International Patenting and the European Patent Office: A Quantitative Assessment

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Abstract

The European Patent Office (EPO) provides a simplified, and less costly, means of seeking patent protection in the majority of European countries. We discuss issues in measurement of patenting raised by the European Patent, and then survey patterns in patenting behavior in Europe over the last decade. Notable developments are that: (1) European Patent publications grew by 70 percent between 1991 and 2000; (2) this growth was not at the expense of patents sought directly through national patent offices, which were small in number relative to European Patents throughout the period; (3) the number of destinations designated for protection in a typical European Patent has grown substantially, to the point where most now designate all EPO members. A simple structural model of an inventor's patenting decision attributes 40 percent of the growth in European Patents and all of the growth in the extent of designation to the evolution of the fee structure for European Patents over the period.

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1 Introduction

Interest in international patent institutions has increased over the past decade . As national patent offices have struggled under the weight of increasing patent applications and cuts to their budgets, a number of observers have suggested the internationalization of the patent application and examination process as a solution.[1] By consolidating the filing, review, and issuance of patents into a truly international body, it is argued, many of the ills affecting today's national patent offices could be cured.

Despite the enthusiasm of pundits for international patent institutions, we know very little about how these organizations have worked in practice. The history of patent policy reform teaches us to be skeptical: Many well-intentioned and seemingly reasonable changes have had unintended consequences that have proven counter-productive. Jaffe and Lerner (2004) provide examples. These unexpected outcomes suggest the need for an examination of the historical record of international patent-granting bodies before embracing the proposed reforms.

The international patent body that has undoubtedly played the most substantive and sustained role to date is the European Patent Office (EPO).[2] The International Patent Institute, set up by a group of European countries in The Hague in 1947 as a common resource for patent searching and archiving, ushered in a more international approach to patents. Two years later, the Council of Europe advocated the creation of the European Patent Office. The European Patent Office (EPO), however, was not established until 1973 by the Convention on the Grant of European Patents. Despite what the name suggests, these are not European Union patents or even Europe-wide patents. The European Patent Convention, according to which the EPO was founded, provides a single patent grant procedure, but not yet a single patent. After grant, the European patent becomes a number ("bundle") of national patents.

[1] Example are Bonitatibus (2001), Desantes and Strobel (2002), Campbell (2003) and Barton (2003).

[2] The World Intellectual Property Organisation, which traces its origin back as far as the Paris Convention of 1883, allows applicants to file applications in multiple countries under the Patent Cooperation Treaty. It does not, however, undertake a full-fledged examination of these patents, but rather only a preliminary review. Schmoch (1998) provides a thorough discussion of its procedures, and how the relate to the European Patent.

In this analysis, we proceed in two parts. We first examine the patent data themselves. The first source of data is the World Intellectual Property Organization (WIPO), which records patent applications according to the national patent office in which they are taken out and the nationality of the inventor. These data do not indicate the extent to which patents sought in different national offices represent the same invention. The second source of data is the EPO, which records the patents it publishes and the EPO members the patent designates. The Organization for Economic Cooperation and Development (OECD) refines these data. Our own examination of these various sources suggested some anomalies in how they are reported, and we offer our own reconciliation of the EPO and WIPO data.

Having identified what the various data sources actually report, we then provide an overview of the basic patterns in the evolution of EPO and national patenting. Our analysis is guided by the "gravity" literature examining cross-national patterns in patenting. Slama (1981) is an early contribution. In particular we follow the analysis in Eaton and Kortum (1996) and Kortum and Lerner (1998) identifying "source" and "destination" effects. This allows us to assess the probability that residents in a given nation will develop innovations, and how this probability evolves over time, and the probability the residents of other nations will choose to file in a given country. We incorporate data as to whether filings were made directly in European national patent offices or through the EPO to understand the impact of the Office's formation.

We focus on the decade 1991-2000. At the beginning of the period the major members of the EPO were Austria, Belgium, Switzerland, Germany, Denmark, Spain, France, Great Britain, Greece, Italy, Luxembourg, Netherlands, and Sweden. Ireland and Portugal joined in 1992 and Finland in 1996. During the period the total number of national patents emerging from European Patents patents more than doubled, from just under 428,000 to over 1.3 million. Much of this increase represented an increase in the average family size, from about 7.3 to around 13.3. But a preponderance of the growth was the result of an increase in the number

of EPO patents, which grew by nearly 70 per cent (from just over 58,000 to just over 98,000).

We find that the European Patent has had a profound effect on how inventors sought protection among EPO members in three respects:

1. The European Patent has almost entirely replaced direct applications to national patent offices. For almost all EPO members in most years, patents that do not originate with the EPO constitute fewer than 10 percent of patent applications arriving at the national patent offices.

2. In contrast with the earlier "gravity" literature, which suggested that the proximity of the source and destination mattered a great deal to patent applications, we find that the pattern of countries designated for protection varied only slightly across sources. The role of geography is only apparent in a few cases.

3. By 2000 most European Patents designated all EPO members for protection. Hence by then inventors were exploiting the European Patent to protect their inventions across the Continent, more or less ignoring the national route. This universality contrasts significantly with the past. Putnam (1993) painstakingly constructs patent families from raw data on national patents for 1974, providing evidence on the extent to which inventors seek protection in multiple countries. Back then the mean family size was two, and 70 percent of patented inventions were patented in only one country.

Technometricians have used national patent applications (usually from the OECD and WIPO) as indicators of innovative activity. As just discussed, these numbers nearly doubled among EPO members during this decade. But by examining the family data shows that these numbers give an exaggerated picture of the increase in the number of inventions seeking patents, which nevertheless grew by a remarkable 70 percent.

An examination of the fee structure associated with the EPO suggests explanations for growth in both the level and breadth of patenting. The price of a European patent was about

US$1500 for the first six years of the decade, falling to around $1000 after 1997. The cost for each country designated for national protection fell more dramatically. It was a little over US$200 for the first six years, falling to under $100 in 1997. Moreover, after June 30, 1999, the EPO offered free designation in any EPO member after payment for seven. Hence the cost of patenting at all and patenting widely through the EPO fell dramatically.[3]

To what extent can we sort out the effects of lower fees from an increase in inventive activity in explaining the growth in patenting? We examine these patterns more systematically through a simple structural model in which the decision of a resident in one country to patent in another is driven by a comparison of the cost of filing a patent application to the value of a patent there, which we treat as a random variable proportional to the destination country's gross domestic product (GDP). We allow the random component in the value of an invention to have a component that is common across destinations and a component that is specific to each destination. Inventors may choose to file in each destination through the national patent office or apply to a portfolio of EPO members through a European patent. An invention may turn out not to be worth patenting anywhere, in which case no protection is sought.

We estimate the parameters of the model to match (1) patterns of designation within European patents, (2) patents taken out directly in EPO member national patent offices, and (3) the distribution of family sizes of EPO patents, all for 1995. We then see how well we can explain developments throughout the decade.

We find that we can explain the increase in the breadth of patenting among EPO members totally in terms of the declining cost of designating additional members, in particular the bulk discount offered after 1999. Moreover, the decline in the overall cost of seeking protection through the European patent can explain nearly 40 percent of the 70 percent increase in the number of EPO patents. If an increase in inventive output is treated as the residual

[3] In contrast, estimates of the cost of filing nationally are around $1000. See Helfgott (1993). Hence once protection is sought in more than one or two EPO members, the EPO offers a better deal than direct application to national patent offices.

explanation, we are down to a still impressive (but much more plausible) 30 percent increase over the period.

This paper is related to a variety of other work on the operation of the global patent system. In particular, a number of other papers have looked at institutional changes and their impact on the propensity to patent (and, in some cases, to invent). Kortum and Lerner (1998) undertake a variety of statistical decompositions and model-fitting exercises to explore the impact of the establishment of the Court of Appeals for the Federal Circuit on the number of filings in the United States. McCalman (2001) seeks to quantify the impact of international patent harmonization as implied by the TRIPs agreement in the 1993 General Agreement of Tariffs and Trade through the estimation of a simulation model. Lerner (2002) explores the overall response of patenting by domestic and foreign entities to patent policy changes over the past 150 years, looking both at applications filed in the nation undertaking the policy change and in a nation with a relatively constant patent policy, Great Britain. Eaton and Kortum (1999), and Eaton, Gutierrez, and Kortum (1998) model the effect of tighter, and more geographically extensive, patent protection on innovative activity and growth.

More generally, this work is related to the literature on patent statistics as indicators of scientific progress and technological innovations. Griliches (1990) provides an insightful, and rather cautionary, survey of the literature, which includes such classic contributions as Schmookler's *Invention and Economic Growth* (1966), Scherer (1965), and, of course, the many contributions of Griliches himself and his students, notably various papers in Griliches (1984), Schankerman and Pakes (1986), Griliches, Pakes, and Hall (1987) and Griliches (1989). This literature has long been aware of the impact of the changing institutions on patent awards, and the distortions that such events can introduce into seemingly straightforward analyses. For instance, when discussing the seeming slow-down in patenting during the 1970s in his 1991 review article, Griliches urged researchers to be cautious about the possibility of "a statistical mirage, caused by a bureaucratic rather than an economic or technological cycle."

The organization of this paper is as follows. The next section describes the sources of data. Section 3 discusses specific issues in reconciling WIPO and EPO patent data. Having sorted out these issues as satisfactorily as we can, Section 4 provides a presentation of some basic features of these data. Section 5 presents our model of the decision to patent among EPO members, our estimation results, and what they imply.

2 Patent Families in the EPO Publications Data

Standard sources of data on patent applications and grants across countries (e.g., WIPO or the OECD) report total the total number of applications in different destination countries by the country of origin of the inventor. These patent statistics have served, among other things, as indicators of the intensity of inventive activity in source countries and the diffusion of ideas across borders.

Since inventors often seek protection in multiple destinations, these data do not provide unambiguous insight into inventors' decisions about the range of countries in which to seek protection. An increase in the number of patent applications worldwide, for example, could reflect either more ideas being patented or else the same number of ideas being patented more widely. Data on the portfolio of destinations in which single inventions are patented would further illuminate such issues.

The European Patent allows an inventor to apply for protection in any members of the EPO with a single application. The inventor must pay a fee for the European Patent itself with an additional fee for each country designated for protection. The cost of designating a country for protection in a European Patent is typically lower than the cost of applying for a patent directly through the individual national patent offices. Hence the European patent provides an attractive instrument for inventors seeking protection in several destinations among members of the EPO. Since the European Patent itself is relatively expensive, however, inventors seeking protection in only one member are likely to seek protection directly through the relevant

national patent office.

Since the data on individual patents published by the EPO report the member countries designated for patent protection, they provide one window on the range of destinations in where inventors seek protection. These data record, for example, how many applicants from France choose to protect their invention in Germany and Belgium and in no other EPO countries. Combined with data on the fee structure for EPO patenting, we can use these data to estimate a model of how application decisions react to changes in the fee structure. Since patenting through the EPO has become so popular, understanding the designation decisions of EPO applicants (and how it reacts to changes in the fee structure) is crucial for understanding the overall trends in international patenting.

Since inventors continue to exercise the option of seeking patent protection directly through national patent offices, in modeling the EPO patenting decision we want simultaneously to consider the applicant's decision to use the EPO at all. We expect a selection issue to arise, since the decision to use the EPO process will be correlated with the desire for patent protection in a large set of countries (for which the EPO provides a relatively low cost process).

This modeling procedure requires data on the family of destinations reported in EPO patents and on national patents applied for directly through the national patent offices of EPO members. Before turning to an analysis of these data we must first confront serious measurement issues in how these data are reported.

3 Reconciling EPO Publications with OECD Patent Application Data

To construct complete accounts of patent applications in EPO countries we merged the applications data from OECD (by destination country, country of applicant, and year of application) with the EPO publications data aggregated (from the level of individual EPO publications) by designated country, country of applicant and year of application. Each EPO publication with

designation in France and Belgium and no where else, for example, counts as 1 patent application in France and one patent application in Belgium. Our plan was to take the difference between the OECD applications data and our aggregate EPO publications data to obtain an estimate of the number of patent applications (by destination country, country of applicant, and year of application) that did not use the EPO.

Pursuing this procedure yields a measure of national patents which implied that, very frequently, the majority of patent applications did not go through the EPO. Moreover, the measure indicates explosive growth in the number of non-EPO patents to EPO destinations. Pursuing this measure we turned to the annual WIPO Industrial Property Statistics (Table II A: "Patent application filed by non-residents broken down according to the country of residence of the applicant") which are the basis for the OECD numbers.

Conceptually, since 1985 applications for patent protection in an EPO-member country can follow any one of four mutually exclusive routes: (1) applications to the national office directly, (2) applications via the Patent Cooperation Treaty (PCT), (3) applications via the EPO, and (4) applications via the EPO via the PCT. WIPO presents (in bold face) the sum of these four numbers.

In each year, starting in 1985, WIPO presents up to four separate numbers for each EPO-member country as a destination (what WIPO refers to as the "reporting country or organization"). WIPO describes these four measures as follows:

1. (N): "patent applications filed directly with the office concerned."

2. (P): "designations in international applications filed under the Patent Cooperation Treaty (PCT)" (not reported for some EPO members).

3. (RE): "designations in European patent applications filed under the European Patent Convention."

4. (RPE): "designations in applications filed under the PCT with a view to obtaining a European patent."

It might first seem that these four categories in the WIPO data correspond to the four mutually exclusive routes to apply for a patent. Indeed, WIPO reports the sum of these four numbers in boldface. The OECD data on patent application, however, report applications by foreign residents as the sum of only (N), (RE), and (RPE). (When the country of applicant is the same as the destination country the OECD makes additional adjustments.) The OECD procedure suggests that the (P) applications are contained within the (RPE) applications. Further evidence for this conjecture is that the WIPO itself reports that currently over 95% of PCT applications designate the EPO each year (while treating the (P) applications as distinct from the (RPE) would imply a much smaller percentage).

Our concern is that the OECD has not gone far enough in correcting the WIPO figures in arriving at a measure of total applications. Virtually the same number appears for the (RPE) category appears across EPO destinations for any given year. To give one example, WIPO reports 1993 (RPE) applications by US applicants as 12223 in Austria, 12235 in Belgium, 12225 in Denmark, 12271 in France, and 12280 in Germany. But the EPO data report that in 1993 only about half of the published EPO patents designate Denmark or Belgium while about 90 percent designated Germany and France. The EPO figures are inconsistent with the WIPO ones reporting that the number of (RPE) patents was virtually the same across these destinations. We suspect that the WIPO designates an (RPE) application as an application to all EPO members regardless of whether or not the individual member was a designated country in the application.

Table 1 illustrates the problem. It reports patent data on applications from Germany and Japan to Belgium, Germany, Denmark, and to the as a whole EPO for the year 1996: . It reports, first, the number of EPO patent applications designating the destination as reported

by the EPO, followed by the OECD figure on total applications. It then reports the four types of applications reported by WIPO.[4]

Note first that the OECD figure corresponds to the sum of WIPO (N), WIPO (RE), and WIPO (RPE). WIPO (P) is not included.

Note next that the number of WIPO (RPE) patent applications for each of the three sources is virtually the same across EPO destinations. The number of WIPO (RE) patents varies much more, but not enough to explain the much greater variation in the EPO figures. Note, finally, that when Japan and the U.S. are sources, the sum of WIPO (RE) and WIPO (RPE) corresponds quite closely with the EPO figure. The discrepancy between the EPO and WIPO figures for overall EPO patenting can be explained by the distinction between patent applications (WIPO) and patent publications (EPO). Given that application precedes publication and the growth in applications during the period, and since applications are occasionally withdrawn before publication, We would expect the WIPO figure to exceed the EPO one. Our explanation for the discrepancy at the level of national destinations is that WIPO is attributing EPO applications as destined for nearly all EPO members when in fact only a much smaller subset of destinations were designated.

Data from other years tell the same story, although by 2000 the problem is largely over as by then the EPO reports that most EPO patent publications typically designated nearly all members (a phenomenon which our analysis below seeks to explain).

We deal with this measurement issue by calculating total EPO-member applications as the sum of (N) applications from WIPO to the aggregates constructed from EPO publications. Since there are relatively few (N) applications even as far back as 1986, the overall trends in our totals will largely appear just slightly higher than those we construct from the EPO publications data. For example, from US applicants in 1986 there were only 156 (N) applications

[4]The EPO publications data occasionally report patents sought by inventors from different countries. We divide these patent publications across the different sources. Hence the potential for noninteger values in the EPO column.

in Austria, 329 in Belgium, and 2,034 in Germany (representing, at most, 20% of applications from the US in those countries).

4 An Overview of the Data

The cross-country patent data have many dimensions to them: most importantly source, destination, and time. A patent can represent the idea of inventors from several countries who can take apply for protection in any number of countries, either directly as designated members of the EPO. As just discussed, even by 1985 the European patent was by far the most popular means of seeking protection among the EPO members. It grew in popularity to the extent that by 2000 the fraction of patents sought directly through the national patent offices rarely constituted more than 2 per cent of the total. Notable exceptions are patents applied for in Germany and in Great Britain. Only 61 percent of Austrian patents and only 77 percent of Swiss patents to Germany are through the EPO. The shares for Japanese and U.S. inventions are .83 and .94, respectively. In the case of Great Britain, Australia, Belgium, Canada, Denmark, Finland, Ireland, New Zealand, and the United States take out more than 10 per cent of their patents directly through the national patent office. (Since there are no data on the families of patents that do not go through the EPO, we do not know the extent to which inventors seeking protection through the German and U.K. patent office were applying for patents in other countries inside or outside the EPO membership.)

Since the EPO patents tell most of the story, and are from a single consistent source, we direct most of our subsequent analysis toward the European Patents. We first look at trends in who uses the EPO, and then look at the patterns of designated countries in EPO patent publications. We then look at the interaction of source and destination, and the size of families.

4.1 Sources of European Patents

Figure 1 depicts the evolution of European Patents during 1991-2000 according to the nationality of the inventor.[5] Over the decade the total number of patents grew from 58,210 to 98,505. U.S. inventors were the most frequent users of the patent, accounting for around 30 per cent of the total throughout the period. The Japanese share fell from 21.9 to 17.6 percent while Germany replaced Japan as the second-most frequent user, with its share rising 17.8 to 20.8 per cent. France and Great Britain follow with initial shares of 8.8 and 5.4 percent, respectively, falling by about a point over the decade. During the period the Finnish and Swedish shares grew from .7 to 1.15 and from 1.6 to 2.5 percent respectively. Overall, however, the picture is one of relative stability in terms of which countries' inventors were making use of the European Patent. Notably nearly half of the total EPO publications were from inventors in countries which were not members, most of them from the United States and Japan.

4.2 Destinations Designated in European Patents

Figure 2 depicts the evolution of European Patents during the same decade according to EPO members designated for patent applications. (The total number is the same as in Figure 1.) Throughout the decade around 95 percent of the European patents designated Germany, the most popular destination. France and Britain follow closely at around 90 percent, rising to 95 percent in the last two years. In the first half of the decade other EPO members trailed significantly. Italy, the fourth most popular destination, was designated in 73 percent of applications in 1990, a share which remained stable until the last two years, when its frequency jumped to 87 percent. Switzerland and Sweden were designated in just under half the patents, again until the last two years when they started to be named in nearly 80 percent. For the smallest members the designation was around 25 percent for most of the decade.

[5] As mentioned, a patent may list inventors from multiple countries. In these cases we have simply alloted a *pro rata* share of the invention to the source country according to the fraction of total inventors listed from that country.

A remarkable development is the movement toward universality of designation in the last two years of the decade. By 2000 even the smallest EPO members were designated in nearly 80 percent of European Patents. An obvious explanation is the substantial drop in the size of the fee per designee that occurred in 1999.

4.3 Source-Destination Interaction

To what extent do source countries differ in their designation of destination countries? As mentioned, by 2000 inventors were designating most EPO members irrespective of where they were from, while during 1991-1998 larger destinations were designated much more often.

An examination of designated states by source during the period reveals a couple of patterns. Most strikingly, Japanese inventors tended to omit smaller EPO members much more than average. A number of smaller countries (New Zealand, Denmark, and Ireland, for example) tended to designate smaller members, including those other than themselves, somewhat more than average. Patterns across the other countries (e.g., Australia, Canada, France, Germany, Great Britain, the Netherlands, and the United States) conformed quite closely to the overall average. To illustrate these three sorts of patterns Figures 3a, 3b, and 3c depict the 1995 designations in European Patents from Japan, Ireland, and the United States. There is also some evidence of geography playing a role. Inventors are more likely to designate countries nearby (e.g., Great Britain in Denmark, France in Switzerland, etc.)

In summary, however, we find differences in designation propensities across sources sufficiently slight and idiosyncratic not to warrant systematic investigation at this point (although Japan's very low propensity to designate in the earlier part of the decade puzzles us). The real story in these data over the period is the general movement toward universality in designating EPO members. For this reason we ignore differences across sources in designation propensities in what follows.

Indeed, that designation propensities differ so little by source, especially in view of the

strong geographic patterns found in earlier work, and that designation is becoming so universal, suggests that the European Patent has been highly successful in enhancing inventors' ability to seek protection in a wide range of markets. One explanation is that the EPO, by unifying the process of applying for a patent across the Continent, has made it as simple to apply far away as nearby. Another is that European unification has made technology much more mobile across the Continent.

To the technometrician, however, this enhanced ability comes at a cost. By lowering the bar to patenting in a large number of countries, the European Patent removes the need for inventors to spend much time thinking about where their inventions will ultimately prove useful. Hence where they apply for patents reveals less about the flow of ideas across borders.

5 A Simple Structural Model of Patenting Choice

As discussed above, the 1990's saw major growth in the amount of patenting taking place among EPO members. As discussed above, the EPO publications data reveal that about 30 percent of this increase reflects growth in the size of patent families. But that leaves a 70 percent increase in the number of inventions seeking patents. The lowering of the fees both for taking out an European patent and for designating an EPO member for protection may explain some of the increase both in the number of EPO patents and in the number of countries designated per patent. But how much?

To get a handle on the answer we model the applicant's decision about how and where among EPO members to obtain patent protection for an invention. We then estimate this model using a cross-section of data on EPO and national patenting for 1995. We then see what the model predicts for the other years of the decade, and how much of the increase in patenting it attributes to the lowering of fees.

The applicant faces a trade-off between the value of obtaining patent protection in a destination and the cost of applying for a patent there. The European Patent complicates the

picture since, by paying the fixed for the European patent, the inventor can apply for protection in any EPO member at a much lower cost than if she applied directly through the national patent office.

Since we are only modeling the application stage, our specification of the value of patent protection implicitly builds in the expectation of future choices made by the applicant, and any additional fees resulting from these choices, such as shepherding the application through to a patent award and renewing the patent as desired.[6]

The value of obtaining patent protection in a country arises most directly from the reduced threat of imitation that a patent provides. One aspect of this value relates to the size of the economy in that country. We treat the value of fending off an imitator in a market as proportional to the size of the market at stake. Another aspect of this value has to do with the value of stopping imitators from producing in country n, which is linked to size of the market elsewhere.

We reduce all these complications into a simple specification in which the value of patent protection in country n for invention j depends on the size of n's market Y_n, on the size of the world market $\overline{Y}$, and on the quality of invention j as it applies to country n:

$$V_{nt}(j) = a(Y_{nt} + b\overline{Y}_t)\eta_n(j),$$

where a and b are parameters. The term $\eta_n(j)$, representing the quality of invention j as it applies to n, has two components

$$\eta_n(j) = \exp(u(j) + u_n(j)),$$

where $u(j)$ and $u_n(j)$ are the realizations of independent normal random variables with means zero and variances σ_1^2 and σ_2^2, respectively. The $u(j)$ term relates to the value of invention j wherever it is patented while $u_n(j)$ relates to the value of invention j specific to destination n.

[6] In particular, our model does not include the payment of renewal fees as part of the cost of patenting.

(It is important to remember that $V_{nt}(j)$ is not the value of the invention j in market n itself, but just the incremental value of having it protected by a patent there.)

It costs c_t^E to apply for a European Patent in year t,and, having paid this cost, an additional cost c_t^D for each country designated by the European Patent. For an inventor to apply directly for a patent in country n through the national patent office costs c_{nt}^N at time t.

We simulate an invention as a particular draw of a $u(j)$ and a $u_n(j)$. We simulate 100,000 inventions by drawing $(N+1)*100,000$ standard normal random variables, weighting the first by σ_1 and the last N by σ_2, to create our $\eta_n(j)$. We combine these with annual GDP, Y_{nt}, and the parameters a and b to calculate $V_{nt}(j)$.

We then calculate the value of (i) optimally patenting in each national destination directly, $V_{nt}^N(j) = \max[V_{nt}(j) - c_{nt}^N, 0]$, and (ii) applying for a European Patent:

$$V_t^E = \sum_n \max[V_{nt}(j) - c_{nt}^D, 0] - c_t^E.$$

We assume that whenever $V_t^E \geq 0$ and $V_t^E \geq \sum_{n \in EPO} V_{nit}^N(j)$ then an EP is applied for, designating each country for which $V_{nit}(j) \geq c_t^E$. In this case no national patents are sought among EPO members. A national patent is applied for whenever $V_{nit}^N \geq 0$ and either (i) n is not an EPO member or (ii) n is a member but the conditions for an EP application failed to hold.

We use the actual patenting costs to obtain the c's, and data on GDP's for Y_{nt}, $.and$ sum them across n to get $\overline{Y}_t$. To deal with the countries that joined the EPO after our period of observation begins (Ireland, Portugal, and Finland) by setting their designation costs in the EP, c_{nt}^D, equal to a prohibitively high number during their years of nonmembership. We also take as data the GDP's of the EPO members during the period. (GDP measures are in billions of dollars.)

We estimate the four parameters of the model, a, b, σ_1, and σ_2 using simulated method of moments. We search for the parameter values that minimize the difference between patents

in our simulated data and patents in the actual data in terms of: (1) the fraction of EP's designating each country, (2) the number of national patents to each EPO member as a fraction of total EP's, and (3) the frequency of each family size, for 1995. Specifically, we minimize the sum of squared deviations for each set of figures, equally weighted, using the amoeba algorithm programmed on GAUSS, obtaining: $(a, b, \sigma_1, \sigma_2) = (123, .4, .396, 1.22)$. Given the GDP data, these parameter values imply patent values with means ranging from US$130 (Luxembourg) to US$2360 (Germany) in our simulated data.

Figures 4a, 4b, and 4c show our fit for each of the three criteria we try to match. Figure 4a shows that our model matches the patterns of designating destinations in EPO patent publications successfully. It also captures the essence of patterns in national patenting, although more roughly. It fails to capture the bimodal nature of the family size distribution, however.

How well does the model perform out of sample? By 1998 the costs of designating an EPO destination had fallen from over US$200 (during 1991-1996) to around US$85. As Figure 5 shows, the inventors in our simulations responded by designating more broadly than did actual inventors. By 2000, however, when the EPO was offering a bulk discount, designation was virtually universal, and our model predicts full universality. (Figures 6a and 6c).

In simulating patenting behavior in years outside 1995, we keep the draw of inventions at 100,000 and, of course, assume the same distribution of the random components of patent values. Hence values are only affected by shifts in GDP over time. We are holding inventive activity constant. Any changes in patenting activity in are model are thus due only to changes in GDP relative to patenting costs.

To what extent, then, can we explain developments in the level of EPO patenting only as a consequence of falling patenting costs and GDP shifts (which were modest over the period). Figure 7 compares actual patenting with what we simulate, normalizing our simulated patents to match the actual number in 1991. While are predictions are a bit choppier than the actual

data, we pick up the increase in 1996 quite well.[7] Moreover, our model can explain 39 per cent of the just under 70 percent increase in EPO patenting over the period. This explanation is purely on the basis of lower patent costs and GDP growth. If residual growth is to be explained on the basis of greater inventive activity, the annualized growth rate over the period is 2.71 percent.

6 Conclusion

This paper was motivated by a desire to understand the role of international institutions on the patent application and award process. Such institutions are increasingly held out as solutions to the problems facing the various national patent offices. But our understanding of their workings and their impact on innovation remains limited.

To address this issue, we have first sought to understand the flow of patent applications across nations. Such information is reported by, among other sources, the EPO, OECD, and WIPO. We discover that the data are frequently somewhat misleading, which reflects anomalies in how they are reported. We offer our own reconciliation of the patterns reported in the various statistical compilations.

We then focus on understanding the changing pattern of patent applications during the decade of the 1990s and the early twenty-first century. We first look at the simple patterns in the raw data. We then fit a more sophisticated model, which models the patenting decision in terms of the economic opportunity in each nation, the cost of the various routes to patent protection, and unobserved factors.

Several conclusions emerge:

- European patents became increasingly important over the course of the 1990s. Throughout the decade, only a modest fraction of applications arriving at the various European

[7] An obvious explanation for the greater smoothness in the data is that figures represent patent publications, which occur with a variable lag with respect to patent applications.

patent offices did not originate with the EPO. The effect was particularly pronounced in the smaller European nations.

- The rise of the European Patent coincided with a declining importance of geographic distance as a determinant of patent filings: few patterns today are readily apparent in the data.

- The fee structure of the EPO has had a profound affect on the distribution of patent applications across countries. Some forty percent of the 70% increase in European patenting between 1990 and 2000 can be attributed to the changing fee structure employed by the EPO. This analysis suggests the need to be cautious when employing patent applications as an indicator of innovation.

- Even after adjusting for the changing fee structure of the European patents, a substantial the boost in European patenting occurred over the 1990s. Our best estimate is that over the course of this decade, adjusted patenting in Europe increased by a more modest (but still impressive) 30%.

Clearly, this work is only a first look at an important question. Several extensions could give us a fuller understanding of these issues. Among these steps, which we hope to pursue in future research, are better modeling the economic opportunities associated with filing patent applications in each nation, incorporating the series of renewal fees that most nations charge patent awardees, and looking at other international patent institutions in addition to the EPO. Nonetheless, we believe that this paper is an important first step in exploring these increasingly important policy institutions.

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Patent Applications in EPO-Member Countries, 1996

Source Country	Destination Country	Source of the Data EPO	OECD	WIPO (N)	WIPO (P)	WIPO (RE)	WIPO (RPE)
Germany	Belgium	5581.431	9335	65	n/a	3816	5454
Germany	Germany	12131.25	42957	42322	746	8230	5459
Germany	Denmark	3525.632	7868	39	661	2374	5455
Germany	EPO	12830.25	n/a	n/a	n/a	n/a	n/a
Japan	Belgium	1606.167	3928	25	n/a	918	2985
Japan	Germany	11925.25	15515	2755	404	9470	3290
Japan	Denmark	1005.333	3449	10	192	485	2954
Japan	EPO	12196.25	n/a	n/a	n/a	9662	3303

Figure 1: EPO Patent Publications by Source

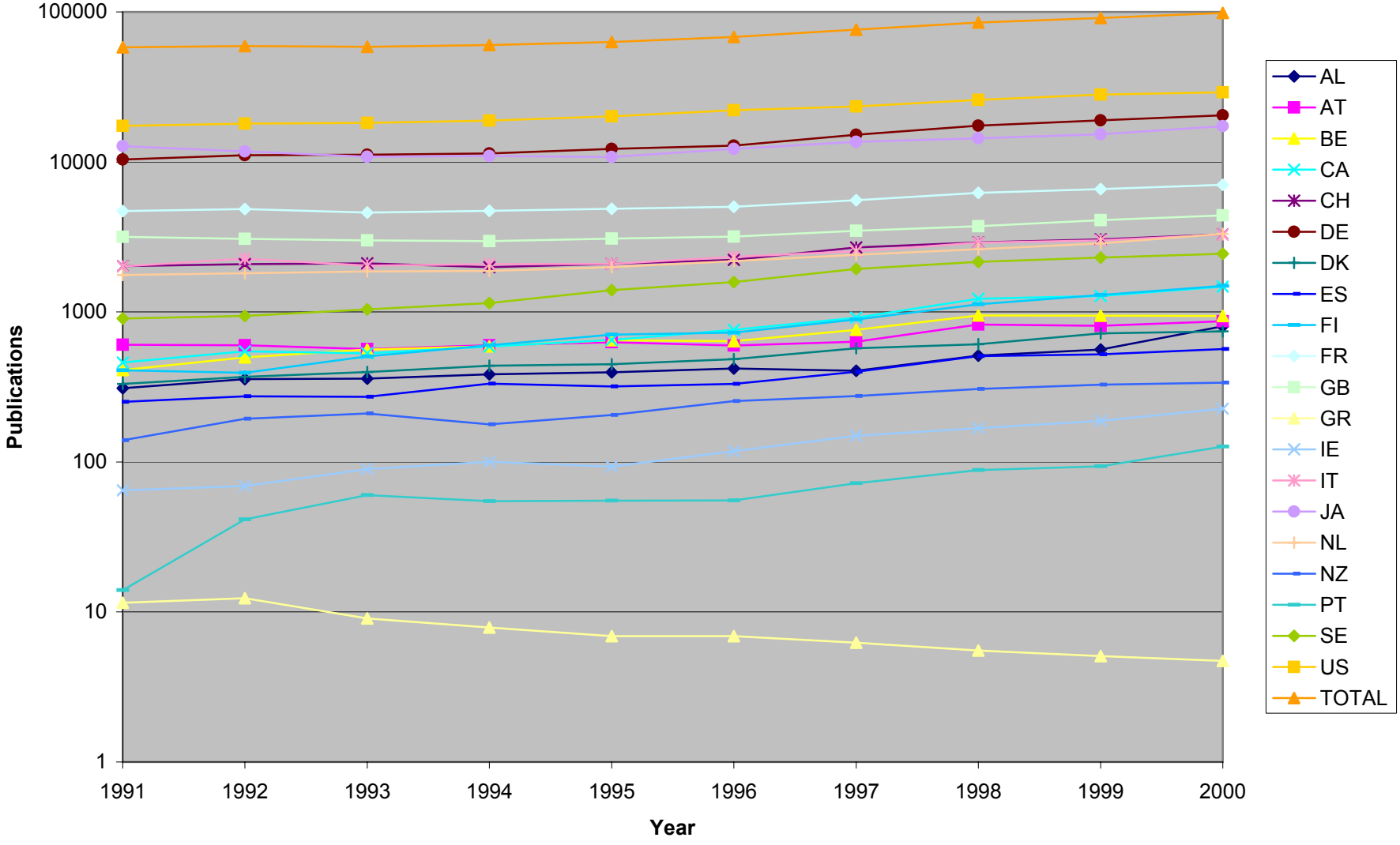

Figure 2: EPO Patent Publications by Destination

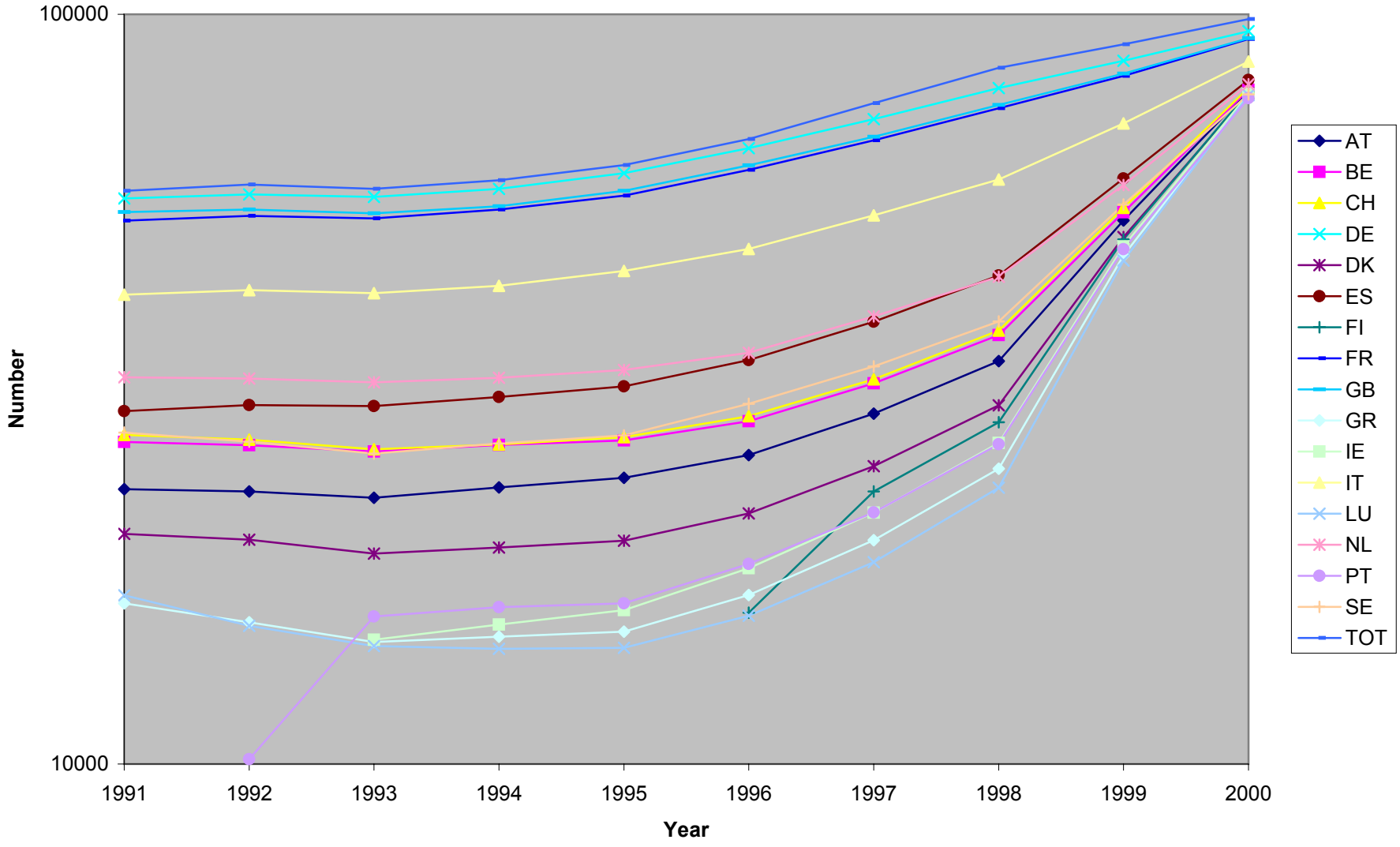

Figure 3a: Japan's 1995 Designees

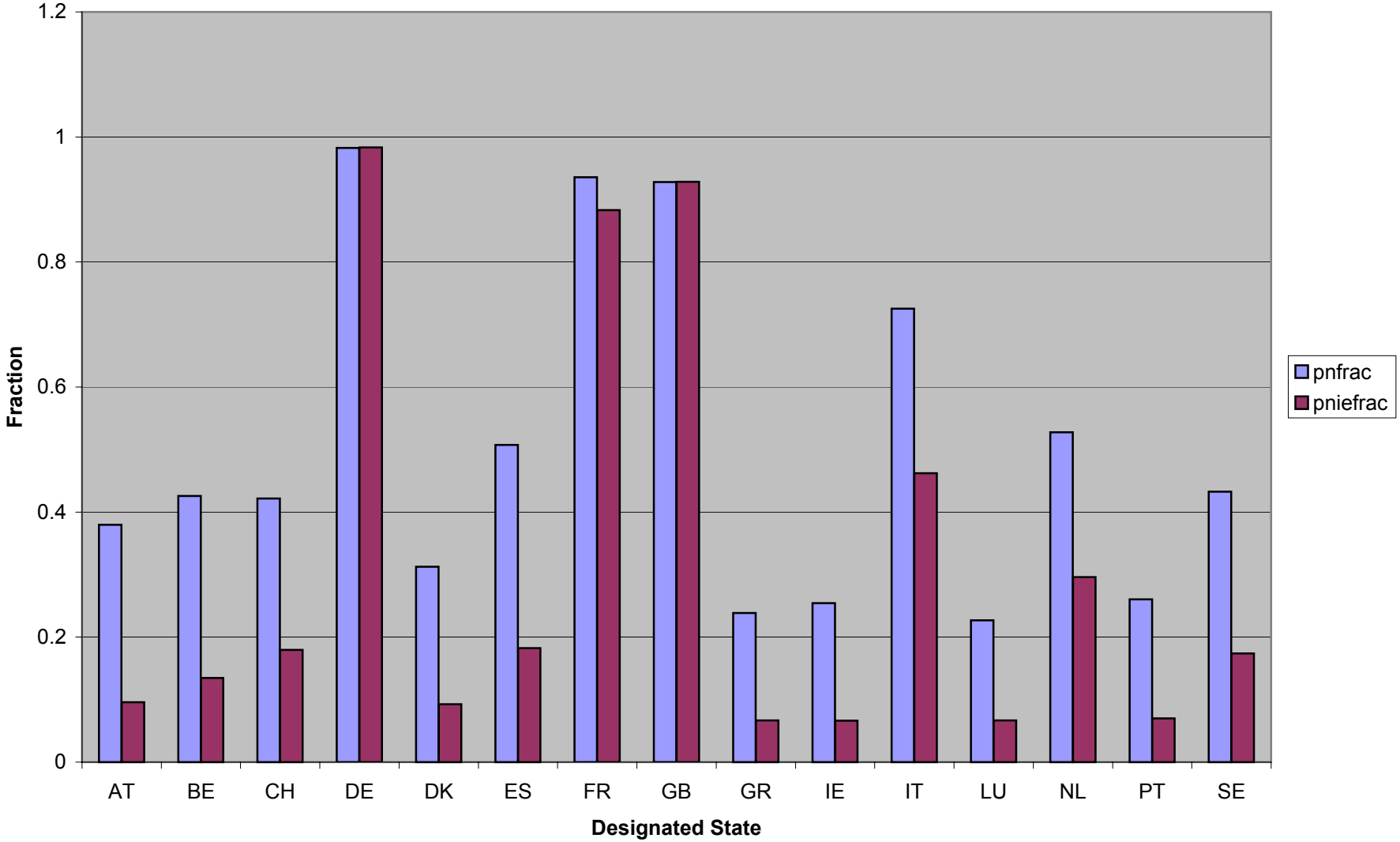

Figure 3b: Ireland's 1995 Designees

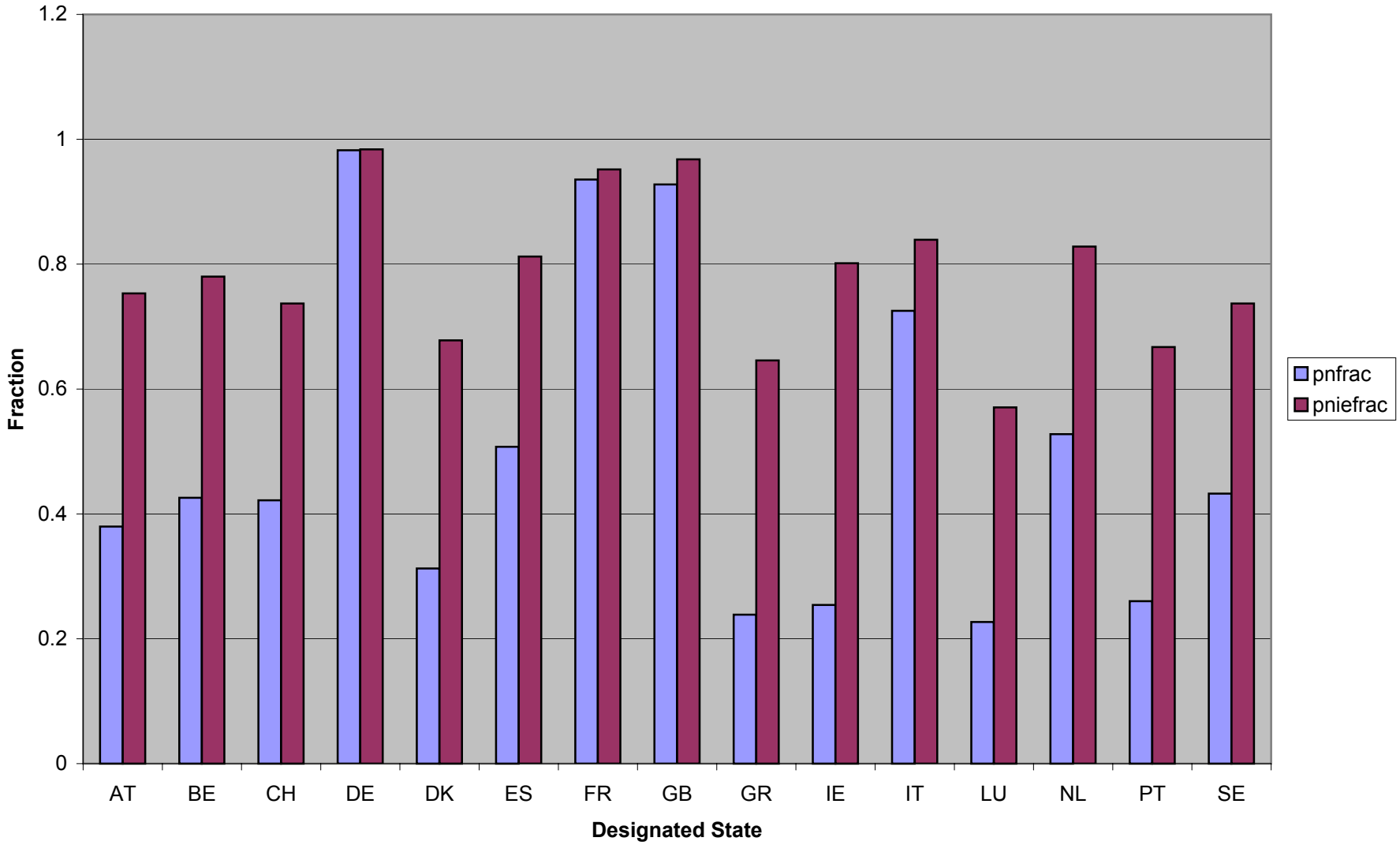

Figure 3c: USA's 1995 Designees

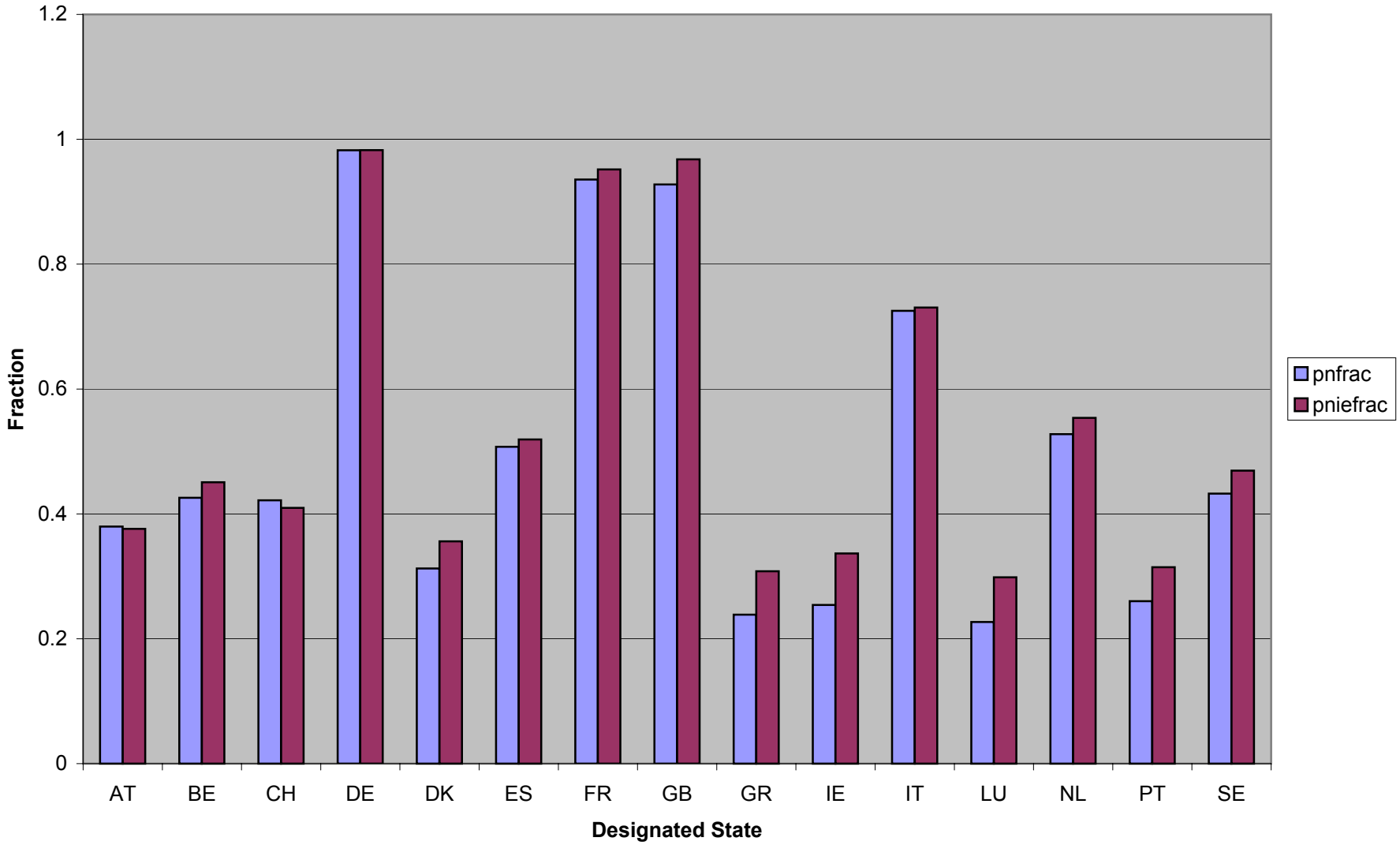

Figure 4a: EPO Designations in 1995: Model and Data

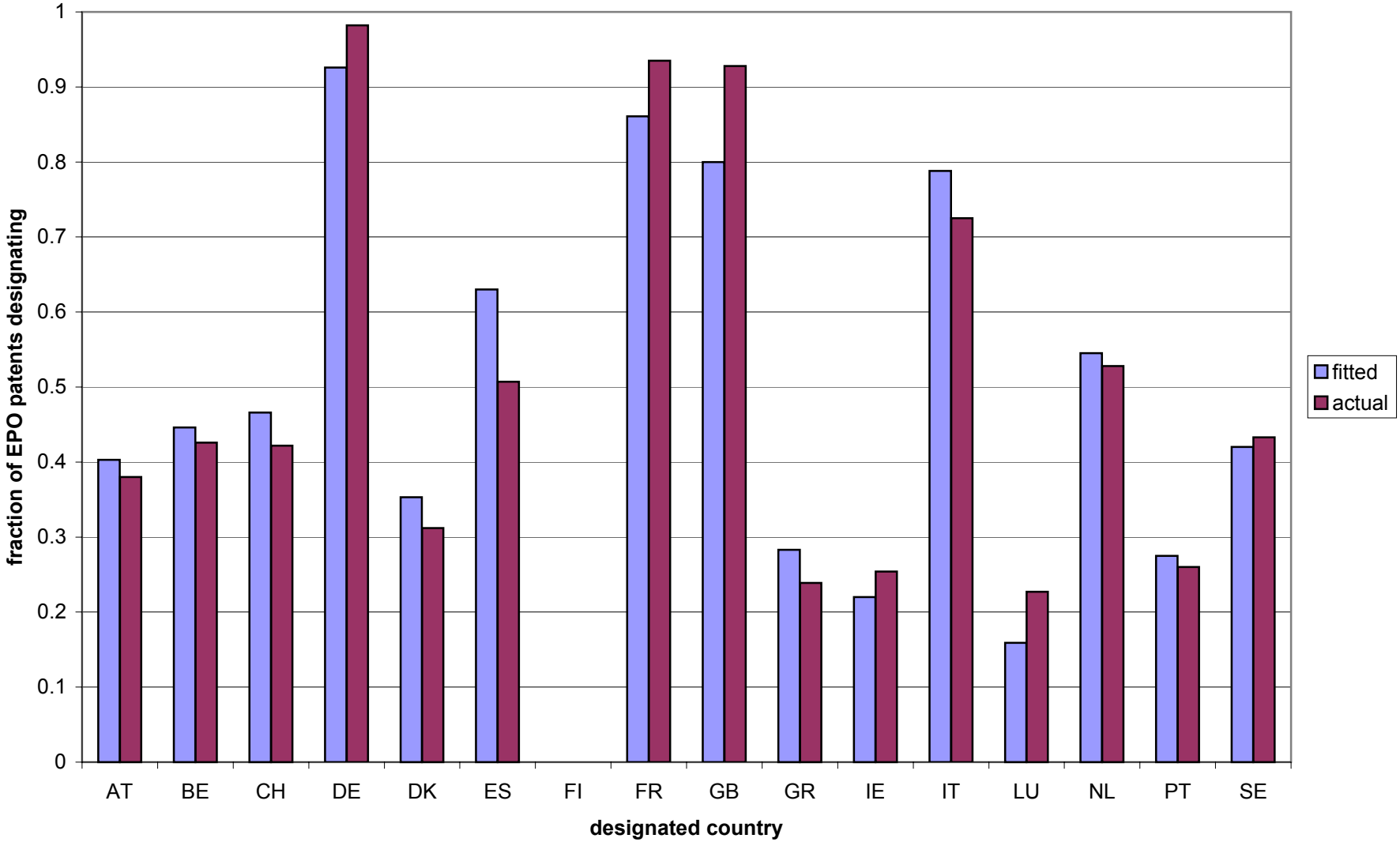

Figure 4b: Patent Applications to the National Offices in 1995: Model and Data

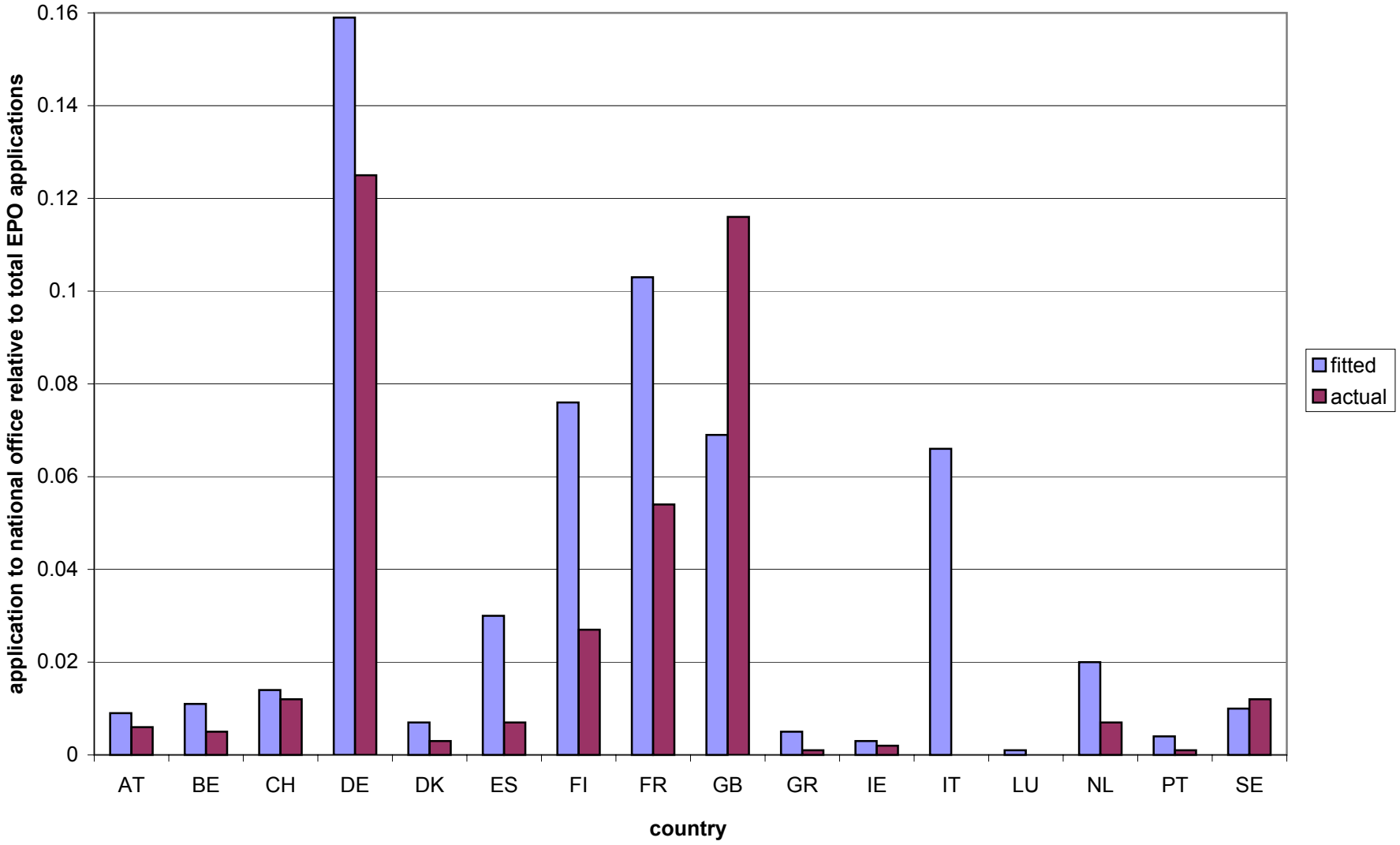

Figure 4c: EPO Family Size Distribution in 1995: Model and Data

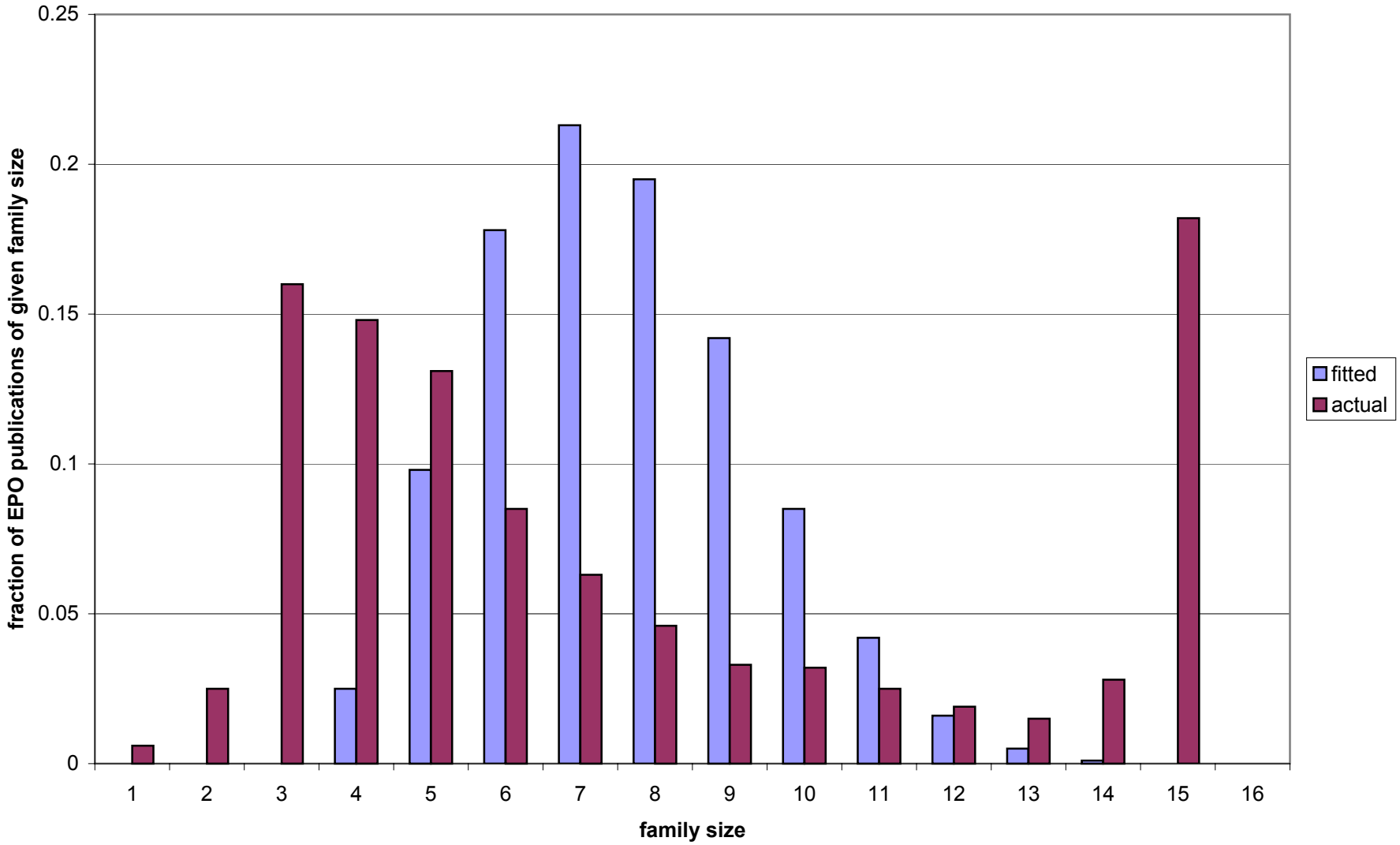

Figure 5: EPO designations in 1998: Model and Data

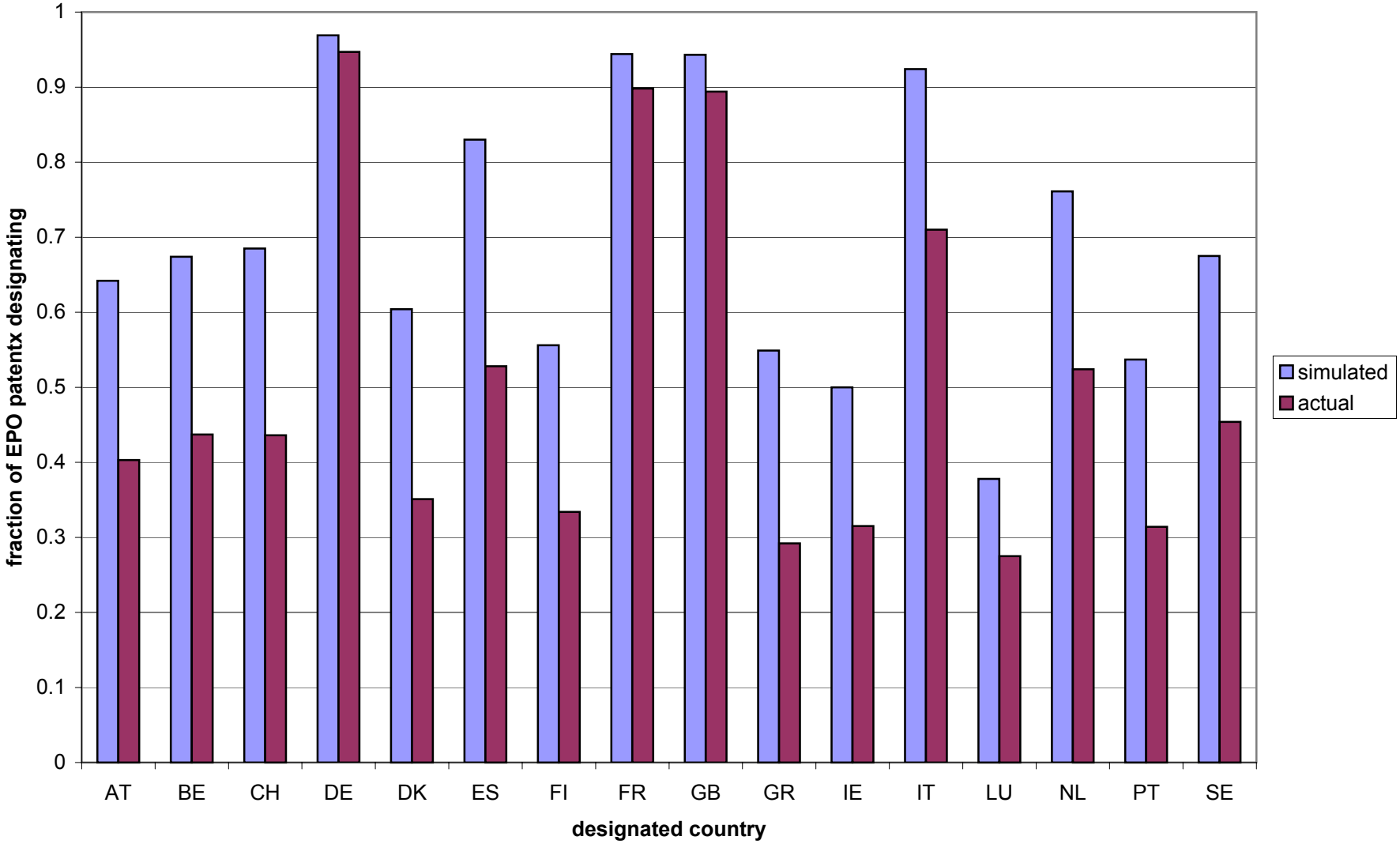

Figure 6a: EPO Designations in 2000: Model and Data

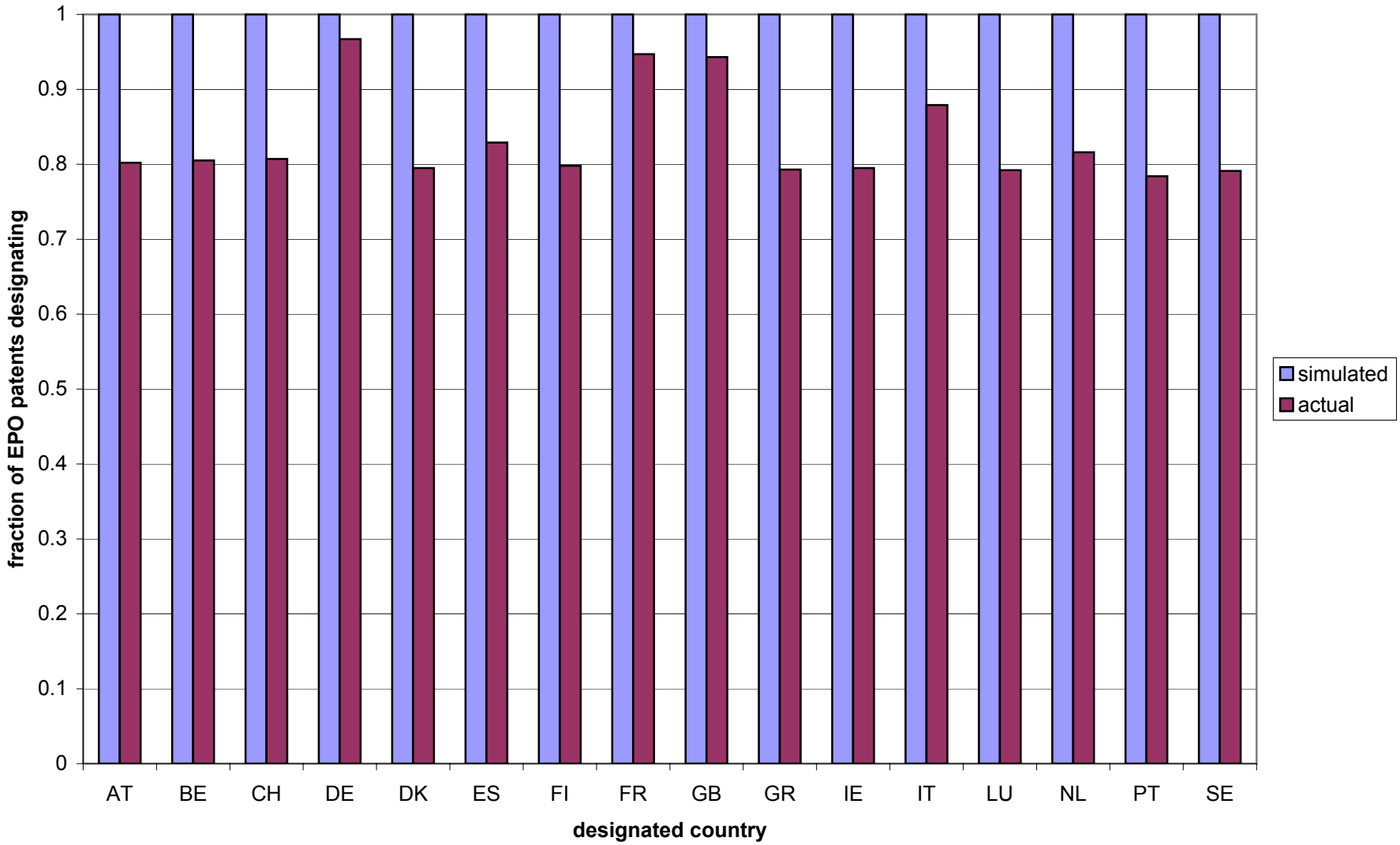

Figure 6a: EPO Designations in 2000: Model and Data

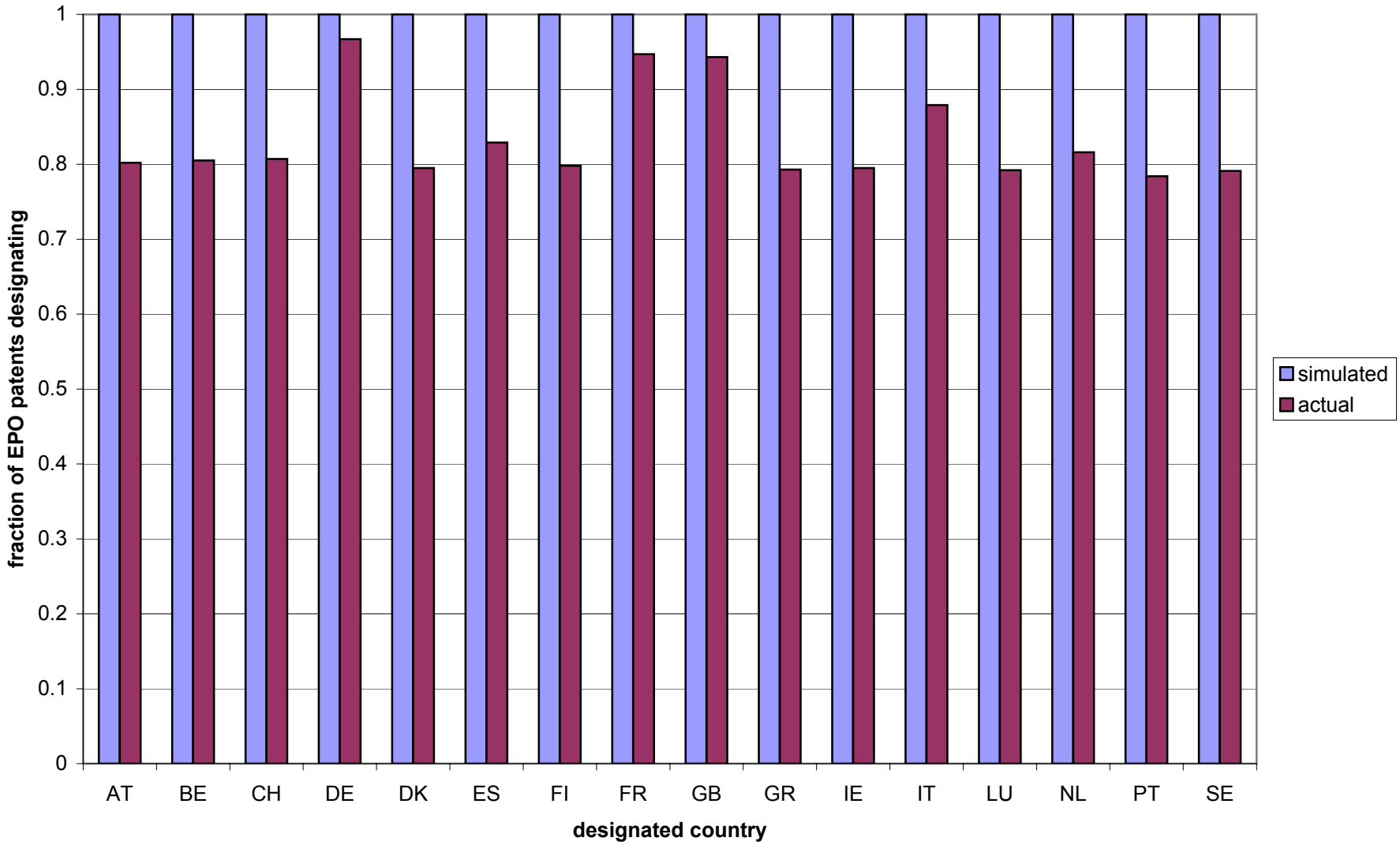

Figure 6c: EPO Family Size Distribution in 2000: Model and Data

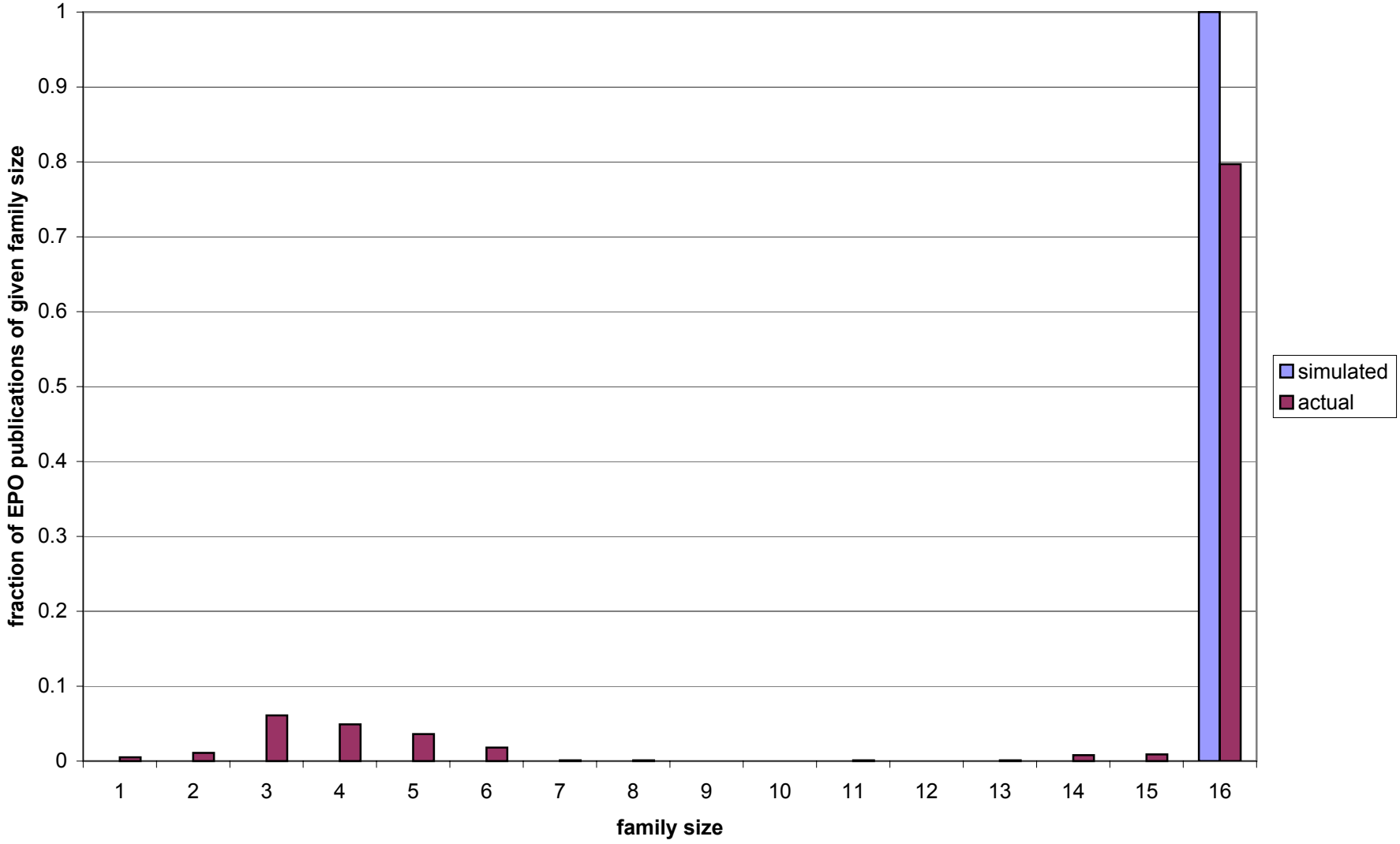

Figure 7: Estimated and Actual European Patents