$NPV_{ij} = prob_{gr} \sum_{t=5}^{T_{ij}^*} 1(D_{ij}) \beta^{t-1} (\beta r_{ijt} - c_{jt}) \tag{3.1}$$

where $\beta$ denotes real discount rate, $r_{ijt}$ returns in country $j$ at age $t$, $c_{jt}$ annual renewal fees, and $1(D_{ij})$ indicates whether country $j$ is designated or not. $prob_{gr}$ is the expected approval rate of patent application, and $T_{ij}^*$ denotes the optimal length of patent life in country $j$ (which equals zero if the country is not designated). It is assumed that, while the patent approval is pending, patent applicants cannot receive any returns from the pending patents (the examination and approval process takes on average four years at the EPO). Thus, conditional on the application being submitted to the EPO, the applicant will compare the expected net present value of the invention in each country with the designation fee $C_0$ and decide which countries to designate:

$$1(D_{ij}) = 1 \qquad iff \qquad NPV_{ij} \geq C_0 \tag{3.2}$$

Note that the designation decision depends on expected net present value $NPV_{ij}$, which is a function of $T_{ij}^*$, the optimal length of patent life in country $j$.

Patent returns are assumed to depreciate over time at a constant rate $(1 - \delta)$

$$r_{ijt} = \delta^{t-1} r_{ij1}. \tag{3.3}$$

Moreover, each invention is assumed to draw an initial return from a lognormal distribution:

$$r_{ij1} = \exp(\alpha_i + bX_i + q_j + \upsilon \log(GDP_j) + \varepsilon_{ij}) \tag{3.4}$$

where $\alpha_i \sim N(\mu_\alpha, \sigma_\alpha^2)$ is a common factor (across different destination country $j$'s) determined by quality of the invention. $X_i$ denotes a list of patent-specific characteristics including dummies on inventor's nationality and technology fields inventions belong to. $\varepsilon_{ij}$ is an *i.i.d.* error term and follows $N(0, \sigma_\varepsilon^2)$.

$q_j$ and $\upsilon \log(GDP_j)$ are two country-specific determinants of patent returns in the destination country $j$. Patents belonging to the same patent family, even though they are all based on the same invention, may have different returns in different destination countries, because market size of the economy or enforcement of intellectual property rights may differ across countries. Thus in equation (3.4) a fixed-effect parameter $q_j$ is introduced to proxy institutional differences in enforcing patent rights, and $\upsilon \log(GDP_j)$ is included to measure the relative magnitude of real GDP (with Germany normalized to one) or relative market sizes. Note that relative real GDP enters with power $\upsilon$:

$$r_{ij1} \propto \exp(\upsilon \log(GDP_j) = (GDP_j)^\upsilon$$

which measures returns to scale of the economy. If $\upsilon > 1$, an invention would exhibit increasing returns to scale with respect to size of the economy.

Now let us focus on patent renewal decision in country $j$ and solve for $T^*_{ij}$. Since the returns $r_{ijt}$ are monotonically decreasing (equation (3.3)) and the renewal fees $c_{jt}$ are monotonically increasing (Figure 1), there exists a unique $T^*_{ij}$ such that for any $t \leq T^*_{ij}$, $r_{ijt} \geq c_{jt}$, and for any $t > T^*_{ij}$, $r_{ijt} < c_{jt}$. A rational patent holder will choose to renew the patent at each age before $T^*_{ij}$ to maximize the present value of patent returns, and let the patent lapse after $T^*_{ij}$. In other words, the patent holder will pay the renewal fee and keep the patent alive as long as $\beta\delta^{t-1}r_{ij1} - c_{jt} \geq 0$. This will maximize the net present value of his patent in country $j$, conditional on the patent being granted.

Thus the joint application-renewal decision rule can be summarized as follows: the applicant will designate country $j$ if and only if

$$r_{ij1} \geq r^*_{j1} \tag{3.5}$$

where $r^*_{j1}$ solves for

$$prob_{gr} \sum_{t=5}^{T^*_j} \beta^{t-1}(\beta\delta^{t-1}r^*_{j1} - c_{jt}) = D_1 \tag{3.6}$$

and $T^*_j$ is defined by

$$\beta\delta^{T^*_j-1}r^*_{j1} - c_{j,T^*_j} \geq 0 \text{ but } \beta\delta^{T^*_j}r^*_{j1} - c_{j,T^*_j+1} < 0 \tag{3.7}$$

Conditional on the patent being granted, he will be paying the renewal fees and keep the patent alive until the optimal patent age $T^*_{ij}$ as defined above.

## 4. Private Value of European Patents and R&D Subsidy

The model is estimated using a simulated method of moments (SMM) estimator. To alleviate the computational burden, the real discount rate $\beta$ is set to equal 0.95 and the depreciation rate $(1-\delta)$ is fixed at 0.15, consistent with previous literature. Table 2 presents the parameter estimates, with asymptotic standard deviations reported in the parentheses. Most parameters are significant, in particular, inventions with the U.S. origin have higher value than those from other countries, and the economic value of patent rights is statistically different across technological fields, with "pharmaceutical" patents having the highest median value. Finally, estimates of the destination country dummies $q_j$ reveal substantial institutional differences in enforcing patent rights, which we will explore in details in simulation exercises.

Based on the model estimation results, I simulate the model and derive the value distribution of European patent rights in the sample. In particular, I simulate 524,898 inventions ($nsim = 3$), and preserve the nationality-technology field correlations by simulating each nationality-technology field cell separately. For each simulated application I derive the optimal designation and renewal decisions based on the decision rules solved in Section 3, and calculate the associated patent value in each designated country as well as total value of the whole patent family, conditional on the application being finally approved.

Tables 3a and 3b present the simulated value distribution of the German and French patents, as well as that of the whole EPO patent family, for each nationality group (source country) and major technology fields. Patents in different technology fields have substantially different value distribution: pharmaceutical patents have the highest value on average, with a median value of \$0.39 million (in 2000 dollar value, same below) for the whole EPO patent family, followed by chemicals (\$0.17 million), patents in the "miscellaneous" (\$0.16 million) and mechanical groups (\$0.12 million), and electronics patents have the lowest median value (\$0.08 million). Value distribution in each destination country has the same ranking, with pharmaceuticals having highest median values (\$0.09 million in Germany and \$0.07 million in France), and electronics having the lowest median values (\$0.02 million in Germany and France). Previous studies based on national patent samples do not have a consensus on such ranking. For instance, Schankerman (1998) reports that pharmaceutical patents have the lowest value among different technology groups in France due to the drug price regulations in France, whereas Lanjouw (1998) finds that pharmaceutical patents in Germany have the highest value. The distribution presented in Table 3 is based on patent application and renewal record in all ten EPC member countries, and is thus abstracted from such idiosyncrasy.

Patents originated from different nationality groups have distinctively different value distributions, as the median patent family value of the most valuable nationality group, i.e., patents originated from the U.S., is about 50% higher than that of the least valuable nationality group (Japan). Table 3b also confirms that there is no "home bias" in EPO patenting, as value of patents originated from the home countries — here the EPC member countries — is only slightly lower than those from the U.S. but much higher than patents from Japan and the rest of the world. This is consistent with the similar findings based on patent counts in Section 2.

The patent value distributions in Tables 3a and 3b also indicate sharp skewness in each nationality group and technology field, with mean value several times larger than median value. Such skewness is consistent with the previous empirical estimates based on national patent samples, only the degree of skewness of the patent family value distribution reported here is even larger, as owners of more valuable inventions not only hold more valuable patents in each country, but also seek for patent protection in more countries.

To quantify the importance of EPC patent protection, I adopt the measure of "equivalent subsidy rate" (ESR) as constructed by Schankerman (1998), which is the ratio of total value of patent rights relative to R&D expenditures used to produce these patents. This rate measures the cash subsidy that would have to be paid to R&D performers to yield the same level of R&D if patent protection were eliminated. Tables 4 present the estimates of total value of patent protection for each technology field and the corresponding ESR. The first row gives the mean value of EPO patent families in each nationality group and technology field, taken from the last rows of Table 3a. Multiplied by the number of granted patent inventions in each group as in row two, the third row of the table displays the total value of patent protection for cohorts 1980 to 1985.

The fourth row of the table presents private R&D expenditures in each technology field during 1980 to 1985,[3] and the last row of Table 4 reports the estimated equivalent subsidy rates. As shown in the last column, the EPC patent system provides an average implicit subsidy rate of 31% to private R&D performers, slightly higher than Schankerman (1998)'s estimate of the ESR provided by the French patent system (24%). The importance of patent protection substantially varies across technology fields, with the highest subsidy rate for pharmaceuticals (47%) and chemical (43%), and lowest for electronics (26%) and mechanical (24%). Such ranking is strictly consistent with findings from survey and anecdotal evidences that patent protection is particularly important for R&D in pharmaceutical and chemical industries, and less so for other industries (Mansfield, Schwartz, and Wagner 1981, Levin, Klevorick, Nelson and Winter

[3]The OECD ANBERD database provides annual data on private R&D expenditure across different SIC industries. To obtain estimates of R&D expenditures in each technology group (which is classified according to the IPC code), I use the OECD Technology Concordance (Johnson 2002) to assign the R&D expenditure in each SIC industry to each 4-digit IPC code, and then sum them up according to my definition of the five technology fields. On the other hand, as we can only observe total R&D expenditure of each source country but not the explicit expenditures devoted to R&D targeting the EPO market, I choose to calculate the R&D expenditures relevant to the European market by using the ratio of each country's goods exports to the ten EPC member countries to its total industrial production as weights, similar to Schankerman (1998)'s treatment of French market.

1987).

## 5. The "Trade Flows" of Patent Rights

In an international patent protection regime, inventors in every country receive patent protection from other countries, while at the same time each country offers patent protection to inventors in other countries. Not every country receives the same share of protection as it offers, and by how much a country may gain from the international patent protection arrangement lies in the heart of debates over patent harmonization. The availability of EPO patenting data and the analyses in previous sections facilitate a thorough study of the net flow of patent rights in terms of monetary value, as well as determinants of such net flows.

The traditional approach of simple patent counts can be quite misleading in studying patent flows. For instance, Austria issued 39,106 patents to all European inventors in cohorts1980 to 1985, whereas Austrian inventors only received patent protection for 1,328 inventions, or in total 9,419 patents (Table 5). Calculation based on simple patent counts would conclude that Austria provided far more patent protection than its citizens received and thus suffered a patent "trade deficit" of 29,687 patents during this period. On the other hand, Germany provided patent protection to 61,767 patent holders, whereas German inventors obtained patent protection for 28,814 of their inventions, or in total 204,154 patents from all EPC member countries, implying a large patent "trade surplus" of 142,387 patents during the sample period.

However, Table 3 reveals substantial heterogeneity in the value of patents as awarded by different countries, even for patents from the same patent family (i.e. derived from the same invention). An Austrian patent does not have the same economic value as a German patent, due to country differences in both the market size and other relevant institutional factors, such as differences in national patent laws and the enforcement of such laws, etc. The economic value of patent protection an Austrian inventor receives from a German patent may be much higher than that of the protection a German inventor receives from an Austria patent. Consequently a more accurate way to measure the net flows of patent rights is to weigh the patent counts by the mean value of different patents based on model estimates in Section 4.

Table 5 presents the estimates of patent "trade flows" based on such calculation. It shows, for instance, that although Austria awarded much more patents to foreign inventors than it received, the mean value of the patents it received are much higher than those it awarded. The total private value of patents Austrian inventors received from the EPC for cohorts 1980 to 1985 is about \$1.6 billion, \$0.36 billion larger than the value of patent protection it provided, or 30% of the latter. Thus Austria indeed had a patent trade "surplus," not a "deficit." The last two rows of Table 5 also indicate that, among the ten EPC member countries, Germany enjoyed the largest patent "trade surplus" of about \$9.7 billion, or 37% of the total patent protection it provided to EPC inventors. Switzerland has the second largest "surplus" of \$6.5 billion, which is about four times as large as the total protection it provided. The U.K. ran the largest patent "trade deficits" of around \$11.8 billion, or about 56% of the total patent protection it provided.

*Patent trade imbalance and regular trade balance*

Patent harmonization was often linked to trade liberalization in recent trade negotiations. For instance, in Uruguay round, "many, if not most, developing countries accepted TRIPS with the expectation that ... in exchange developed countries would make concessions in agricultural subsidies," and in the most recent Doha round, developed countries' reluctance to agricultural market concession made many think that "the compromises assumed by developing countries in the field of intellectual property rights could and should be revised, based on equitable, moral and legal reasons" (Barrio 2006). Thus it would be interesting to compare European countries' gains and losses from European patent harmonization to those from the corresponding market concession arrangements, given the successes along both dimensions in Europe.

However, the market integration process in Europe is the result of a long and gradual trade liberalization, so it is entirely impossible to isolate any single event as the most relevant one to negotiations over patent harmonization.[4] So instead I present in Table 6 each country's regular trade balance (goods and services) with the other nine EPC member countries, averaged over 1980 to 1996, compared to patent trade balance, averaged over cohorts 1980 to 1985.

The first fact we can learn from the table is that the volumes of patent trade are smaller but still comparable to those of regular trade. The sum of total patent protection each country provided to other EPC member countries averaged \$13.4 billion each year, compared to the sum of total exports of \$196 billion, or 7% of the latter. On the other hand, patent harmonization within the EPC significantly changed the trade pattern — Germany's goods and services trade

[4] Soloaga and Winters (1999) find that increased integration within the European Union had negative impact on EU imports from countries outside the EU and prompted their application for EU membership. However, few studies have tried to give a numeric evaluation of EU's effects on trade volumes.

surpluses are substantially enhanced by patent harmonization, an increase of $1.61 billion or 15%; Switzerland's regular trade deficits are partly compensated by its patent trade surplus (32%), while France, the U.K. and Italy recorded deficits on both regular and patent trade, with patent trade deficits amounting to 57%, 44%, and 10% of their regular trade deficits, respectively. These numbers underscore the importance of patent harmonization (and the protection of other forms of intellectual property rights in general) in shaping today's international economic and trade relations.

## 6. Determinants of Patent Trade Imbalance

What determines such substantial patent trade imbalance? The total patent protection a country receives (offers) depends on the number of patents or inventions it applies for (offers), as well as the average patent value in each country. The former depends further on the R&D input and R&D efficiency of each country, and the latter depends on (in addition to the size-of-the-economy effect) the following factors: first, the patenting or renewal costs to keep the patents alive in each country (Figure 1); secondly, the degree of patent protection or enforcement of patent laws in each country (the estimated $q_j$); and finally, the technological composition of the invention pool in each country, as the patent family value in different technology fields are substantially different (Table 3a). Through a series of sequential simulation experiments, below I will decompose the total imbalance and examine the individual effects of each of these factors.

*Simulation I: Eliminating country differences in patenting costs*

First, I consider the implications of country differences in patenting costs. In particular, in this simulation I assume that the patenting costs in different countries are strictly proportional to its size of economy (proxied by the average real GDP from 1980 to 1996, as shown in row 2 of Table 5), and simulate the patenting (designation and renewal) decisions for the whole sample according to the optimal patenting rules derived in Section 3. In defining the counterfactual patenting costs, I set the German renewal fee schedule as the reference and costs in other countries are assumed to be proportional to German costs, as the German schedule features low renewal fees in the beginning years but they rise sharply as patents become older, very close to the optimal renewal fee schedule designed by Cornelli and Schankerman (1999).

The lower panel of Table 7a presents the results of this simulation. Compared with the imbalance estimated from Table 5 (replicated in top panel of Table 7a), the elimination of country differences in patenting costs does not have significant effects on patent "trade imbalance." The largest changes come from France, whose investors will receive \$0.13 billion more from the synchronization of patenting costs, and Netherlands will provide \$0.18 billion more to the European inventors as they will hold 533 more Netherlands patents in response to the decline in its renewal fees. Inventors in all ten EPC member countries as a whole will receive \$0.74 billion more, but the implied changes are too small compared to the estimated patent "trade imbalance" in the top panel of Table 7a. In other words, the observed country differences in patenting costs only have modest influences in generating the estimated "trade imbalance."

*Simulation II: Eliminating country differences in patent protection*

Next I eliminate the influences of country-specific differences in patent protection, by setting the country fixed effect parameter $q_j$'s to zero. This essentially eliminates the national differences in enforcing patent rights, and results in an entirely internationally "harmonized" patent regime. The only difference in the potential value of an invention across different countries comes from differences of the size of the economy of the destination countries.

The lower panel of Table 7b shows that this will significantly change the estimated patent trade imbalance. In particular, Germans will obtain 16,056 more patents and \$6.6 billion more worth of patent protection, and the net "surplus" will rise to \$16.9 billion. This indicates that Germany has a stronger degree of patent protection than average, and enforcing the same patent laws in other countries with the same effectiveness as the German practice will boost German investors' incentives to obtain patent rights from those countries, and further increase the patent trade surplus it already enjoys. On the other hand, by setting the degree of patent protection in Italy the same as in Germany, Italy will issue 7,676 more patents to European inventors, and the mean value of Italian patents will increase by \$0.16 million, bringing the total value of patent protection to \$16 billion, more than tripling the value it provided in simulation I. On average, the elimination of country differences in patent protection generates higher patent trade imbalance among countries, as indicated by the increase of the standard deviations of net surplus from \$5.68 billion in simulation I to \$7.39 billion in this simulation.

*Simulation III: Eliminating country differences in technological composition of inventions*

The next candidate that I examine is the country differences in technological composition of their invention pools. As one may suspect, since some industries (pharmaceuticals and chemicals) rely more heavily on patent system to appropriate rents of their R&D activities, countries with relatively higher concentrations in such industries may benefit disproportionately more than other countries from patent harmonization.

To evaluate the effects of such industrial composition differences, in simulation III the coefficients on the dummy variable of technology fields are set to zero, as well as the coefficient on the multi-IPC dummy variable. This essentially suppresses the differences in patent value across industries. The results, as displayed in the lower panel of Table 7c, indicate that such differences have modest influences in generating the trade imbalance: the largest effects on the net surplus come from Germany ($1.5 billion) and Italy (-$1.5 billion). Compared with the net surplus each country holds ($18.4 billion and $-13.2 billion), such effects are quite limited. Overall , the elimination of country differences in technological composition tend to slightly increase patent trade imbalance, as indicated by the small increases in standard deviations of the net surplus (by $0.69 billion, or almost 10%).

*Simulation IV: Eliminating country differences in R&D efficiency*

Simulation I through III are based on the observed pool of inventions in each country. However, countries have substantially different R&D input, relative to their economy sizes. For instance, as the top panel of Table 8 shows, Germany has the highest R&D expenditure during 1980 to 1985, with a total of $112.16 billion, or more than one-third of the total R&D input by all ten EPC member countries, much higher than its GDP share (27%). On the other hand, the total R&D expenditure by Italy in 1980 to 1985 is about $26 billion, or less than 8% of the total R&D input by EPO countries, despite the fact that its GDP share is more than 16%. Country differences in R&D intensity, as measured by R&D/GDP ratio, may directly affect their ability to benefit from international patent harmonization.

On the other hand, even for the same amount of R&D input, European countries exhibit significant differences in their R&D efficiency, which will also affect the number of valuable inventions generated and thus the patent protection they receive. The lower panel of Table 8 displays the number of granted EPO applications (i.e., patent families) per million dollar R&D expenditure, in each technological field. It can then be seen that countries differ in R&D efficiency, with Austria, Switzerland and Netherlands having the highest number of successful applications/R&D ratio, more than doubling that of Italy, Belgium-Luxemburg, and the U.K.

Simulation experiment IV suppresses the country differences in R&D efficiency and simulates the total patent value each country provides and receives (however, the actual amount of R&D expenditure by each country is kept unchanged). As shown in Table 7d, by assuming the same R&D efficiency (at the average European level) for every country, inventors in Germany and Switzerland are now producing much less inventions (reduced by 3,075 and 5,755 inventions, respectively), and as a result the net patent trade surplus of these two countries decline significantly. On the other hand, if the U.K. and Italy's R&D efficiency were increased to the average European level, their number of inventions would have increased by 5,912 and 2,918, respectively, and such increases would have significantly increased their surplus (more than doubled). Overall, the elimination of country differences in R&D efficiency decreases patent trade imbalance significantly, as the standard deviation of the net surplus declines from $8.08 billion to $5.40 billion.

*Simulation V: Eliminating country differences in relative R&D input*

Finally I explore the implications of country differences in R&D intensity on patent "trade imbalance." Assuming that each country devotes the same share of their GDP on R&D activities, Table 7e displays the total patent protection a country offers and receives. By dragging down the high R&D intensity in Germany, Switzerland, and the U.K. to the average European level (Table 8), the number of patent families owned and thus the total value of patent protection received by these countries decline, and those by countries such as Italy and Austria increase. Note that in this simulation all kinds of country differences are suppressed. As a result each country receives and provides the same amount of patent protection, and their net "trade surplus" is close to zero. The significant change in standard deviation of the net surplus (by $5.30 billion) suggests that country differences in R&D intensity is another major source of the estimated patent "trade imbalance."

*Summary*

Patent "trade imbalance" can be attributed to country differences in five dimensions: R&D intensity, R&D efficiency, technological composition of countries' invention pool, differences in patent laws and enforcement of such laws as well as other kinds of institutional differences, and patenting costs. The sequential simulation experiments performed above suggest that, the observed country differences in R&D intensity and R&D efficiency are the most important determinants of the patent "trade imbalance" within the EPC patent regime, as the combined effects of these two factors are more than enough to explain the estimated overall imbalance, with countries such as Germany and Switzerland enjoying larger shares of patent protection than they provide because of their high R&D intensity and efficiency. Country differences in enforcing the patent rights, on the other hand, tend to offset such an imbalance, as more R&D active countries tend to provide stronger patent protection.[5] Country differences in technological composition of their invention pools or in their patenting costs only have mild effects in generating the observed patent "trade imbalance."

## 7. Concluding Remarks

This paper analyzes the economic consequences of patent harmonization in European countries. Based on detailed patenting data since the early 1980s, I estimate European patent value distributions and evaluate the importance of European Patent Convention to R&D activities across different technological fields. I find that the existing patent regime in Europe implies substantial patent "trade imbalance," with Germany and Switzerland benefiting the most from the EPC and the U.K. and Italy the least. Country differences in R&D intensity and efficiency, as well as differences in the enforcement of patent rights, explain most of the imbalance. This study provides empirical evidence on the welfare implications of international patent harmonization, which lies in the center of policy debates over optimal patent system and trade-related intellectual property rights negotiations.

## References


[1] Barrio, Fernando, "Time to Rethink TRIPS?" *Intellectual Property Watch*, September 27, 2006. Available at http://ip-watch.org/weblog/wp-trackback.php?p=381.

[2] Chin, Judith and Gene M. Grossman (1990), "Intellectual Property Rights and North-South Trade," in R.W. Jones and A.O. Kruger, eds., *The Political Economy of International Trade*, Cambridge MA, Basil Blackwells Publishers, 90-107


[5] It would thus be interesting to explore whether the stronger degree of patent protection in these countries has stimulated more R&D input as well as higher R&D efficiency, an intriguing topic for future research.

[3] Cornelli, F. and Mark Schankerman (1999), "Optimal Patent Renewal," *Rand Journal of Economics*, Vol. 30, 197-213.

[4] Deng, Yi (2006a), "Private Value of European Patents," *European Economic Review*, forthcoming.

[5] Deng, Yi (2006b), "The Effects of Patent Regime Changes: A Case Study of the European Patent Office," *International Journal of Industrial Organization*, forthcoming.

[6] Eaton, Jonathan, Samuel Kortum, and Josh Lerner (2003), "International Patenting and the European Patent Office: A Quantitative Assessment," manuscript.

[7] Grossman, Gene M. and Elhanan Helpman (1994), "Endogenous Innovation in the Theory of Growth," *The Journal of Economic Perspective*, Vol. 8, No.1.

[8] Grossman, Gene M. and Edwin L.-C. Lai (2004), "International Protection of Intellectual Property," working paper, Princeton University.

[9] Helpman, Elhanan (1993), "Innovation, Immitation, and Intellectual Property Rights," *Econometrica*, 61(6), 1247-1280.

[10] Johnson, K.N. Daniel (2002), "The OECD Technology Concordance (OTC): Patents by Industry of Manufacture and Sector of Use," OECD Working Paper, 2002/5.

[11] Kortum, Samuel and Jonathan Putnam (1997), "Assigning Patents to industries: Tests of the Yale Technology Concordance," *Economic Systems Research*, Vol. 9, No.2.

[12] Lanjouw, Jean O. (1998), "Patent Protection in the Shadow of Infringement: Simulation Estimations of Patent Value," *Review of Economic Studies*, Volume 65, issue 4.

[13] — and Josh Lerner (1998), "The Enforcement of Intellectual Property Rights: A Survey of the Empirical Literature," *Annals d'Economic et de Statistique*, July 1998.

[14] — and Mark Schankerman (1997), "Stylized Facts of Patent Litigation: Value, Scope, and Ownership," NBER working paper NO. 6297.

[15] Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, and Sidney G. Winter (1987), "Appropriating the Returns from Industrial R&D," *Brookings Papers on Economic Activity*, 783-820.

[16] Mansfield, E., Schwartz, M., and Wagner, S (1981). "Imitation Costs and Patents: An Empirical Study," *Economic Journal*, Vol. 91, 907-918.

[17] Matutes, Carmen, Pierre Regibeau, and Katharine Rockett (1996), "Optimal Patent Design and the Diffusion of Innovations," *Rand Journal of Economics*, Vol. 27, 60-83.

[18] McCalman, Phillip (2001), "Reaping What You Sow: An Empirical Analysis of International Patent Harmonization," *Journal of International Economics*, Volume 55, 161-186.

[19] O'Donoghue, Ted, Suzanne Scotchmer, and Jacques-Francois Thisse, "Patent Breadth, Patent Life, and the Pace of Technological Progress," *Journal of Economics and Management Strategy*, Vol. 7, 1-32.

[20] Pakes, Ariel (1984), "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks," NBER Working Paper, No. 1340.

[21] — (1986), "Patents as Options: Some Estimates of the Value of Holding European Patent Stocks," *Econometrica*, Volume 54, Issue 4, 755-784.

[22] — and Mark Schankerman (1984), "The Rate of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources", in Zvi Griliches (ed.) *R&D, Patents and Productivity*, NBER Conference Series. Chicago, The University of Chicago Press.

[23] — and Margret Simpson (1989), "Patent Renewal Data," *Brookings Papers: Microeconomics*, 1989, 331-410.

[24] Schankerman, Mark (1998), "How Valuable is Patent Protection? Estimates by Technology Field", *Rand Journal of Economics*, volume 29(1), Spring, 77-107.

[25] Soloaga, Isidro and L. Alan Winters (1999), "Regionalism in the Nineties: What Effect on Trade?" CEPR Discussion Paper No. 2183, London.

**Table 1a: Sample Composition, by Nationality of Source Country**

| | Austria | Belgium | Switzerland | Germany | France | U.K. | Italy | Luxembourg | Netherlands | Sweden | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Number of patents awarded by each country* | | | | | | | | | | | |
| | 48,563 | 62,451 | 62,716 | 113,308 | 108,588 | 110,656 | 82,296 | 29,012 | 77,025 | 63,193 | 757,808 |
| *Number of patents received by each country* | | | | | | | | | | | |
| Austria | 421 | 831 | 982 | 1,274 | 1,255 | 1,141 | 1,055 | 510 | 868 | 956 | 9,294 |
| Belgium | 606 | 669 | 653 | 914 | 892 | 871 | 763 | 452 | 745 | 630 | 7,193 |
| Switzerland | 3,423 | 3,449 | 4,457 | 5,781 | 5,766 | 5,367 | 4,774 | 1,617 | 3,946 | 3,504 | 42,084 |
| Germany | 16,046 | 16,915 | 18,979 | 23,059 | 27,661 | 26,398 | 22,989 | 6,541 | 19,469 | 16,434 | 194,490 |
| France | 5,319 | 7,914 | 7,031 | 12,077 | 4,874 | 11,586 | 10,263 | 4,595 | 8,807 | 7,644 | 80,111 |
| U.K. | 3,468 | 4,812 | 4,230 | 7,208 | 7,066 | 4,964 | 5,735 | 2,557 | 5,570 | 5,024 | 50, 634 |
| Italy | 1,691 | 1,845 | 1,867 | 2,669 | 2,653 | 2,611 | 687 | 1,187 | 2,065 | 1,905 | 19,179 |
| Luxembourg | 155 | 160 | 103 | 199 | 193 | 199 | 182 | 68 | 171 | 155 | 1582 |
| Netherlands | 1,958 | 2,741 | 2,164 | 4,444 | 4,170 | 4,276 | 3,431 | 1,091 | 3,510 | 2,618 | 30,649 |
| Sweden | 1,551 | 1,449 | 1,729 | 2,481 | 2,453 | 2,401 | 1,409 | 816 | 1,845 | 1,150 | 17,284 |
| U.S. | 9,274 | 15,456 | 12,806 | 29,711 | 29,334 | 28,758 | 20,456 | 6,995 | 18,696 | 15,385 | 186,871 |
| Japan | 2,013 | 3,478 | 4,773 | 19,277 | 17,834 | 18,088 | 7,720 | 862 | 8,085 | 4,453 | 86,582 |
| ROW | 1,732 | 1,830 | 1,993 | 2,928 | 2,889 | 2,734 | 2,001 | 1,150 | 2,179 | 2,222 | 21,656 |

**Table 1b: Sample Composition, by Technology Classifications**

| | Austria | Belgium | Switzerland | Germany | France | U.K. | Italy | Luxembourg | Netherlands | Sweden | Total | Grant Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pat Number | 48,563 | 62,451 | 62,716 | 113,308 | 108,588 | 110,656 | 82,296 | 29,012 | 77,025 | 63,193 | 757,808 | 69.20 |
| Technology fields | | | | | | | | | | | | |
| Pharmaceutical | 3,619 | 4,373 | 4,697 | 5,131 | 5,038 | 4,820 | 4,528 | 2,788 | 4,665 | 4,055 | 43,714 | 68.26 |
| Chemicals | 11,746 | 18,537 | 16,650 | 26,732 | 26,057 | 25,843 | 21,680 | 7,039 | 20,520 | 14,082 | 188,886 | 74.55 |
| Electronics | 9,685 | 11,728 | 13,792 | 34,401 | 32,066 | 33,818 | 19,571 | 4,874 | 20,056 | 14,603 | 194,595 | 70.74 |
| Mechanical | 15,853 | 18,142 | 18,269 | 33,195 | 32,168 | 33,057 | 25,671 | 9,559 | 21,116 | 21,095 | 228,125 | 66.56 |
| Misc. | 7,661 | 9,670 | 9,308 | 13,849 | 13,258 | 13,118 | 10,845 | 4,752 | 10,669 | 9,359 | 102,488 | 63.83 |

## Table 2: Model Parameter Estimates

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Parameter[a] | | | | | | | | | | | |
| $\mu_\alpha$ | 9.32 | (1.47) | $\sigma_\alpha$ | 2.08 | (0.35) | $\sigma_\varepsilon$ | 1.02 | (0.29) | $\upsilon$ | 1.03 | (0.14) |
| Nationality (source country) dummies (ROW = 0) | | | | | | | | | | | |
| EPO | 0.22 | (0.11) | U.S. | 0.43 | (0.21) | Japan | -0.001 | (0.10) | | | |
| Technology field dummies (Misc = 0) | | | | | | | | | | | |
| Pharmaceuticals | 1.22 | (0.28) | Chemicals | 0.00 | (0.15) | Electronics | -0.94 | (0.33) | Mechanical | -0.30 | (0.23) |
| Multi nationality | | | | 0.00 | (0.14) | Multi technology | | | | 0.40 | (0.18) |
| Destination country dummies (Germany = 0) | | | | | | | | | | | |
| Austria | -0.69 | (0.31) | Belgium | -1.38 | (0.45) | Switzerland | -0.81 | (0.37) | France | -0.15 | (0.22) |
| U.K. | 0.29 | (0.23) | Italy | -1.23 | (0.42) | Luxembourg | 0.49 | (0.43) | Netherlands | 0.001 | (0.13) |
| Sweden | -0.60 | (0.27) | | | | | | | | | |
| B. Summary Statistics[b] | | | | | | | | | | | |
| $\chi^2/dof$ | 2.08 | | MSE($\widetilde{\pi}$) | 0.0131 | | V($\widetilde{\pi}$) | 0.0409 | | MSE($\widetilde{\pi}$)/V($\widetilde{\pi}$) | 0.32 | |
| MSE($\widetilde{\pi}_{desig}$) | 0.0262 | | V($\pi_{desig}$) | 0.0651 | | MSE($\widetilde{\pi}_{desig}$)/V($\pi_{desig}$) | | | | 0.40 | |
| MSE($\widetilde{\pi}_{renewal}$) | 0.0061 | | V($\pi_{renewal}$) | 0.0089 | | MSE($\widetilde{\pi}_{renewal}$)/V($\pi_{renewal}$) | | | | 0.68 | |

**Table 3a: Value Distribution of European Patents, by Technology Fields**

| Quantile | Technology Field: Pharmaceuticals | | | Chemicals | | | Electronics | | | Mechanical | | | Miscenaneous | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | German | French | Family | German | French | Family | German | French | Family | German | French | Family | German | French | Family |
| 25% | 0.02 | 0.02 | 0.08 | 0.01 | 0.01 | 0.04 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.04 |
| 50% | 0.09 | 0.07 | 0.39 | 0.04 | 0.03 | 0.17 | 0.02 | 0.02 | 0.08 | 0.03 | 0.02 | 0.12 | 0.04 | 0.03 | 0.16 |
| 75% | 0.45 | 0.30 | 1.70 | 0.21 | 0.14 | 0.75 | 0.09 | 0.07 | 0.31 | 0.15 | 0.10 | 0.52 | 0.19 | 0.13 | 0.69 |
| 90% | 2.04 | 1.21 | 6.62 | 0.83 | 0.55 | 2.80 | 0.34 | 0.24 | 1.11 | 0.56 | 0.39 | 1.87 | 0.76 | 0.53 | 2.50 |
| mean | 1.64 | 0.78 | 3.17 | 0.68 | 0.41 | 1.87 | 0.24 | 0.16 | 0.69 | 0.39 | 0.25 | 1.13 | 0.52 | 0.34 | 1.53 |

**Table 3b: Value Distribution of European Patents, by Source Countries**

| Quantile | Nationality: EPO | | | U.S. | | | Japan | | | ROW | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | German | French | Family | German | French | Family | German | French | Family | German | French | Family |
| 25% | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.03 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.03 |
| 50% | 0.03 | 0.03 | 0.13 | 0.04 | 0.03 | 0.15 | 0.03 | 0.02 | 0.10 | 0.03 | 0.02 | 0.12 |
| 75% | 0.15 | 0.11 | 0.55 | 0.18 | 0.13 | 0.65 | 0.17 | 0.08 | 0.41 | 0.14 | 0.11 | 0.51 |
| 90% | 0.61 | 0.43 | 2.05 | 0.72 | 0.50 | 2.35 | 0.45 | 0.33 | 1.53 | 0.60 | 0.42 | 2.07 |
| mean | 0.44 | 0.30 | 1.27 | 0.56 | 0.35 | 1.59 | 0.49 | 0.23 | 1.18 | 0.38 | 0.31 | 1.22 |

**Tables 4: Equivalent Subsidy Rates, by Technology Fields**

| | Technology Field | | | | | |
|---|---|---|---|---|---|---|
| | Pharmaceuticals | Chemicals | Electronics | Mechanical | Miscenaneous | Total |
| Mean value | 3.17 | 1.87 | 0.69 | 1.13 | 1.53 | |
| Number of patent families | 1,811 | 26,644 | 35,346 | 34,623 | 14,083 | 112,507 |
| Total value ($billion) | 5.7 | 49.7 | 24.3 | 39.0 | 21.5 | 140.3 |
| R&D ($billion) | 12.0 | 116.5 | 91.9 | 163.9 | 68.3 | 452.7 |
| ESR | 0.47 | 0.43 | 0.26 | 0.24 | 0.31 | 0.31 |

**Table 5: Trade Flows of Patent Rights within the EPO**

| | Austria | Belgium | Switzerland | Germany | France | U.K. | Italy | Luxembourg | Netherlands | Sweden | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.21 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.01 | 0.31 | 0.22 | 6.08 |
| % of total | 2.74 | 3.46 | 3.77 | 27.74 | 20.62 | 16.46 | 16.31 | 0.18 | 5.07 | 3.65 | 100 |
| protection offered to | | | | | | | | | | | |
| pat. num. | 39,106 | 37,387 | 40,481 | 61,767 | 60,218 | 61,582 | 53,925 | 26,214 | 40,426 | 36,894 | 458,000 |
| % of total | 8.54 | 8.16 | 8.84 | 13.49 | 13.15 | 13.45 | 11.78 | 5.72 | 8.83 | 8.06 | 100 |
| mean value (thous.$) | 31.47 | 22.22 | 40.10 | 425.76 | 292.79 | 344.06 | 86.80 | 9.99 | 119.01 | 52.25 | 175.73 |
| total value ($bil.) | 1.23 | 0.83 | 1.62 | 26.30 | 17.63 | 21.19 | 4.68 | 0.26 | 4.81 | 1.93 | 80.48 |
| % of total | 1.53 | 1.03 | 2.02 | 32.67 | 21.91 | 26.33 | 5.82 | 0.33 | 5.98 | 2.40 | 100 |
| protection received by | | | | | | | | | | | |
| pat. num. | 9,419 | 6,682 | 43,435 | 204,154 | 85,381 | 51,938 | 19,413 | 1,462 | 31,473 | 17,927 | 471,285 |
| % of total | 2.00 | 1.42 | 9.22 | 43.32 | 18.12 | 11.02 | 4.12 | 0.31 | 6.68 | 3.80 | 100 |
| pat. family num. | 1,328 | 937 | 6,064 | 28,814 | 12,195 | 7,310 | 2,713 | 206 | 4,509 | 2,540 | 66,618 |
| % of total | 2.00 | 1.41 | 9.10 | 43.25 | 18.31 | 10.97 | 4.07 | 0.31 | 6.77 | 3.81 | 100 |
| mean value (thous.$) | 1,197.3 | 1,297.3 | 1,346.2 | 1,249.8 | 1,162.7 | 1,286.2 | 1,339.4 | 1,206.2 | 1,143.0 | 1,174.2 | 1,239.7 |
| total value (bil.$) | 1.59 | 1.22 | 8.16 | 36.01 | 14.18 | 9.40 | 3.64 | 0.25 | 5.15 | 2.98 | 82.59 |
| % of total | 1.92 | 1.47 | 9.89 | 43.61 | 17.17 | 11.39 | 4.40 | 0.30 | 6.24 | 3.61 | 100 |
| patent trade surplus (protection received - protection offered) | | | | | | | | | | | |
| net value (bil.$) | 0.36 | 0.39 | 6.54 | 9.71 | -3.45 | -11.79 | -1.04 | -0.01 | 0.34 | 1.05 | — |
| net value / offered | 0.29 | 0.47 | 4.04 | 0.37 | -0.20 | -0.56 | -0.22 | -0.04 | 0.07 | 0.54 | — |

**Table 6: Balance of Regular Trade and Patent Trade**

| | Austria | BE-LU | Switzerland | Germany | France | U.K. | Italy | Netherlands | Sweden | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.22 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.31 | 0.22 | 6.08 |
| % of total | 2.74 | 3.65 | 3.77 | 27.74 | 20.62 | 16.46 | 16.31 | 5.07 | 3.65 | 100 |
| *Balance of goods and services trade, averaged over 1980 to 1997* | | | | | | | | | | |
| Imports (bil.$) | 8.42 | 21.93 | 12.14 | 46.88 | 30.80 | 26.04 | 24.53 | 18.82 | 6.59 | 196.15 |
| Exports (bil.$) | 6.59 | 22.31 | 8.77 | 57.46 | 29.78 | 21.55 | 22.76 | 24.45 | 6.64 | 200.31 |
| gds & ser. trade surplus (bil.$) | -1.83 | 0.38 | -3.37 | 10.58 | -1.02 | -4.49 | -1.77 | 5.63 | 0.05 | — |
| *Balance of patent trade, averaged over cohorts 1980 to 1985* | | | | | | | | | | |
| pat. protection offered (bil.$) | 0.21 | 0.19 | 0.27 | 4.38 | 2.94 | 3.53 | 0.78 | 0.80 | 0.32 | 13.41 |
| pat. protection received (bil.$) | 0.27 | 0.25 | 1.36 | 6.00 | 2.36 | 1.57 | 0.61 | 0.86 | 0.50 | 13.76 |
| pat. trade surplus (bil.$) | 0.06 | 0.06 | 1.09 | 1.61 | -0.58 | -1.96 | -0.17 | 0.06 | 0.18 | — |

## Table 7a: The Decomposition of Patent Trade Imbalance: Simulation I

| | Austria | Belgium | Switzerland | Germany | France | U.K. | Italy | Luxembourg | Netherlands | Sweden | Total / std |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.21 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.01 | 0.31 | 0.22 | 6.08 |
| % of total | 2.72 | 3.47 | 3.78 | 27.29 | 20.80 | 16.67 | 16.27 | 0.18 | 5.12 | 3.71 | 100 |
| *model estimates* | | | | | | | | | | | |
| pat. num. granted | 39,106 | 37,387 | 40,481 | 61,767 | 60,218 | 61,582 | 53,925 | 26,214 | 40,426 | 36,894 | 458,000 |
| pat. value provided (bil.$) | 1.23 | 0.83 | 1.62 | 26.30 | 17.63 | 21.19 | 4.68 | 0.26 | 4.81 | 1.93 | 80.48 |
| pat. num. received | 9,419 | 6,682 | 43,435 | 204,154 | 85,381 | 51,938 | 19,413 | 1,462 | 31,473 | 17,927 | 471,285 |
| pat. value received (bil.$) | 1.59 | 1.22 | 8.16 | 36.01 | 14.18 | 9.40 | 3.64 | 0.25 | 5.15 | 2.98 | 82.59 |
| patent trade surplus (bil.$) | 0.36 | 0.39 | 6.54 | 9.71 | -3.45 | -11.79 | -1.04 | -0.01 | 0.34 | 1.05 | 5.68 (std) |
| net value / offered | 0.29 | 0.47 | 4.04 | 0.37 | -0.20 | -0.56 | -0.22 | -0.04 | 0.07 | 0.54 | — |
| *simulation I: setting patenting costs proportional to the size of economy* | | | | | | | | | | | |
| pat. num. granted | 39,560 | 37,808 | 40,944 | 62,240 | 60,308 | 61,844 | 54,371 | 26,448 | 40,959 | 37,325 | 461,806 |
| pat. value provided (bil.$) | 1.28 | 0.84 | 1.67 | 26.59 | 17.64 | 21.30 | 4.65 | 0.27 | 4.99 | 1.97 | 81.21 |
| pat. num. received | 9,498 | 6,735 | 43,772 | 205,841 | 86,130 | 52,369 | 19,565 | 1,474 | 31,753 | 18,077 | 475,213 |
| pat. value received (bil.$) | 1.60 | 1.23 | 8.23 | 36.34 | 14.31 | 9.49 | 3.67 | 0.25 | 5.20 | 3.01 | 83.33 |
| patent trade surplus (bil.$) | 0.32 | 0.39 | 6.56 | 9.75 | -3.33 | -11.81 | -0.98 | -0.02 | 0.21 | 1.01 | 5.68 (std) |
| changes from model est. | -0.04 | 0.00 | 0.02 | 0.04 | 0.12 | -0.02 | 0.06 | -0.01 | -0.13 | -0.04 | 0.01 |

**Table 7b: The Decomposition of Patent Trade Imbalance: Simulation II**

| | Austria | Belgium | Switzerland | Germany | France | U.K. | Italy | Luxembourg | Netherlands | Sweden | Total / std |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.21 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.01 | 0.31 | 0.22 | 6.08 |
| % of total | 2.72 | 3.47 | 3.78 | 27.29 | 20.80 | 16.67 | 16.27 | 0.18 | 5.12 | 3.71 | 100 |
| *simulation I: setting patenting costs proportional to the size of economy* | | | | | | | | | | | |
| pat. num. granted | 39,560 | 37,808 | 40,944 | 62,240 | 60,308 | 61,844 | 54,371 | 26,448 | 40,959 | 37,325 | 461,806 |
| pat. value provided (bil.$) | 1.28 | 0.84 | 1.67 | 26.59 | 17.64 | 21.30 | 4.65 | 0.27 | 4.99 | 1.97 | 81.21 |
| pat. num. received | 9,498 | 6,735 | 43,772 | 205,841 | 86,130 | 52,369 | 19,565 | 1,474 | 31,753 | 18,077 | 475,213 |
| pat. value received (bil.$) | 1.60 | 1.23 | 8.23 | 36.34 | 14.31 | 9.49 | 3.67 | 0.25 | 5.20 | 3.01 | 83.33 |
| patent trade surplus (bil.$) | 0.32 | 0.39 | 6.56 | 9.75 | -3.33 | -11.81 | -0.98 | -0.02 | 0.21 | 1.01 | 5.68 (std) |
| *simulation II: eliminating country-specific differences in patent protection* | | | | | | | | | | | |
| pat. num. granted | 47,109 | 52,846 | 49,701 | 61,573 | 60,576 | 59,491 | 62,047 | 20,524 | 40,091 | 43,958 | 497,916 |
| pat. value provided (bil.$) | 2.54 | 3.35 | 3.73 | 26.08 | 20.13 | 15.54 | 16.00 | 0.16 | 4.89 | 3.55 | 95.96 |
| pat. num. received | 10,237 | 7,251 | 47,085 | 221,897 | 93,073 | 56,412 | 21,049 | 1,589 | 34,331 | 19,506 | 512,430 |
| pat. value received (bil.$) | 1.90 | 1.45 | 9.74 | 42.95 | 16.89 | 11.21 | 4.34 | 0.30 | 6.13 | 3.56 | 98.46 |
| patent trade surplus (bil.$) | -0.64 | -1.9 | 6.01 | 16.87 | -3.24 | -4.33 | -11.66 | 0.14 | 1.24 | 0.01 | 7.39 (std) |
| changes from simulation I | -0.96 | -2.29 | -0.55 | 7.12 | 0.09 | 7.48 | -10.68 | 0.16 | 1.03 | -1.00 | 1.71 (std) |

**Table 7c: The Decomposition of Patent Trade Imbalance: Simulation III**

| | Austria | Belgium | Switzerland | Germany | France | U.K. | Italy | Luxembourg | Netherlands | Sweden | Total / std |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.21 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.01 | 0.31 | 0.22 | 6.08 |
| % of total | 2.72 | 3.47 | 3.78 | 27.29 | 20.80 | 16.67 | 16.27 | 0.18 | 5.12 | 3.71 | 100 |
| *simulation II: eliminating country-specific differences in patent protection* | | | | | | | | | | | |
| pat. num. granted | 47,109 | 52,846 | 49,701 | 61,573 | 60,576 | 59,491 | 62,047 | 20,524 | 40,091 | 43,958 | 497,916 |
| pat. value provided (bil.$) | 2.54 | 3.35 | 3.73 | 26.08 | 20.13 | 15.54 | 16.00 | 0.16 | 4.89 | 3.55 | 95.96 |
| pat. num. received | 10,237 | 7,251 | 47,085 | 221,897 | 93,073 | 56,412 | 21,049 | 1,589 | 34,331 | 19,506 | 512,430 |
| pat. value received (bil.$) | 1.90 | 1.45 | 9.74 | 42.95 | 16.89 | 11.21 | 4.34 | 0.30 | 6.13 | 3.56 | 98.46 |
| patent trade surplus (bil.$) | -0.64 | -1.9 | 6.01 | 16.87 | -3.24 | -4.33 | -11.66 | 0.14 | 1.24 | 0.01 | 7.39 (std) |
| *simulation III: eliminating country differences in the technological composition* | | | | | | | | | | | |
| pat. num. granted | 48,263 | 53,996 | 51,122 | 61,995 | 61,062 | 60,128 | 62,379 | 22,095 | 41,892 | 45,614 | 508,907 |
| pat. value provided (bil.$) | 2.80 | 3.66 | 4.03 | 28.58 | 21.79 | 17.17 | 17.62 | 0.18 | 5.36 | 3.90 | 105.08 |
| pat. num. received | 10,435 | 7,370 | 47,699 | 226,711 | 95,878 | 57,491 | 21,343 | 1,618 | 35,467 | 19,959 | 523,971 |
| pat. value received (bil.$) | 2.15 | 1.51 | 9.79 | 47.00 | 19.78 | 11.80 | 4.40 | 0.33 | 7.35 | 4.10 | 108.203 |
| patent trade surplus (bil.$) | -0.65 | -2.15 | 5.76 | 18.42 | -2.01 | -5.37 | -13.22 | 0.15 | 1.99 | 0.20 | 8.08 (std) |
| changes from simulation II | -0.01 | -0.25 | -0.25 | 1.55 | 1.23 | -1.04 | -1.56 | 0.01 | 0.75 | 0.19 | 0.69 (std) |

**Table 7d: The Decomposition of Patent Trade Imbalance: Simulation IV**

| | Austria | BE-LU | Switzerland | Germany | France | U.K. | Italy | Netherlands | Sweden | Total / std |
|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.22 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.31 | 0.22 | 6.08 |
| % of total | 2.72 | 3.65 | 3.78 | 27.29 | 20.80 | 16.67 | 16.27 | 5.12 | 3.71 | 100 |
| *simulation III: eliminating country differences in the technological composition* | | | | | | | | | | |
| pat. num. granted | 48,263 | 76,091 | 51,122 | 61,995 | 61,062 | 60,128 | 62,379 | 41,892 | 45,614 | 508,907 |
| pat. value provided (bil.$) | 2.80 | 3.84 | 4.03 | 28.58 | 21.79 | 17.17 | 17.62 | 5.36 | 3.90 | 105.08 |
| num. of patent families | 1,328 | 1143 | 6,064 | 28,814 | 12,195 | 7,310 | 2,713 | 4,509 | 2,540 | 66,618 |
| pat. num. received | 10,435 | 8988 | 47,699 | 226,711 | 95,878 | 57,491 | 21,343 | 35,467 | 19,959 | 523,971 |
| pat. value received (bil.$) | 2.15 | 1.84 | 9.79 | 47.00 | 19.78 | 11.80 | 4.40 | 7.35 | 4.10 | 108.203 |
| patent trade surplus (bil.$) | -0.65 | -2.00 | 5.76 | 18.42 | -2.01 | -5.37 | -13.22 | 1.99 | 0.20 | 8.08 (std) |
| *simulation IV: eliminating country differences in the R&D efficiency* | | | | | | | | | | |
| pat. num. granted | 49,733 | 78,275 | 52,827 | 63,735 | 63,295 | 61,961 | 64,257 | 43,238 | 46,922 | 524,243 |
| pat. value provided (bil.$) | 3.16 | 4.23 | 4.25 | 31.59 | 24.28 | 19.46 | 19.05 | 6.08 | 4.43 | 116.53 |
| num. of patent families | 739 | 2,237 | 2,989 | 23,059 | 13,912 | 13,222 | 5,631 | 3,407 | 1,401 | 66,598 |
| pat. num. received | 5,817 | 17,610 | 23,529 | 181,517 | 109,512 | 104,083 | 44,326 | 26,817 | 11,032 | 524,243 |
| pat. value received (bil.$) | 1.30 | 3.92 | 5.24 | 40.42 | 24.38 | 23.18 | 9.87 | 5.97 | 2.46 | 116.73 |
| patent trade surplus (bil.$) | -1.38 | -0.31 | 0.99 | 8.83 | -1.11 | 5.47 | -10.91 | 0.06 | -1.63 | 5.40 (std) |
| changes from simulation III | -0.73 | 1.69 | -4.77 | -9.59 | 0.9 | 10.84 | 2.31 | -1.93 | -1.83 | -2.68 (std) |

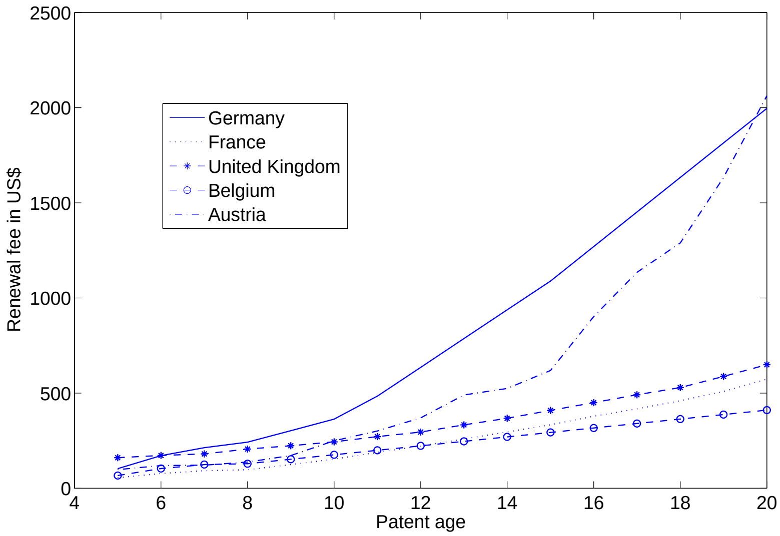
**Table 7e: The Decomposition of Patent Trade Imbalance: Simulation V**

| | Austria | BE-LU | Switzerland | Germany | France | U.K. | Italy | Netherlands | Sweden | Total / std |
|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.22 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.31 | 0.22 | 6.08 |
| % of total | 2.72 | 3.65 | 3.78 | 27.29 | 20.80 | 16.67 | 16.27 | 5.12 | 3.71 | 100 |
| *simulation IV: eliminating country differences in the R&D efficiency* | | | | | | | | | | |
| pat. num. granted | 49,733 | 78,275 | 52,827 | 63,735 | 63,295 | 61,961 | 64,257 | 43,238 | 46,922 | 524,243 |
| pat. value provided (bil.$) | 3.16 | 4.23 | 4.25 | 31.59 | 24.28 | 19.46 | 19.05 | 6.08 | 4.43 | 116.53 |
| num. of patent families | 739 | 2,237 | 2,989 | 23,059 | 13,912 | 13,222 | 5,631 | 3,407 | 1,401 | 66,598 |
| pat. num. received | 5,817 | 17,610 | 23,529 | 181,517 | 109,512 | 104,083 | 44,326 | 26,817 | 11,032 | 524,243 |
| pat. value received (bil.$) | 1.30 | 3.92 | 5.24 | 40.42 | 24.38 | 23.18 | 9.87 | 5.97 | 2.46 | 116.73 |
| patent trade surplus (bil.$) | -1.38 | -0.31 | 0.99 | 8.83 | -1.11 | 5.47 | -10.91 | 0.06 | -1.63 | 5.40 (std) |
| *simulation V: eliminating country differences in the R&D input* | | | | | | | | | | |
| pat. num. granted | 49,733 | 78,275 | 52,827 | 63,735 | 63,295 | 61,961 | 64,257 | 43,238 | 46,922 | 524,243 |
| pat. value provided (bil.$) | 3.16 | 4.23 | 4.25 | 31.59 | 24.28 | 19.46 | 19.05 | 6.08 | 4.43 | 116.53 |
| num. of patent families | 1,812 | 2,425 | 2,518 | 18,173 | 13,854 | 11,101 | 10,835 | 3,411 | 2,470 | 665,98 |
| pat. num. received | 14,264 | 19,092 | 19,823 | 143,052 | 109,053 | 89,382 | 85,289 | 26,848 | 19,441 | 524,243 |
| pat. value received (bil.$) | 3.18 | 4.25 | 4.41 | 31.85 | 24.28 | 19.46 | 18.99 | 5.98 | 4.33 | 116.73 |
| patent trade surplus (bil.$) | 0.02 | 0.02 | 0.16 | 0.26 | 0.00 | 0.00 | -0.06 | -0.10 | -0.10 | 0.11 (std) |
| changes from simulation IV | 1.40 | 0.33 | -0.83 | -8.57 | 1.11 | -5.47 | 10.85 | -0.16 | 1.53 | -5.30 (std) |

**Table 8: R&D input and R&D efficiency**

| | Austria | BE-LU | Switzerland | Germany | France | U.K. | Italy | Netherlands | Sweden | Total / avg |
|---|---|---|---|---|---|---|---|---|---|---|
| Avg. GDP (78-96, tril.$) | 0.17 | 0.22 | 0.23 | 1.69 | 1.25 | 1.00 | 0.99 | 0.31 | 0.22 | 6.08 |
| % of total | 2.72 | 3.65 | 3.78 | 27.29 | 20.80 | 16.67 | 16.27 | 5.12 | 3.71 | 100 |
| R&D expenditure (bil.$), 1980 to 1985 | | | | | | | | | | |
| pharmaceutical | 0.10 | 0.34 | 0.46 | 2.99 | 1.75 | 1.85 | 0.69 | 0.35 | 0.33 | 8.86 |
| chemicals | 0.94 | 3.30 | 4.41 | 28.87 | 16.88 | 17.89 | 6.67 | 3.35 | 3.23 | 85.54 |
| electronics | 0.74 | 2.60 | 3.48 | 22.77 | 13.31 | 14.11 | 5.26 | 2.65 | 2.55 | 67.47 |
| mechanical | 1.32 | 4.65 | 6.21 | 40.61 | 23.74 | 25.17 | 9.39 | 4.72 | 4.55 | 120.36 |
| miscenaneous | 0.55 | 1.94 | 2.59 | 16.92 | 9.89 | 10.49 | 3.91 | 1.97 | 1.89 | 50.15 |
| all tech. fields | 3.65 | 12.84 | 17.15 | 112.16 | 65.57 | 69.51 | 25.92 | 13.03 | 12.56 | 332.39 |
| % of total | 1.10 | 3.86 | 5.16 | 33.74 | 19.73 | 20.91 | 7.80 | 3.92 | 3.78 | 100 |
| num. of inventions / mil.$ R&D | | | | | | | | | | |
| pharmaceutical | 0.34 | 0.16 | 0.77 | 0.38 | 0.24 | 0.22 | 0.23 | 0.34 | 0.18 | 0.31 |
| chemicals | 0.19 | 0.08 | 0.37 | 0.27 | 0.11 | 0.09 | 0.10 | 0.30 | 0.10 | 0.18 |
| electronics | 0.20 | 0.09 | 0.33 | 0.31 | 0.28 | 0.12 | 0.09 | 0.62 | 0.18 | 0.25 |
| mechanical | 0.57 | 0.09 | 0.32 | 0.23 | 0.18 | 0.10 | 0.11 | 0.23 | 0.27 | 0.18 |
| miscenaneous | 0.39 | 0.10 | 0.37 | 0.21 | 0.17 | 0.09 | 0.10 | 0.32 | 0.26 | 0.18 |
| average | 0.36 | 0.09 | 0.35 | 0.26 | 0.19 | 0.11 | 0.11 | 0.35 | 0.20 | 0.20 |

**Figure 1: Renewal Fee Schedule in Selected Countries in 1990**




Note: Figure 1 displays the renewal fee schedule in selected EPC member countries in 1990, which is representative of the fee schedules in other cohorts during the sample period. Fees are in 2000 U.S. dollar value.