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International Patent Harmonization and Trade Balance of Patent Rights [*]

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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. 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 (Barrio 2006). All these new developments in the global economy call for quantitative analyses of the economic consequences of international patent harmonization. In particylar, understanding whether the benefits of harmonization are equitably distributed among countries provides insight into the likely success of any harmonization efforts.

Most of the existing literature, however, focuses on theoretical analysis of the welfare gains and losses in international patent harmonization (for instance, Chin and Grossman 1990, Grossman and Lai 2004), 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 value is 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 value 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 monetary value 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 country offers and receives under the European Patent Convention (EPC) regime. Finally, a series of simulation exercises are conducted to explore the determinants of the significant patent trade imbalance as revealed by model estimation.

The estimates of patent value are imputed from a structural model relating 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, with a patent been sought only in countries where expected return of seeking such a patent exceeds the associated patenting costs, and will be kept alive until net returns of doing so becomes negative. Estimation of such a 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 the patent trade 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 25% on average, ranging from 13% for electronics to 53% for pharmaceutical industry.

Secondly, the economic rents appropriated by inventors in individual countries through European patent system exhibit significant differences. Within the sixteen European Patent Convention (EPC) member countries in the 1990s, there is significant imbalance on the value of patent protection received and provided by each country. For instance, out of patent cohorts 1993 to 1996, Swiss inventors expect to receive a total of $2,625 million (in 2000 U.S. dollar value) worth of patent protection from the EPC, whereas Switzerland is expected to provide only $433 million worth of patent protection to EPC inventors as a whole, thus generating a net patent "trade surplus" of $2,192 million, five times as large as the protection it provides. On the other hand, inventors from the U.K. will receive $3,895 million worth of patent protection from the EPC, whereas it will award $9,334 million worth of patent rights to EPC inventors, generating a net patent "trade deficit" of about $5,439 million, or 58% of the protection it provides.

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 and Spain 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 intensity 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 examines the patent sample that will be used. Section 3 presents a patent evaluation model based on patent application and renewal analysis and describes the Simulated Method of Moments (SMM) estimator. Based on the estimation results, Section 4 simulates the patent value distribution and calculates "implicit R&D subsidy" the European Patent Convention provides to private inventors. Section 5 calculates the "trade flows" of patent rights among European countries, 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 the EPC patent regime, 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 around the world. Most patents in European countries are now granted by the EPO, and by the late 1990s the EPO route had already "almost entirely replaced direct applications to national patent offices" in Europe (Eaton, Kortum, and Lerner 2003). The following estimation and simulation analyses are based on the universe of all 761,540 patent applications submitted to the EPO during 1978 to 1996 (referred to as cohorts 1978 to 1996, same below). In particular, I use disaggregated data on the designation and renewal records in

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[1] Although the term "European patent" is often used in the literature and press to refer to patents granted by the EPO, one should realize that, such a "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.

every EPC member country for each patent application, up until 1996 when the data set ends, as well as detailed information on various patent characteristics such as the application and grant dates, the nationality of the patent applicants, the technological classifications (International Patent Classification codes or IPC codes), etc.

Based on the above information, I first group the patent applications or patent families (i.e., patents derived based on the same patent application) into different nationality-technology-cohort cells. In particular, the nationality of each patent applicant is identified as belonging to one of the following four categories: EPC member countries (*EPC*), United States (*US*), Japan (*JP*), and other countries (*OTH*), or combination of them when the inventors come from more than one countries (*multi nationality*). Similarly, along the technological dimension, the 3-digit IPC codes are aggregated into five major technology fields: pharmaceutical, chemicals, electronics, mechanical, and miscellaneous, and each patent application may belong to one or multiple of such fields. On the time dimension, the 19 patent cohorts are combined into 6 cohort groups: 1978 to 1980, 1981 to 1983, 1984 to 1986, 1987 to 1989, 1990 to 1992, and 1993 to 1996. This procedure generates a total of 2,604 possible nationality-technology-cohort cells, many with zero observations. Finally, the 378 cells with sizes equal or larger than 50 are included in the estimation sample (so as to ensure the accuracy of the observed designation and renewal frequency within each cell), generating a total sample size of 751,376 applications, or 98.7 percent of the universe of the 761,540 patent applications. All the designation records of these patent applications, as well as their entire renewal history up until 1996, will be used in the model estimation.

Table 1 summarizes characteristics of this sample. By the end of 1996, the EPO had approved 380,712 patent applications[2], generating a total of 2,617,326 patents. Among the EPC member countries, Germany is the largest patent granter, awarding 364,423 patents to applicants around the world, or about 14 % of the total number of European patents. The second largest patent granter is the U.K. (13.5%), followed by France (13.1%), Italy (10.4%), and Netherlands (8.8%). 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, over the nineteen years since 1978, Luxemburg, the smallest EPC

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[2] Note that this is the total number of patent applications being approved as of the end of 1996. There is a long lag between the initial applications and the final granting decisions being made, with a median waiting period of three to four years at the EPO (Deng 2007a).

member country, granted 98,681 patents, or 27% of the number of patents awarded by Germany, 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 sizable differences. Germany and the U.S. are the largest patent source countries, owning 667,518 and 612,892 patents, respectively. More than 60% of all the patents were issued to inventors from the EPC member countries, followed by inventors in the U.S. (23.4%), Japan (12.4%). 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. 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, which does not differ much across different destination countries. Overall, among the five technology fields, mechanical patents are the largest group, accounting for 31.7% of all patents in total, followed by electronics (24.8%) and chemical (23%), and pharmaceutical is the smallest group (6.2%). About 16% of the total sample belong to more than one technology fields. On the other hand, as indicated in the last column of Table 1b, the grant rate across different technology fields is very close, between 65% to 70%.[3]

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[3] Because of the substantial patent grant lags (see previous footnote), many applications in the later cohorts (e.g., those submitted in the 1990s) had not received the granting decisions from the EPO by the end of 1996. Thus the observed grant rate in these cohorts would undoubtedly carry a downward bias. To solve this problem, in the last column of Table 1b I show the average grant rate of cohorts 1978 to 1989, where the grant lag is much less problematic. This will also be the grant rate to be used in simulating the expected patent value for cohorts

All 2,617,326 patents are derived from the group of 380,712 patent applications that were successfully approved by the EPO as of the end of 1996. The average size of patent family, therefore, is 6.87, which is much less than the number of EPC countries available to designate (rising from 10 in the early 1980s and 16 in the late 1990s as the EPC membership gradually expanded over time). This is not surprising, as the EPC charges a per-country fee when the patent applicants choose which countries to designate and later transfer the approved applications to. Likewise, most granted 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). These observations suggest that, facing substantial patenting costs, a rational patent applicant/holder will optimize his patenting behavior, including choosing both the set of countries to be designated and the optimal length of patent life in each designated country, by comparing patenting costs with the expected returns from obtaining and maintaining a patent. Such designation and renewal decisions will be explicitly analyzed in the structural model in the next section.

3. A Joint Patent Application-Renewal Model

Patenting through the EPO is a two-stage process. 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 has designated and obtain national patents in those countries. As long as the annual renewal fee c_{jt} is 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

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

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after 1990 in later sections.

where β 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. It is assumed that, while the patent approval is pending, patent applicants cannot receive any returns from the pending patents. 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}, another choice variable to be solved later.

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:

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

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

q_j and $\log(GDP_j)$ are two country-specific determinants of patent returns in 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 either the market size of the economy or the laws on intellectual property rights or the enforcement of such laws 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 $\log(GDP_j)$ is included to measure the relative magnitude of real GDP (with Germany normalized to one) mimicking relative market sizes.

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.

The model is estimated using a simulated method of moments (SMM) estimator. In particular, for each of the 378 nationality-technology-cohort group cell, at each age, I calculate the hazard rates in each country, defined as

$$\pi^N_{cell,j}(t) = [R_{cell,j}(t-1) - R_{cell,j}(t)]/R_{cell,j}(t-1) \tag{3.8}$$

where $R_{cell,j}(t)$ denotes the renewal rates or the percentage of living patents in country j in a specific cell by the end of age t. $R_{cell,j}(1)$ is the designation rate of country j and $\pi_{cell,j}(1)$ is thus the percentage of applications not designating country j in this cell, as $R_{cell,j}(0) = 1$. The moment conditions are

$$E[\pi_N - \pi(\omega)] = 0 \tag{3.9}$$

where π_N is a vector stacking up the hazard rates $\{\pi^N_{cell,j}(t)\}_{cell,j,t}$ of all nationality-technology cell in each country and at each age as observed in the sample. Thus the dimension of π_N equals the sum over all 378 nationality-technology-cohort group cells, of the products of number of observed patent ages (1 to 17 depending on which cohort) and the number of EPC member countries (10 to 16 depending on the observation year) in each cell. $\pi(\omega)$ is the vector of hazard rates as predicted by the model, where ω a vector of model parameters. The SMM estimator, $\widehat{\omega}_N$, is then constructed as

$$\begin{aligned}\widehat{\omega}_N &= \arg\min ||G_N(\omega)|| \\ &= \arg\min ||\pi_N - \widetilde{\pi}_N(\omega)||_{W_N(\omega)} \qquad (3.10)\end{aligned}$$

where $\widetilde{\pi}_N(\omega)$ is a vector of simulation hazard rates implied by ω, with the simulation size set to be proportional to the sample size for each cell. $W_N(\omega)$ is a semi-definite weighting matrix which is specified as

$$W_N(\omega) = diag(\sqrt{n/N}), \qquad (3.11)$$

where n is the number of patent applications in each nationality-technology-cohort cell and N is the total sample size. In other words, observations are weighted by sample size of each cell.[4] Given that all the regularity conditions hold (Pakes and Pollard 1989 and Lanjouw 1998) and $W_N(\omega)$ converges in probability to a semi-definite matrix W, the asymptotic distribution of $\widehat{\omega}_N$ is given by

$$\sqrt{N}(\widehat{\omega}_N - \omega_0) \backsim N(0, (\Gamma' W \Gamma)^{-1} \Gamma' W V W \Gamma (\Gamma' W \Gamma)^{-1}) \qquad (3.12)$$

where Γ and V are the full-ranked derivative matrix and the asymptotic variance matrix of the moment conditions $\pi_N(\omega) - \widetilde{\pi}_N(\omega)$, respectively.

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

Parameter estimates are obtained by minimizing equation (3.10) using a combination of grid search and a hill-climbing algorithm. Because of the large sample and simulation sizes and high dimension of moment conditions as well as the large number of parameters (22 parameters in total), numerical optimization turns out to be very challenging. To alleviate the computational

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[4] The optimal weighting matrix should be the sample estimate of the inverse of the asymptotic variances of the moment conditions. However, calculating such a weighting matrix is computationally very challenging due to the large dimension of the moment conditions, and thus I choose to weigh the moment conditions by the number of patent applications in each cell.

burden, the real discount rate β is set to equal 0.95 and the depreciation rate $(1-\delta)$ is fixed at 0.15, consistent with the previous literature.

Table 2 presents the parameter estimates, with the asymptotic standard deviations reported in the parentheses. Formal χ^2 statistic testing the over-identification of the moment conditions easily rejects the null, as the large sample and simulation sizes make the variance of the estimated hazard rates very small. On the other hand, by comparing the variance of the fitted residuals of hazard rates with the variance of hazard rate as observed in the data, it can be seen that the model is able to explain 63 percent of the total variations of actual hazard rates, or when the fitness of designation and renewal patterns are examined separately, 75 percent of designation rate variations and 44 percent of renewal rate variations.

Estimates of model parameters are very informative of the underlying patent value distribution. In particular, inventions with European origin tend to have higher value than those from the U.S. and Japan, although such source-country difference is not statistically significant. On the other hand, value of patent rights is statistically different across technological fields, with pharmaceutical patents having the highest median value and electronics the lowest. Patent value from different cohort groups also exhibits some variations, although not statistically significant.

The estimate of multi-technology field dummy indicates a statistically significant and positive premium for inventions belonging to more than one technology fields, consistent with Lerner (1994)'s finding that broader patents tend to be more valuable in the bio-tech industry. However, inventions with multiple nationalities do not necessarily have higher value than those with single natinality. Finally, estimates of the destination-country dummies q_j exhibit statistically significant difference across countries. Note that these country fixed effects reflect the systematic difference in the value of patent rights as drived from the same invention, after controlling for the size of economy of the destination countries. Thus they directly quantify the institutional differences in enforcing patent rights in these countries. Previous researchers (for instance, Baxter and Sinott (1989)) usually construct 0-1 dummy variables to proxy such differences, based on information such as whether certain industrial sectors are excluded from patent protection, or whether importation of products is excluded from protection, etc. The current approach provides a direct and quantitative measure of the effects of such institutional differences on patent value.

Based on the model estimation results, I simulate the model and derive the value distribution of European patent rights in cohorts 1993-1996. In particular, I simulate 601,197 inventions, three times the total number of inventions in these cohorts, 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 in two selected countries, Germany and France, as well as that of the whole EPO patent family, for each nationality group (source country) and major technology fields for cohort group 1993-96.[5] Patents in different technology fields have substantially different value distribution: pharmaceutical patents tend to have the highest value, with a median of \$1.84 million (in 2000 U.S. dollar value, same below) for the whole EPO patent family, followed by chemicals (\$0.25 million), "miscellaneous" (\$0.24 million) and mechanical (\$0.18 million), and electronics have the lowest median value (\$0.08 million). Value distribution in each destination country has the same ranking, with pharmaceuticals having the highest median value (\$0.15 million in Germany and \$0.11 million in France), and electronics having the lowest (\$0.01 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 records in all EPC member countries, and is thus abstracted from such idiosyncrasy.

Value distribution of patents originated from different nationality groups also varies. Specifically, patent families with EPC origin have the highest value, with a median of \$0.26 milllion, followed by inventions from ROW group (\$0.24 million). Inventions from Japan have the lowest value. Such a ranking of patent value 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 the highest among different nationality groups. This is consistent with the similar findings based on patent counts in Section 2.

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[5] For exposition, Table 3 and the tables thereafter only display estimation and simulaiton results for a subset of the countries. Full tables are available from the author upon request.

Patent value distribution in Tables 3a and 3b also indicates 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 destination country, but also seek patent protection in more countries.

To quantify the importance of EPC patent protection in promoting R&D activities, 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.

Table 4 presents the estimates of total expected value of patent protection for each technology field for cohorts 1993 to 1996 and the corresponding ESR. In particular, the first two rows display the mean value and the expected total number of patent families to be granted by the EPO, among all the applications submitted by inventors from the EPC member countries as well as the U.S. and Japan during 1993 to 1996. The third row reports the total value of patent protection these inventors expect to receive over the whole life of their patents, the fourth row presents the total private R&D expenditures from these countries targeting European market during 1993 to 1996,[6] and the last row reports the estimated Equivalent Subsidy Rate. As shown in the last column, the EPC patent system provides an average implicit subsidy rate of 25% to private R&D performers, very close to 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 (53%) and chemical (36%), and lowest for mechanical (20%) and electronics (13%). Such ranking is strictly consistent with findings from survey and anecdotal evidences that patent protection is particularly important

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[6] 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 expenditures in each SIC industry to each 4-digit IPC code, and then sum them up according to the 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 European market, I choose to calculate the R&D expenditures relevant to European market by using the ratio of each source country's goods exports to the EPC member countries to its total manufacturing production as weights, similar to Schankerman (1998)'s treatment of French market.

for R&D in pharmaceutical and chemical industries, and less so for other industries (Mansfield, Schwartz, and Wagner 1981, Levin, Klevorick, Nelson and Winter 1987).

5. “Trade Flows” of Patent Rights: Cohorts 1993-1996

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 provides, 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 quantitative 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, based on patent application records, Austria was designated by 31,722 patent applicants from Europe in cohorts 1993 to 1996, and is thus expected to issue 22,056 patents to all European inventors in these cohorts (assuming patent grant rates the same as their historical avearage). However, Austrian inventors only submitted 1,828 patent applications during 1993 to 1996, and thus expect to receive patent protection for 1,225 inventions, or a total of 7,631 patents (first column in Table 5). Calculation based on simple patent counts would then conclude that Austria will provide far more patent protection to other EPC member countries than its citizens expect to receive from them and thus suffers a patent “trade deficit” of 14,425 patents for those four cohorts. On the other hand, France will provide patent protection to 45,395 inventions in those cohorts, whereas French inventors expect to receive patent protection for 10,652 of their inventions, or in total 65,548 patents, from all EPC member countries. And these imply a large patent “trade surplus” of 20,153 patents for France.

However, Table 3 reveals a substantial heterogeneity in the value of patent rights as awarded by different countries, even for patents belonging to the same patent family. An Austrian patent does not have the same economic value as a French 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 French patent may be much higher than that of the protection a French inventor receives from an Austria patent. Consequently a more accurate way to examine the 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.[7] It shows, for instance, that although Austria expects to award much more patents to foreign inventors than it expects to receive, the mean value of the patents it expects to receive is much higher than those it expects to award. The total private value of patents Austrian inventors expect to receive from the EPC for cohorts 1993 to 1996 is about \$672 million, \$257 million higher than the value of patent protection Austria expects to provide, or about 60% of the latter. Thus Austria indeed expects a substantial patent trade "surplus," not a "deficit." On the other hand, although France expects to receive much more patents than it expects to grant, the total value of the former is substantially smaller than the total value of the latter, implying a "deficit" of \$741 million rather than a "surplus."

Among all the sixteen EPC member countries, Germany is the largest patent granter, issuing 51,787 patents (13.5% of all the EPC patents), which worth \$12.6 billion, or 35% of the total value. The U.K. is the second largest granter, issuing 48,027 patents, which in total worth \$9.3 billion or 26% of the total patent value. The proportion of patent protection offered by each country is largely consistent with the relative size of their economy (rows 2 and 6 of the table), although not strictly identical because of country differences in patenting costs and in enforcing patent rights, etc. On the other hand, German inventors receive the largest portion of the total patent protection, \$14.2 billion or almost 40% of total patent value, followed by France (\$6.6 billion, 18%), the U.K. (\$3.9 billion, 11%), Italy and Switzerland (both at \$2.6 billiion and 7.3%).

Patent trade flows are quite imbalanced across national borders. In particular, Switzerland

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[7] Here we focus on analyzing the trade flows implied by cohorts 1993 to 1996, as by the late 1990s the EPO had already "almost entirely replaced direct applications to national patent offices" in Europe (Eaton, Kortum, and Lerner 2003), therefore our EPO patent sample is close to a complete count of the patent protection each country provides and receives for those cohorts. Even though some applicants might have chosen to file directly to national patent offices during this period, most of such applications were likly based on low-valued inventions and were only submitted to home-country patent offices ("home bias" discussed by Eaton and Kortum (1999)), as owners of high-valued inventions intending to seek patent protection in multiple EPC member countries should take the EPO route, because the latter is more cost-effective for multi-country applications. Neglecting those directly submitted to home-country patent offices will have no effect on calculating cross-border patent trade balance.

expects to run the largest patent "trade surplus," about \$2.2 billion, five times the total value of patent protection it expects to provide to EPC inventors. Germany has the second largest "surplus" of \$1.6 billion, 13% of the value of protection it expects to provide. The U.K. expects to run the largest patent "trade deficit" of \$5.4 billion, about 58% of the total value of patent protection it expects to provide.

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 difference in patenting costs

First, I consider the implications of country difference 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 1993 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 6a presents the results of this simulation. The elimination of country difference in patenting costs substantially promotes patenting exercise, as the total number of patents granted by all countries increases by 30%, from 382,707 to 499,596. In other words, the current patenting costs in European countries on average are too high, compared with the ones imposed in Germany.

However, synchronizing patenting costs does not have significant effects on patent "trade imbalance" across countries. The largest changes on net flows come from Germany and France, whose patent trade surplus will increase \$157 million and \$102 million, respectively, indicating that these two countries tend to charge relatively lower patenting fees than other countries, after controling for the size of economy. On the other hand, synchronizing patenting costs will reduce Netherland's surplus by \$93 million, suggesting that patenting costs in Netherland are relatively higher than most other countries. Yet these changes are too small compared to the estimated patent "trade imbalance" in the top panel of Table 6a, so the observed country difference in patenting costs only have modest influences in generating the estimated "trade imbalance."

Simulation II: Eliminating country difference 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, same as that of Germany. This essentially eliminates the national difference in enforcing patent rights, and results in an entirely "harmonized" international patent regime. The only difference in the value of an invention across different countries comes from differences of the size of the economy of destination countries.

The lower panel of Table 6b shows that this will significantly change the estimated patent trade imbalance. In particular, Germans will obtain 60,263 more patents and \$3,765 million more worth of patent protection, and the net "surplus" will rise to \$5,536 million. This indicates that Germany has a substantially stronger degree of patent protection than other countries on average, and enforcing the same patent law standards in other countries with the same effectiveness as German practice will boost German investors' incentives to obtain patent rights from those countries, and further increase the patent trade surplus it already enjoys. Similarly, the U.K.'s patent trade deficit will be substantially decreased, by \$4,386 million to \$1,041 million. On the other hand, if the degree of patent protection in Italy is set to be the same as in Germany, Italy will issue 16,694 more patents to European inventors, and the mean value of Italian patents will rise by \$0.09 million. Such changes will increase the total value of patent protection Italy provides to European inventors to \$6,052 million, more than tripling the value it provides in simulation I. Consequently Italy will run a patent trade deficit of \$2,701 million, instead of a substantial surplus as before. On average, the elimination of country difference in patent protection generates higher patent trade imbalance among countries, as indicated by the increase of the standard deviations of net surplus in this simulation.

A complete patent harmonization, as defined by simulations I and II, greatly improves inventors' welfare and encourages international patenting. In particular, the total number of patents increases 258,813, or 68%, and the total value that patent holders receive rises from \$35,785 million to \$45,592 million, a 28% increase. This indicates the potentials of further harmonizing the patenting system in Europe, from what the EPC has already achieved during the past several decades. It should also be noted that these figures simply reflect a lower bound of increases in R&D incentives implied by such patent harmonization efforts, as the above calculation is based on the same set of patent applications as observed in the data, and does not take into account the fact that a more pro-patent environment would stimulate more R&D input and generate more inventions, as well as encourage more inventors to seek patent protection.

Simulation III: Eliminating country difference in technological composition of inventions

The next candidate that I examine is the country difference in technological composition of their invention pools. As one may suspect, since some industries (in particular pharmaceuticals and chemicals) rely more heavily on patent system to appropriate economic 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 6c, indicate that such differences have only modest influences in generating the trade imbalance: the largest changes it brought on the net surplus come from Germany (+\$1,132 million) and France (-\$582 million). Compared with the net surplus these two countries hold, such effects are quite limited. Overall , the elimination of country difference in technological composition slightly increases patent trade imbalance, as indicated by the small increases in standard deviations of the net surplus (by less than 15%).

Simulation IV: Eliminating country difference in R&D efficiency

Simulations 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 7 shows, Germany has the highest R&D expenditure during 1993 to 1996, with a total of $108 billion, or more than one-third of the total R&D input by all EPC member countries, much higher than its GDP share (27%). On the other hand, the total R&D expenditure by Italy in 1993 to 1996 is about $25 billion, or less than 8% of the total R&D input by EPO countries, despite the fact that its GDP share is more than 13%. Country difference in R&D intensity, as measured by R&D/GDP ratio, may directly affect their ability in rent appropriation through international patent harmonization.

On the other hand, even with the same amount of R&D input, European countries exhibit significant difference 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 7 displays for each country the number of patent families per million dollar R&D expenditure, in each technological field. It can be seen that countries differ a lot in R&D efficiency, with Switzerland, Netherlands, Denmark having the highest patent family/R&D ratio, more than doubling that of Belgium, Ireland, and the U.K., both within each technology field and when averaged across different fields.

Simulation experiment IV then suppresses the country difference in R&D efficiency and simulates the total patent value each country provides and receives, while keeping the actual R&D expenditure by each country unchanged. As shown in Table 6d, if one assumies an identical R&D efficiency for each country at the average European level, inventors in Germany, Switzerland and Netherlands will produce much less inventions and possess much less patents, and consequently the net patent trade surplus of these two countries decline significantly. On the other hand, if France, the U.K. and Belgium's R&D efficiency were increased to the average European level, their number of inventions would increase substantially, and such increases would have significantly boosted their surplus. Overall, the elimination of country difference in R&D efficiency decreases patent trade imbalance significantly, as the standard deviations of the net surplus shrinks from $2,087 million to $1,257 million, or 40%.

Simulation V: Eliminating country difference in relative R&D intensity

Finally I explore the implications of country difference in R&D intensity on patent "trade imbalance." Assuming that each country devotes the same share of their GDP on R&D activities, Table 6e displays the total patent protection a country offers and receives. By dragging down the high R&D intensity in Germany, France, and Switzerland to the average European level (from Table 7), the number of patents owned and thus the total value of patent protection received by these countries decline, and those by countries such as Italy and Spain increase dramatically. Note that in this simulation all kinds of country difference are suppressed. As a result each country receives and provides the same amount of patent protection, proportional to their relative size of economy, and their net "trade surplus" is close to zero. The significant change in standard deviations of the net surplus (by $1,215 million) suggests that country difference 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 difference in enforcing the patent rights, on the other hand, tends to offset such imbalance, as more R&D active countries tend to provide stronger patent protection.[8] Country difference in technological composition of their invention pools or in their patenting costs only has very 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 from European Patent Convention in the past two decades, I estimate European patent value distribution 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 inventors in Germany and

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[8] 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.

Switzerland benefiting the most from the EPC and inventors in the U.K. the least, relative to the patent protection these countries provide. 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.

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Table 1a: Sample Composition: Nationality

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.
Number of patents awarded by								
	153,653	188,287	191,757	364,423	40,819	107,901	343,434	353,653
Number of patents received by								
Austria	2,213	2,642	3,340	4,321	670	1,552	4,150	3,746
Belgium	1,753	2,316	1,990	3,005	488	1,131	2,899	2,868
Switzerland	9,790	9,677	12,921	16,331	2,283	5,096	15,986	15,067
Germany	48,434	50,214	56,914	79,817	9,937	29,527	87,017	82,999
Denmark	1,390	1,515	1,469	1,893	584	870	1,870	1,863
Spain	515	613	541	846	228	247	835	833
France	16,294	23,286	20,852	36,891	4,696	15,377	18,308	35,418
U.K.	10,026	13,281	11,945	20,117	2,855	7,005	19,727	15,990
Greece	28	34	33	47	14	30	48	44
Ireland	234	240	237	202	94	180	298	296
Italy	6,551	7,018	7,233	10,969	2,044	6,110	10,874	10,554
Luxembourg	378	430	299	535	65	230	522	537
Monaco	37	40	46	73	10	40	50	68
Netherlands	5,926	8,071	6,682	13,448	1,838	4,346	13,241	13,121
Portugal	10	12	10	18	4	14	18	16
Sweden	4,160	4,168	4,547	6,943	1,129	1,955	6,786	6,636
U.S.	30,774	4,4911	39,217	87,452	9,133	22,482	85,996	85,868
Japan	7,624	12,302	15,514	69,737	2,346	7,472	63,310	66,532
ROW	5,639	5,949	6,143	9,191	1,776	3,259	9,019	8,801

Table 1a: Sample Composition: Nationality (continued)

	Greece	Ireland	Italy	Luxemberg	Monaco	Netherlands	Portugal	Sweden	Total
Number of patents awarded by									
	51,573	7,162	273,247	98,681	6,798	230,252	10,918	194,768	2,617,326
Number of patents received by									
Austria	744	119	3,828	1,658	125	2,871	192	3,081	35,252
Belgium	679	82	2,427	1,486	67	2,470	114	1,891	25,665
Switzerland	2,490	431	14,116	5,177	400	19,088	738	9,914	131,407
Germany	11,038	1,631	75,100	21,114	1,327	58,607	2,981	50,862	667,518
Denmark	563	134	1,551	1,061	119	1,693	134	1,654	18,364
Spain	310	58	823	420	58	602	117	574	7,619
France	6,993	934	32,428	13,810	836	25,271	1,699	22,098	275,192
U.K.	4,015	606	16,881	7,966	515	152,620	704	13,958	160,851
Greece	16	1	46	24	2	37	3	38	439
Ireland	141	41	278	210	30	258	35	255	3,125
Italy	3,472	442	4,598	4,665	499	7,829	768	7,752	91,380
Luxembourg	138	22	507	233	21	453	30	403	4,801
Monaco	18	3	69	35	5	43	4	42	580
Netherlands	2,366	352	10,627	3,550	269	10,850	479	7,754	102,920
Portugal	6	3	16	8	0	12	2	11	157
Sweden	890	131	5,218	2,375	110	4,963	193	3,913	54,114
U.S.	11,950	1,478	65,275	25,030	1,531	54,142	1,751	45,901	612,892
Japan	3,044	249	30,080	4,692	315	25,233	444	15,574	324,468
ROW	2,161	358	7,441	4,166	444	6,909	431	6,870	78,556

Table 1b: Sample Composition: Technology Fields

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.	Greece
Granted Pat Number	153,653	188,287	191,757	364,423	40,819	107,901	343,434	353,653	51,573
Technology Fields									
Pharmaceuticals	12,219	14,081	14,934	16,434	3,803	7,554	16,186	15,686	5,935
Chemicals	35,119	52,366	47,702	77,478	9,068	24,761	74,773	75,202	12,644
Electronics	29,697	35,091	40,750	110,151	7,173	19,888	101,478	107,599	8,537
Mechanical	51,092	56,498	58,300	114,187	13,232	38,447	107,407	111,415	15,562
Miscellaneous	25,526	30,251	30,071	46,172	7,543	17,252	43,589	43,451	8,894

	Ireland	Italy	Luxembourg	Monaco	Netherlands	Portugal	Sweden	Total	Grant Rate
Granted Pat Number	7,162	273,247	98,681	6,798	230,252	10,918	194,768	2,617,326	0.67
Technology Fields									
Pharmaceuticals	714	15,055	10,005	636	14,846	1,006	13,287	162,681	0.64
Chemicals	1,656	63,324	23,444	1,432	57,851	2,462	41,892	601,172	0.70
Electronics	1,001	65,977	16,984	1,060	58,105	1,499	43,289	648,281	0.68
Mechanical	2,477	91,078	31,701	2,433	65,707	4,052	66,287	829,872	0.67
Miscellaneous	1,314	37,813	16,548	1,237	33,744	1,900	30,014	375,319	0.63

Table 2: Model Parameter Estimates

A. Parameter estimates

μ_α	9.59	(0.65)	σ_α	0.30	(0.13)	σ_ε	2.10	(0.46)			
Nationality (source country) dummies (EPC = 0)											
U.S.	-0.11	(0.18)	Japan	-0.62	(0.15)	ROW	0.23	(0.10)			
Technology field dummies (Misc = 0)											
Pharmaceuticals	1.93	(0.28)	Chemicals	0.01	(0.13)	Electronics	-0.89	(0.33)	Mechanical	-0.31	(0.11)
Multi nationality				0.00	(0.10)	Multi technology				0.29	(0.12)
Cohort dummies (1978-1980 = 0)											
1981-1983	-0.01	(0.12)	1984-1986	0.01	(0.15)	1987-1989	-0.23	(0.13)	1990-1992	-0.02	(0.11)
1993-1996	-0.35	(0.18)									
Destination country dummies (Germany = 0)											
Austria	-0.90	(0.32)	Belgium	-1.01	(0.45)	Switzerland	-1.14	(0.36)	Denmark	-0.31	(0.20)
Spain	-1.52	(0.25)	France	-0.12	(0.21)	U.K.	0.44	(0.17)	Greece	-1.29	(0.25)
Ireland	0.22	(0.27)	Italy	-1.72	(0.37)	Luxembourg	0.00	(0.14)	Monaco	-0.01	(0.11)
Netherlands	0.01	(0.11)	Portugal	-1.04	(0.38)	Sweden	-1.09	(0.31)			

B. Summary Statistics

χ^2/dof	4.57	V($\widetilde{\pi} - \pi$)	0.0244	V($\widetilde{\pi}$)	0.0653	V($\widetilde{\pi} - \pi$)/V($\widetilde{\pi}$)	0.37
V($\widetilde{\pi}_{desig} - \pi_{desig}$)	0.0200	V(π_{desig})	0.0798	V($\widetilde{\pi}_{desig} - \pi_{desig}$)/V($\pi_{desig}$)			0.25
V($\widetilde{\pi}_{renewal} - \pi_{renewal}$)	0.0061	V($\pi_{renewal}$)	0.0108	V($\widetilde{\pi}_{renewal} - \pi_{renewal}$)/V($\pi_{renewal}$)			0.56

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

	Technology Field														
Quantile	Pharmaceuticals			Chemicals			Electronics			Mechanical			Miscellaneous		
	German	French	Family	German	French	Family	German	French	Family	German	French	Family	German	French	Family
25%	0.03	0.02	0.87	0.01	0.00	0.11	0.00	0.00	0.03	0.00	0.00	0.08	0.01	0.00	0.10
50%	0.15	0.11	1.84	0.02	0.02	0.25	0.01	0.01	0.08	0.02	0.02	0.18	0.03	0.02	0.24
75%	0.66	0.47	4.08	0.11	0.08	0.61	0.05	0.04	0.20	0.09	0.07	0.45	0.11	0.09	0.59
90%	2.33	1.62	8.94	0.38	0.29	1.41	0.17	0.13	0.50	0.31	0.24	1.07	0.43	0.31	1.38
mean	1.16	0.95	4.54	0.23	0.19	0.77	0.11	0.08	0.26	0.18	0.14	0.53	0.30	0.17	0.70

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

	Nationality											
Quantile	EPC			U.S.			Japan			ROW		
	German	French	Family	German	French	Family	German	French	Family	German	French	Family
25%	0.01	0.01	0.11	0.01	0.00	0.06	0.00	0.00	0.03	0.01	0.00	0.09
50%	0.03	0.02	0.26	0.02	0.02	0.15	0.01	0.01	0.07	0.03	0.02	0.24
75%	0.12	0.09	0.68	0.08	0.08	0.41	0.05	0.04	0.21	0.11	0.08	0.63
90%	0.46	0.34	1.72	0.32	0.31	1.09	0.18	0.15	0.56	0.44	0.31	1.63
mean	0.30	0.23	0.92	0.21	0.20	0.58	0.11	0.10	0.29	0.26	0.20	0.81

Tables 4: Equivalent Subsidy Rates (ESR), by Technology Fields

	Technology Field					
	Drugs	Chemicals	Electronics	Mechanical	Miscenaneous	Total
Mean value ($million)	4.54	0.77	0.26	0.53	0.70	
Number of patent families	3,279	21,222	43,037	38,223	12,662	121,423
Total value ($billion)	14.88	14.85	11.19	20.26	8.86	70.04
R&D ($billion)	27.96	41.21	89.36	100.40	25.32	284.25
ESR	0.53	0.36	0.13	0.20	0.34	0.25

Table 5: Trade Flows of Patent Rights within the EPC

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.
Avg. GDP (93-96, tril US$)	0.23	0.27	0.30	2.45	0.18	0.58	1.58	1.18
% of total	2.60	3.06	3.39	27.40	2.01	6.49	17.67	13.27
Patents expected to award								
pat. num.	22,056	23,854	19,311	51,787	17,519	24,177	45,395	48,027
mean value (thou $)	18.83	19.31	22.40	243.98	33.57	24.61	160.67	194.35
total value (mil $)	415	461	433	12,6345	588	595	7,301	9,334
% of total	1.16	1.29	1.21	35.31	1.64	1.66	20.40	26.08
Patents expected to receive								
exp. pat. family num.	1,225	1,164	4,416	26,200	715	693	10,652	5,901
mean value (thou $)	549	558	594	544	669	666	616	660
exp. pat. num.	7,631	7,104	27,666	160,780	4,691	4,450	65,548	37,126
total pat. value (mil $)	672	650	2,625	14,247	478	462	6,560	3,895
% of total	1.88	1.82	7.33	39.81	1.34	1.29	18.33	10.88
Patent trade surplus (patent value received - patent value awarded)								
net value (mil $)	257	189	2,192	1,612	-110	-133	-741	-5,439
net value / awarded	0.62	0.41	5.07	0.13	-0.19	-0.22	-0.10	-0.58

Table 5: Trade Flows of Patent Rights within the EPO (continued)

	Greece	Ireland	Italy	LU	Monaco	NL	Portugal	Sweden	Total
Avg. GDP (93-96, tril US$)	0.12	0.07	1.20	0.02	0.00	0.40	0.11	0.25	8.93
% of total	1.33	0.75	13.41	0.20	0.01	4.43	1.20	2.77	100
Patents expected to award									
pat. num.	10,088	16,817	30,562	10,115	542	28,468	15,658	18,285	382,707
mean value (thou $)	13.23	21.62	33.26	6.95	2.35	66.87	10.59	20.16	93.50
total value (mil $)	133.51	363.56	1,016.51	70.30	1.27	1,903.61	165.87	368.69	35,784.75
% of total	0.37	1.02	2.84	0.20	0.00	5.32	0.46	1.03	100
Patents expected to receive									
pat. family num.	51	162	4677	136	28	3986	29	2039	62,075
mean value (thou $)	625.06	766.76	562.12	886.06	905.07	523.93	791.02	565.52	576.47
exp. pat. num.	325	1067	28,900	906	194	23,630	196	12,493	382,707
total pat. value (mil $)	32.05	123.84	2,629.03	120.63	25.76	2,088.57	23.33	1,153.21	35,784.75
% of total	0.09	0.35	7.35	0.34	0.07	5.84	0.07	3.22	100
Patent trade surplus (patent value received - patent value awarded)									
net value (mil $)	-101.46	-239.72	1,612.52	50.33	24.49	184.96	-142.54	784.52	1,653.54 (std)
net value / awarded	-0.76	-0.66	1.59	0.72	19.28	0.10	-0.86	2.13	

Table 6a: The Decomposition of Patent Trade Imbalance: Simulation I

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.	Italy	NL	Sweden	Total
Model estimates												
pat. num. expects to award	22,056	23,854	19,311	51,787	17,519	24,177	45,395	48,027	30,562	28,468	18,285	382,707
pat. value awarded ($mil.)	415	461	433	12,635	588	595	7,301	9,334	1,017	1,904	369	35,785
pat. num. received	7,631	7,104	27,666	160,780	4,691	4,450	65,548	37,126	28,900	23,630	12,493	382,707
pat. value received ($mil.)	672	650	2,625	14,247	478	462	6,560	3,895	2,629	2,089	1,153	35,785
patent trade surplus ($mil.)	257	189	2,192	1,612	-110	-133	-741	-5,439	1,613	185	785	1,654 (std)
Simulation I: setting patenting costs proportional to the size of economy												
pat. num. awarded	33,688	33,126	30,877	51,787	27,063	29,674	46,214	52,113	34,107	42,787	26,670	499,596
pat. value awarded ($mil.)	461	485	468	12,635	638	605	7,264	9,359	1,024	2,020	391	36,161
pat. num. received	9,955	9,294	36,038	210,163	6,067	5,769	85,482	48,223	37,734	31,077	16,338	499,596
pat. value received ($mil.)	680	657	2,652	14,404	483	466	6,625	3,931	2,657	2,112	1,165	36,161
patent trade surplus ($mil.)	219	172	2,184	1,769	-155	-139	-639	-5,427	1,634	92	774	1,659 (std)
changes from model est.	-38	-17	-8	157	-45	-6	102	12	21	-93	-11	5

Table 6b: The Decomposition of Patent Trade Imbalance: Simulation II

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.	Italy	NL	Sweden	Total
Simulation I: setting patenting costs proportional to the size of economy												
pat. num. awarded	33,688	33,126	30,877	51,787	27,063	29,674	46,214	52,113	34,107	42,787	26,670	499,596
pat. value awarded ($mil.)	461	485	468	12,635	638	605	7,264	9,359	1,024	2,019	391	36,161
pat. num. received	9,955	9,294	36,038	210,163	6,067	5,769	85,482	48,223	37,734	31,077	16,338	499,596
pat. value received ($mil.)	680	657	2,652	14,404	483	466	6,625	3,931	2,657	2,112	1,165	36,161
patent trade surplus ($mil.)	219	172	2,184	1,769	-155	-139	-639	-5,427	1,634	92	774	1,659 (std)
Simulation II: eliminating country-specific difference in enforcing patent rights												
pat. num. awarded	49,426	48,519	45,849	51,781	30,551	46,060	47,235	48,769	50,801	43,143	39,605	641,520
pat. value awarded ($mil.)	1,183	1,387	1,532	12,634	892	2,948	8,172	5,993	6,052	2,020	1,234	45,592
pat. num. received	12,785	11,952	46,124	270,426	7,684	7,339	109,672	61,528	48,466	40,179	21,000	641,520
pat. value received ($mil.)	858	828	3,343	18,169	609	587	8,349	4,952	3,351	2,663	1,469	45,592
patent trade surplus ($mil.)	-325	-559	1,811	5,536	-283	-2,361	177	-1,041	-2,701	642	235	1,816 (std)
changes from simulation I	-544	-731	-372	3,766	-128	-2,222	817	4,386	-4,335	550	-539	157

Table 6c: The Decomposition of Patent Trade Imbalance: Simulation III

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.	Italy	NL	Sweden	Total
Simulation II: eliminating country-specific difference in enforcing patent rights												
pat. num. awarded	49,426	48,519	45,849	51,781	30,551	46,060	47,235	48,769	50,801	43,143	39,605	641,520
pat. value awarded ($mil.)	1,183	1,387	1,532	12,634	892	2,948	8,172	5,993	6,052	2,020	1,234	45,592
pat. num. received	12,785	11,952	46,124	270,426	7,684	7,339	109,672	61,528	48,466	40,179	21,000	641,520
pat. value received ($mil.)	858	828	3,343	18,169	609	587	8,349	4,952	3,351	2,663	1,469	45,592
patent trade surplus ($mil.)	-325	-559	1,811	5,536	-283	-2,361	177	-1,041	-2,701	642	235	1,816 (std)
Simulation III: eliminating country difference in technological composition												
pat. num. awarded	55,269	55,236	55,243	55,241	55,192	55,208	55,233	55,236	55,211	55,256	55,234	883,712
pat. value awarded ($mil.)	1,187	1,401	1,536	12,630	918	2,961	8,329	6,004	6,092	2,040	1,241	45,967
pat. num. received	17,252	16,672	62,924	371,104	10,224	9,902	152,289	84,566	66,405	57,445	29,138	883,712
pat. value received ($mil.)	897	867	3,272	19,299	531	515	7,925	4,398	3,454	2,993	1,517	45,967
patent trade surplus ($mil.)	-290	-534	1,735	6,668	-387	-2,446	-405	-1,606	-2,638	953	275	2,087 (std)
changes from simulation II	35	25	-76	1,133	-104	-86	-582	-565	64	311	40	271

Table 6d: The Decomposition of Patent Trade Imbalance: Simulation IV

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.	Italy	NL	Sweden	Total
Simulation III: eliminating country difference in the technological composition												
pat. num. awarded	55,269	55,236	55,243	55,241	55,192	55,208	55,233	55,236	55,211	55,256	55,234	883,712
pat. value awarded ($mil.)	1,187	1,401	1,536	12,630	918	2,961	8,329	6,004	6,092	2,040	1,241	45,967
pat. num. received	17,252	16,672	62,924	371,104	10,224	9,902	152,289	84,566	66,405	57,445	29,138	883,712
pat. value received ($mil.)	897	867	3,272	19,299	531	515	7,925	4,398	3,454	2,993	1,517	45,967
patent trade surplus ($mil.)	-290	-534	1,735	6,668	-387	-2,446	-405	-1,606	-2,638	953	275	2,087 (std)
Simulation IV: eliminating country difference in the R&D efficiency												
pat. num. awarded	55,204	55,200	55,270	55,142	55,122	55,133	55,196	55,215	55,225	55,258	55,197	883,170
pat. value awarded ($mil.)	1,188	1,367	1,557	12,482	929	2,988	8,026	6,075	5,970	2,068	1,283	45,498
pat. num. received	18,932	27,633	36,100	298,409	9,709	22,987	184,971	119,074	68,240	33,171	46,369	883,170
pat. value received ($mil.)	975	1,424	1,860	15,373	500	1,184	9,529	6,134	3,516	1,709	2,389	45,498
patent trade surplus ($mil.)	-212	57	303	2,891	-429	-1,804	1,503	59	-2,455	-359	1,106	1,257 (std)
changes from simulation III	78	590	-1,433	-3,777	-42	643	1,908	1,666	183	-1,311	831	-830

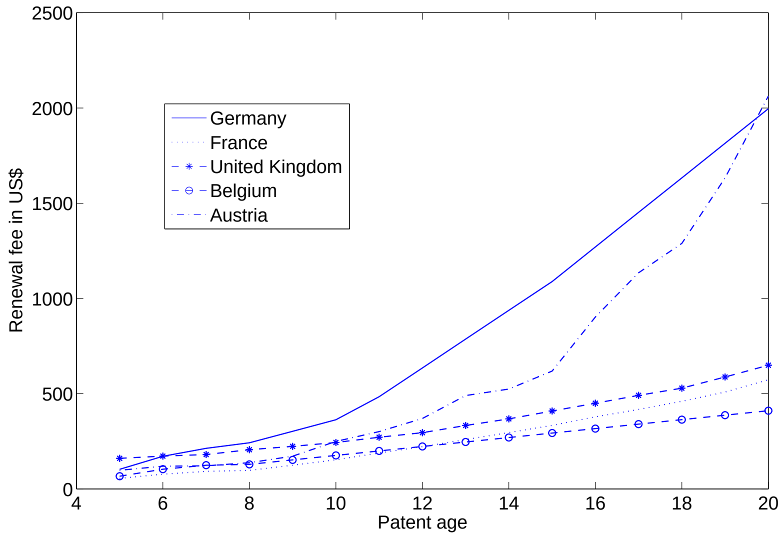
Table 6e: The Decomposition of Patent Trade Imbalance: Simulation V

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.	Italy	NL	Sweden	Total
Simulation IV: eliminating country difference in the R&D efficiency												
pat. num. awarded	55,204	55,200	55,270	55,142	55,122	55,133	55,196	55,215	55,225	55,258	55,197	883,170
pat. value awarded ($mil.)	1,188	1,367	1,557	12,482	929	2,988	8,026	6,075	5,970	2,068	1,283	45,498
pat. num. received	18,932	27,633	36,100	298,409	9,709	22,987	184,971	119,074	68,240	33,171	46,369	883,170
pat. value received ($mil.)	975	1,424	1,860	15,373	500	1,184	9,529	6,134	3,516	1,709	2,389	45,498
patent trade surplus ($mil.)	-212	57	303	2,891	-429	-1,804	1,503	59	-2,455	-359	1,106	1,257 (std)
Simulation V: eliminating country difference in the R&D intensity												
pat. num. awarded	54,441	54,437	54,507	54,380	54,360	54,372	54,433	54,453	54,462	54,495	54,435	870,968
pat. value awarded ($mil.)	1,164	1,348	1,536	12,309	916	2,947	7,915	5,991	5,888	2,039	1,265	44,870
pat. num. received	22,655	26,623	29,533	238,581	17,510	56,524	153,965	115,692	116,953	38,527	24,045	870,968
pat. value received ($mil.)	1,167	1,372	1,521	12,291	902	2,912	7,932	5,960	6,025	1,985	1,239	44,870
patent trade surplus ($mil.)	3	23	-14	-18	-14	-35	17	-31	137	-54	-26	42 (std)
changes from simulation IV	215	-33	-317	-2,910	415	1,769	-1,486	-90	2,592	305	-1,132	-1,215

Table 7: Country Differences in R&D Intensity and R&D Efficiency

	Austria	Belgium	Switzerland	Germany	Denmark	Spain	France	U.K.	Italy	NL	Sweden	Total / avg
Avg. GDP (93-96, tril US$)	0.23	0.27	0.30	2.45	0.18	0.58	1.58	1.18	1.20	0.40	0.25	8.93
% of total	2.60	3.06	3.39	27.40	2.01	6.49	17.67	13.27	13.41	4.43	2.77	100
R&D expenditure ($million, 1993-1996)												
pharmaceutical	203	296	386	3,193	104	246	1,979	1,274	730	355	496	9,450
chemicals	1,333	1,946	2,542	21,012	684	1,619	13,024	8,384	4,805	2,336	3,265	62,186
electronics	1,986	2,898	3,787	31,300	1,018	2,411	19,402	12,490	7,158	3,479	4,864	92,636
mechanical	2,311	3,373	4,406	36,427	1,185	2,806	22,578	14,534	8,329	4,049	5,660	107,799
miscellaneous	1,035	1,511	1,974	16,316	531	1,257	10,114	6,511	3,731	1,814	2,535	48,288
all tech. fields	6,867	10,024	13,095	108,244	3,522	8,338	67,096	43,193	24,753	12,032	16,820	320,359
% of total	2.14	3.13	4.09	33.79	1.10	2.60	20.94	13.48	7.73	3.76	5.25	100
Number of inventios / $mil R&D												
pharmaceutical	0.30	0.25	0.85	0.44	0.67	0.30	0.51	0.53	0.40	0.64	0.26	0.47
chemicals	0.19	0.19	0.53	0.36	0.41	0.08	0.16	0.20	0.23	0.45	0.10	0.26
electronics	0.14	0.21	0.40	0.30	0.14	0.07	0.27	0.21	0.22	0.73	0.18	0.27
mechanical	0.40	0.15	0.56	0.45	0.30	0.15	0.26	0.20	0.35	0.33	0.20	0.32
miscellaneous	0.33	0.16	0.58	0.32	0.48	0.20	0.25	0.19	0.33	0.57	0.28	0.30
avereage	0.27	0.18	0.52	0.37	0.31	0.13	0.24	0.21	0.29	0.51	0.19	0.30

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.