Chapter 7

International patenting at the European Patent Office: aggregate, sectoral and family filings

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Modules: C, D
Software used: STATA

1 Introduction

This chapter provides a panel data perspective of patent filing behavior at the European Patent Office (EPO). The EPO filings of different source countries are observed and analysed over the period 1980–2000. Moreover, forecasting exercises are conducted for different aspects of patent filings at the EPO. In particular, the chapter examines the behavior of total EPO patents as well as patents disaggregated by mode of filing, technological sector, and selected patent families. Analysis of patenting behavior reveals the nature of the underlying demand for patents. Research and development (R&D) is an important influence on both the propensity to file patents and the potential pool of inventive output. In terms of forecasting performance, the analysis finds that a dynamic model augmented with R&D generally performs best (based on root mean squared proportion errors as measures of forecast accuracy). The study includes examples of some sample forecasts for individual source countries.

Nations trade and invest physical capital in each other's markets. Indeed, the international economy has become much more interdependent through these trade and investment linkages. Less well understood, however, is the increased interdependence due to the diffusion of technological ideas among nations. The international patent system and institutions governing intellectual property rights help support a formal marketplace for knowledge capital. Yet the volume, direction, and underlying determinants of international patent flows have not been the subject of much inquiry.

Thus far, few studies exist that seek to explain and forecast patent filings. In general, these studies treat the nation as the unit of analysis, and focus on whether the recent growth of patenting is primarily innovation-driven or due to the strengthening of patent laws. What has not been addressed is the global breadth of patenting activities. Moreover, due to their national perspectives, the existing literature pays scant attention to regional or multilateral patenting systems (among a bloc of nations), such as that of the EPO. Such systems are relevant to accounting for the world wide growth and spread of patenting.

Two factors motivate this study. First, the increasing prominence of regional and supranational offices, such as the EPO or WIPO, has fundamentally changed the way inventors obtain patent protection. This study focuses on analyzing the increased worldwide demand for EPO patents and uses the conceptual models of patenting behavior to assess their ability to explain and predict EPO patent filings. An improved understanding of EPO filing behavior is an important step towards characterizing the growth in world wide patenting.

A second motivation is that, for national and regional patent offices alike, the extent of patenting activity has implications for internal workload (processing applications, conducting searches and examinations, and so forth) and patent office revenues (which are determined, among other things, by the volume of filings and official fees). A better understanding of the underlying determinants of the demand for patents could better assist organizations like the EPO to price its services, project revenues, and make operational decisions. Improved projection of patenting demand could be useful in any work-sharing or revenue-sharing arrangements with national offices or with other supranational offices. For instance, WIPO administers the Patent Cooperation Treaty (PCT) which provides, for among other things, a system of international patent applications (WIPO 2006a). Thus trends in euro-direct filings versus euro-PCT-IP filings would be useful for coordination and workload planning between the EPO and WIPO.

This chapter is organized as follows: the next section provides a brief literature review. Section 3 discusses the empirical framework and methodology. Section 4 presents some forecasting exercises conducted with the basic patenting model. Three kinds of patent filings will be the subject of forecasts: firstly, aggregate patent filings at the EPO. The term *aggregate* here refers to the sum of filings across technological fields. Furthermore, the breakdown of these filings by mode of filing is considered; that is, whether the filing is euro-direct or euro-PCT-IP, and whether the filing is a first filing or a subsequent filing.

The second type of filings for which forecasting exercises will be conducted are sectoral filings. The term sector will refer to the field of technology (classified according to the EPO's joint cluster divisions). The third (and last) type of filings that will be forecast are patent family filings. The definition of a patent family that will be used has been introduced in Chap. 1, “a group of patent filings that claim the priority of a single filing, including the original priority forming filing itself and any subsequent filings made throughout the world” (EPO, JPO, USPTO 2005). First filings are priority forming applications that do not claim the priority of any previous filing, while subsequent filings constitute all other applications. The latter are usually made within one year of the first filings, because of the stipulations of the Paris Convention (WIPO 2006). A distinct set of priority forming filings is used to index the set of patent families. From the data set on international patent family filings, those families that contain a subsequent filing at the EPO (and/or other types of ‘Blocs’) can be selected. Finally, a concluding section will summarize the main results and discuss some extensions for further study.

Overall, this study finds that EPO patenting is significantly driven by R&D activities, and that forecast accuracy is generally improved through the use of R&D along with dynamic terms representing lagged patenting. Forecast performance does vary somewhat by technological field, by mode of filing, and by nature of patent family. The good forecasts can, in some cases, come within 90–95% of actual filings. The forecast accuracies are not too sensitive to the methods of estimation considered.

2 Literature review

Relative to the literature at large on the economics of the patent system, very little empirical work to date exists on the determinants of patenting, and none with a specific focus on regional patenting systems, such as that of the EPO. There are studies on the impacts of the patent system (on innovation, trade, productivity, and welfare), but not very much on what drives patenting behavior.

First, one set of studies is based on firm level surveys (interviewing managers as to why firms patent and as to how important patents and patent laws are to the firms); the second set is based on statistical data sources (conducting regression analyses on patent data in order to infer the factors that influence patenting).

As a prelude to the survey studies, the conventional wisdom had been that firms demand patent protection in order to safeguard their intangible assets, which are easy to copy and distribute at nearly zero marginal cost (without other producers needing to incur any of the ‘sunk’ development costs). Infringement and imitation work to dissipate the gains to firms and thereby (ex ante) reduce their incentives to innovate. Recent surveys have challenged head on whether patent protection is necessary to stimulate investment in invention and commercialization. The Levin et. al. (1987) survey of US firms' patenting behavior reports findings which have generated much controversy – namely that firms do not, in general, regard patent protection as very important to protecting their competitive advantage (and thus to appropriating the returns to their investments). The idea is that firms have various alternative means (other than patenting) for appropriating the rewards to their innovations; for example, trade secrecy, lead time, reputation, sales and service effort, and moving quickly down the learning curve. Patent protection ranked low among these alternative means of appropriation. The study therefore questions previous understanding of what motivates patenting.

The question then is, if a patent is not important as an instrument for appropriating the returns to innovation, why do firms patent (and patent a lot)? The survey by Cohen et. al. (1997) reports that firms have various reasons to patent – as a means to block rivals from patenting related inventions, as strategic bargaining chips (in cross-licensing agreements), as a means to measure internal performance (of the firms' scientists and engineers), and so forth. Thus these various other factors are what primarily determines (or motivates) patenting, rather than the protection of their R&D investment returns.

Some criticisms can be made of these survey analyses. Firstly, it would be useful to update the sectors under study to incorporate new industries which have emerged since the surveys were conducted. The biotechnology and software industries may, for example, provide interesting perspectives on the rationale for and importance of patenting. Secondly, the responses of firms (or their attitudes towards patents) may have been influenced by the patent regime in place. It would be useful to separate these two out. Thirdly, the responses of interviewees may not be fully comparable. One person's rating of 9 out of 10 may differ from another's. There is no anchor in the way that ratings are scaled. Thus it is difficult to tell whether the responses reflect differences in firm behavior or random errors. Finally, while the surveys are very time-consuming and commendable work, the information is based on US firms' experiences. A similar comprehensive study for Europe and Asia, and so forth, would shed more light on patenting behavior – such as why firms patent globally and if so, why they choose certain routes (e.g. EPO, PCT, etc.).

Among the statistical database studies, Schiffel and Kitti (1978) is one of the earliest works. This study was motivated by the fact that foreign patenting in the US, during the period 1963–73, grew at a faster pace than US patenting abroad. This seemed to have created concerns about the loss of US technological leadership, a conclusion which the authors challenged. The study finds that the rise in foreign filings in the US reflected increased world trading opportunities, and not a reduction in US inventiveness vis-à-vis foreigners.

Bosworth (1980) examines a larger sample of countries using cross-sectional data. Bosworth finds that certain patent law features do not explain US patenting abroad. This is at odds with the strong advocacy US firms have shown towards international intellectual property law reform. Later work (as described below), which improves upon the measurement of patent regimes, does show the importance of patent rights to international patenting behavior (including US patenting abroad). Bosworth (1984) repeats the analysis for patenting flows into and out of the UK, and finds qualitatively similar results.

Slama (1981) fits a gravity model to international patenting data (for 27 countries during the pre-EPO period, 1967–78). The dependent variable is cross-country patenting as a function of the GNPs and populations of the country of origin and destination, the geographic distance between (capital cities of) countries, and dummy variables for regional trade membership. A key finding is that regional trade areas create positive preference, in that members engage in more bilateral patenting than would otherwise be the case.

In contrast to the previous studies, Eaton and Kortum (1996) develop a decision-theoretic model of patenting. They use this model patenting behavior to explain some of the sources of differences in productivity across countries, namely to impediments in the diffusion of technology (measured via flows of international patent filings), which would otherwise enable countries to catch up technologically.

Park (2001) studies the extent to which international technology gaps, as measured by total factor productivities, can be explained by differences in patent protection levels and patenting across countries. The focus is on whether international patent reform helps narrow technology gaps. The study finds that patent reforms alone have modest impacts on narrowing technology gaps in the short run due to the fact that, in the short time horizon, patent reform largely stimulates the filings of patents of marginal value.

In other studies, the focus of attention is the trend in patenting itself. Kortum and Lerner (1999) observe an ‘explosion’ in US patenting (domestically and abroad) and examine several hypotheses that might explain that. The two critical competing hypotheses are the pro-patent hypothesis and the fertile technology hypothesis. According to the pro-patent (or friendly court) hypothesis, changes in the legal regime precipitated the increase in patenting (for example, via the establishment of a specialized appellate court called the Court of Appeals of the Federal Circuit, which appeared to render decisions favorable to patent holders, upholding patent validity decisions or reversing invalidity rulings). This increased the incentive to acquire patent rights. According to the fertile technology (or increased inventiveness) hypothesis, firms have become more productive and the management of R&D more efficient – hence the rise in patent applications. In a sense, the two hypotheses are not altogether separable. To the extent that strengthened patent rights stimulate R&D, the regime changes might have led as well to increased innovation potential. Secondly, increased R&D efficiency and innovation potential might have been the reason the courts ruled more favorably to patent rights holders; patents awarded to higher quality technologies would less likely be ruled as invalid. Thus, it is not clear that two distinct hypotheses are being examined.

A micro-level study by Hall and Ziedonis (2001) challenges the hypothesis that US firms patented more because they were more inventive. Using a sample of US semiconductor firms, the authors find that the motive for, or determinant of, patenting is strategic: to pre-empt "hold-ups" or blocking if rivals own key patents. The argument is that if a firm could own critical patents itself, it could better negotiate with others who have rights to technologies that the firm might need. The authors argue that recent legal changes put firms in a situation where they need to patent for this purpose. The legal changes broadened patent scope and facilitated entry by specialized firms. In an environment of cumulative innovation (such as in the semiconductor industry), the possibilities for patent hold-up are greater. Firms can not afford not to acquire patents while others are amassing vast patent portfolios. The filing of these vast patent portfolios may account for the explosion in patenting in recent years.

To summarize, the existing literature suggests a variety of motivations for patenting for addressing particular policy issues (such as the merits of patent reform). The research agenda has been focused on explaining and testing specific hypotheses about patenting behavior rather than on developing models that have predictive value; that is, models that can provide good forecasts of trends in patenting behavior. Ultimately, a useful test of models of patenting behavior is how well they predict real world patenting behavior. In general, models without a dynamic specification (or that do not yield lagged adjustments in patenting) fail to forecast well, which would cast doubt on whether the models fully capture the underlying processes driving patenting behavior.

3 Methodology and data sets

As emphasized in the introduction, good forecasts of patent filings (by technology and/or by mode of filing) are useful to the EPO for purposes of allocating internal resources. For the EPO's external relations with other patent offices, coordination of tasks is enhanced by good forecasts of the breadth of international patent filing activities (whether they involve two or more countries, or blocs of countries). Three types of forecasting exercises are conducted:

- Overall patent filings in the EPO, broken down by modes of filing; in particular, applicants can file patents directly at the EPO or indirectly via the PCT. Furthermore, these filings may be 'first filings' or 'subsequent filings'.
- Patent filings broken down by technological field. The technological classification adopted here is that of the EPO joint cluster (JC) system, which consists of fourteen technological units (e.g. unit 1 is electricity and electrical machines, unit 2 is handling and processing, etc.). The EPO examining divisions consist of directorates assigned to particular JC's.
- Patent filings comprising patent families. The EPO patent family database PRI is indexed by priority forming filings and provides related subsequent filing activity in the major blocs: EPC (including the EPO), US, Japan, and Others. The database thus enables the user to pick out the type of patent families one seeks to examine.[1]

Each of these exercises will be considered in turn. For each forecasting exercise, there will be a discussion of some recent trends in filings, regression estimates, forecast accuracy, and sample forecasts for a given year (by individual source countries).

3.1 Conceptual framework and methodology

3.1.1 Static view

This section builds on the conceptual framework developed in Chap. 3, Sect. 2. Consider the following model of patenting behavior:[2]

$$P_{ij} = \alpha_i \, \delta_{ij} \, f_{ij} \qquad (1)$$

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[1] For more details on the EPO patent family statistics database PRI, see Hingley and Park (2003). This study draws upon material in that earlier paper.

[2] See Chap. 3 of this volume for the microfoundations underlying this model.

where P_{ij} denotes patent applications from source country i in destination country j, α_i the flow of patentable innovations (in source country i), δ_{ij} the fraction of α_i that has applicability in destination j, and f_{ij} the fraction of $\alpha_i\delta_{ij}$ that is applied for patents in destination j. The pool of patentable innovations (in a given period) should depend on the extent of research and development (R&D) activity, while the propensity to patent them in a given destination should depend on the attractiveness of the destination market. The cross-country applicability of innovations should depend on bilateral factors, which will be treated as country-pair specific random effects. The propensity to patent, f_{ij}, should depend on whether the value of patenting exceeds the cost. The value of patenting should be the difference between the rewards to an inventor from patenting an innovation and the rewards from not patenting that innovation (say the default reward). In other words, patent applicants should be motivated by the increment in reward from patenting (relative to the cost).

3.1.2 Forecasting

Suppose patent applications are a function of some independent variable x:

$$P_{it} = \beta_0 + \beta_1 x_{it} + \varepsilon_{it} \tag{2}$$

where t = 1, . . . , T denotes time (sample period), i = 1, . . . , N denotes source countries, j = EPO (hence subscript j is omitted), and where $\varepsilon_{it} = \upsilon_i + \mu_{it}$ is the error term. In the panel dataset below, υ_i is used to capture the bilateral specific effect between a source country and the EPO destination.

Given (future values)

$$x_{iT+1}, x_{iT+2}, \ldots, x_{iT+k},$$

the estimates $\hat{\beta}_0, \hat{\beta}_1$ can be used to generate predictions for each source country i = 1, . . ., N.

$$\hat{P}_{iT+1}, \hat{P}_{iT+2}, \ldots, \hat{P}_{iT+k}$$

Note that in the actual estimation and forecasting below, the dependent variable will be the natural logarithm of patent applications per (source country) worker. Thus, the above methodology needs to be modified slightly to take the exponent of P and multiply by number of workers to obtain the predicted number of patent applications (in natural units).

3.1.4 Forecast accuracy

Among the different criteria that could be used, this paper evaluates forecast accuracy by examining the Root Mean Square Proportion Errors (RMSPE).

For date T+k, given actual patent applications P_{iT+k} and predicted $\hat{P}_{iT+k}$:

$$\mathrm{RMSPE}_{iT+k} = \sqrt{\left(\frac{P_{iT+k} - \hat{P}_{iT+k}}{P_{iT+k}}\right)^2}$$

The empirical section below provides mean RMSPE across source countries i = 1, . . . , N for different k-step ahead periods, as well as provides some sample forecasts by individual source countries.

To get an anchor for the root mean square proportion error, note that RMSPE = 1 if the predicted value is either twice that of the actual value or equal to zero. In other words, it gives us an idea of the proportion deviation from actual.

3.1.5 Dynamics

Suppose patent applications depend on past applications. Then an extension to Eq. (2) is:

$$P_{it} = \beta_0 + \beta_{11}P_{it-1} + \ldots + \beta_{1j}P_{it-j} + \beta_2 x_{it} + \upsilon_i + \mu_{it}, \qquad (3)$$

Through the lagged variables, the entire history of the dependent variables P_{it} is reflected in the equation. Thus the effect of the independent variable x is conditioned on this history. The impact of x on P reflects the effect of *new* information.

For comparison, the autoregressive models (AR1 and AR3) – i.e. models without x’s – are examined. Typically the x’s will be measured by the logarithm of real research and development (R&D) expenditures of the source country per source country worker. The outcomes of using other independent variables will also be described below. For comparison, the paper provides estimates of the above dynamic equation using generalized least squares (GLS) and generalized method of moments (GMM). The GLS here is random effects estimation and the GMM the Arellano and Bond (1991) method. The presence of lagged variables in the panel data introduces correlations between the right-hand side variables and the error term, for which differencing and instrumental variables are used to handle this problem. The Annex provides a brief review of these estimation methods.

The regression models tended to produce much better forecasts if lagged values of the dependent variable are included, given the serial correlation or momentum in patent filings over time. The reason for the primary focus on R&D as the independent variable of interest is that other variables such as output are correlated with R&D (since output is a function of R&D, among other factors). Hence R&D is both important in itself and acts as a proxy for other important factors.

The R&D variable, however, represents a source country characteristic. It should be noted, though, that the characteristics or attributes of the EPO tend largely to vary not across source countries but over time. In other words, the source countries all face (largely) the same conditions in the EPO destination (whether it be EPO policy, institutional factors, rules, market size, market conditions, and so forth). Thus most of the variation between the EPO filings of different source countries is likely to be due to source country factors. Nonetheless, developments in the EPO do occur over time that could stimulate or decrease the patenting of source countries (though not necessarily in the same way or to the same extent), and it would therefore be useful to develop proxy measures of EPO destination characteristics. However, in preliminary analyses, some difficulties were encountered in defining and deriving EPO destination variables (e.g. weighting and aggregating the member country characteristics). If the destination were a single country, this is easy to do. But for a bloc (such as the EPC contracting states that together run the EPO) one needs a measure of the market size or other characteristics of the bloc as a whole, and then to weight the underlying individual countries comprising the bloc. While the development of these variables is a work in progress, the dynamic lagged dependent variables may proxy for time shifts in conditions in the destination EPC contracting states.

Lastly, it would be useful to discuss the possible lag structure of R&D in relation to the effects on patenting. In preliminary analyses, the results were not qualitatively different if the first, second, or third lags of R&D flows are used. This may be due to a couple of factors. First, R&D itself is correlated with past values, reflecting the fact that the R&D behind an innovation is not a one-shot investment but part of a cumulative effort, which is why the stock of R&D was important. Secondly, while a given period's R&D may yield a patentable innovation with a lag, this is not to say that current R&D cannot influence current patenting activity. Firms may wish to file for patents before further refining their research projects or devoting more resources to them. The priority right gives added security and incentive to continue their R&D, if only to acquire proprietary rights to early versions of their innovations. Thus, R&D activity may stimulate current patent filing activity to the extent that firms take anticipatory action and seek priority rights to forthcoming innovations.

3.2 Data sources

A panel data set is used to estimate Eq. (3). The sample consists of 53 source countries over the period 1980–2000, and one destination, namely the EPO. Given a number of missing observations (due to incomplete data on the independent variables of interest), in practice this sample reduces to about 30 source countries over a 21 year period (providing 630 observations = 21 x 30). Data on EPO patent applications are from the European Patent Office. Data on national research and development (R&D) are from the OECD's Main Science and Technology Indicators database.[3] The main measure of R&D used is Gross Expenditure on Research and Development (GERD). This is a broad country-wide measure, encompassing R&D funded by industry, government, and non-profit sectors (such as universities). Due to knowledge spillovers, innovative activity is likely to depend on a broad stock of knowledge, not limited to industrially funded and performed research. In the sectoral sample, however, the measure of R&D used is Business Enterprise Research and Development (BERD) expenditures (funded by various sources, including government and industry).

For non-OECD and/or developing countries, R&D data are taken from UNESCO's Statistical Yearbook (UNESCO 1980–2002). For a number of countries, data are missing. For data that were missing between years, we filled in gaps by a linear interpolation.[4]

Table 7.1 shows some sample means (over the period 1980–2000) of patent filings at the EPO and R&D as a percentage of GDP by country group. The countries in the sample are grouped according to their sample average real GDP per capita, using World Bank (2002) figures. The high-income group refers to those countries whose GDP per capita exceeded $ 17000 (real 1995 US dollars); the low-income group to those whose GDP per capita was less than $3500 (real 1995 US dollars); and the medium-income group to those whose GDP per capita was between those two limits. For each income group, the within-group mean values are provided, and at the end of the table, the overall mean values of the variables are

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[3] See http://www.sourceoecd.org, June 2002.

[4] For example, if there were a three year gap in R&D flows, the total change in R&D values over that period would be divided by three and the value of R&D would then be incremented by that figure for each year that was missing. For example let $\Delta = (x(t+3) - x(t))/3$, where t denotes time. Then $x(t+1) = x(t) + \Delta$, $x(t+2) = x(t+1) + \Delta$.

provided. In general, the high-income nations do most of the patenting in the EPO. The high-income nations generally have the highest rates of R&D spending (averaging 1.53% of GDP), while the low-income nations have an average R&D to GDP ratio of 0.48%.

Table 7.1. Sample statistics of EPO patenting and R&D-to-GDP: Average 1980–2000

	EPO Patent Filings	R&D as a % of GDP
High Income Group Mean (19 countries)	3346	1.53
Medium Income Group Mean (17 countries)	104	1.02
Low Income Group Mean (17 countries)	35	0.48
Overall Mean (53 countries)	1244	1.02

Countries are classified as high income if their sample average GDP per capita exceeds $17000 (real 1995 dollars); low income if their sample average GDP per capita is below $3500 (real 1995 dollars); and medium if their incomes are in-between.

4 Empirical analysis

4.1 Case 1. Aggregate filings (by mode of filing)

The first forecasting exercises are with total EPO filings, aggregated across all technological fields. The total filings, however, can be broken down by mode of filing, depending on whether a particular filing is a first or a subsequent filing, and whether it is a direct EPO filing or an indirect one where the EPO is designated in a PCT application. Consider the following notation:

EF	euro-direct first filings
ES	euro-direct subsequent filings
PF	Euro-PCT International phase first filings
PS	Euro-PCT International phase subsequent filings

Total= EF + ES + PF + PS

Table 7.2 shows some sample statistics on total filings as well as the composition of those filings: namely EF, ES, PF, and PS. To conserve space and to highlight the key stylized facts, only three years are shown: 1985, 1995, and 2000. The countries are grouped by bloc: EPC contracting states, Japan, US, and Other. Note that, because the data set goes up to 2000, the more recently joined contracting states of the EPC, such as Hungary and Romania, are treated as Other Bloc countries.

For EPC contracting states, a significant increase in euro-direct first filings has occurred as a share of all modes of filing. While a slight decline has occurred in the share of euro-direct filings that are subsequent filings (i.e. ES), there has been a greater increase in the share euro-PCT-IP filings that are subsequent filings (i.e. PS). For Japan and the US, direct first filings constitute a small share of filings at the EPO. Moreover, the share of EFs by the US and Japan has declined over time. Instead a tremendous increase in euro-PCT-IP filings has occurred, particularly subsequent filings (i.e. PS). In other words, PS is the most popular mode of filing for Japanese and US patent applicants.

Table 7.2. Breakdown of EP filings by route (euro-direct vs. euro-PCT-IP) and type of filing (first or subsequent)

Bloc	Year	%EF	%ES	%PF	%PS
EPC	1985	4.7	83.0	0.6	11.7
EPC	1995	8.6	48.7	1.5	41.2
EPC	2000	13.2	33.6	1.3	51.9
Japan	1985	3.4	87.5	1.2	7.9
Japan	1995	2.2	76.5	2.7	18.7
Japan	2000	1.2	60.1	3.2	35.5
USA	1985	4.5	74.2	2.1	19.2
USA	1995	1.9	35.4	3.3	59.4
USA	2000	2.6	20.3	1.6	75.4
Other	1985	7.7	55.7	3.2	33.5
Other	1995	4.2	18.8	7.2	69.8
Other	2000	1.5	14.3	5.4	78.8

EF, ES are euro-direct first filings and subsequent filings respectively. PF, PS are euro-PCT-IP first filings and subsequent filings respectively.

Among the Other bloc countries, there is quite a bit of variance in modes of filing. During the early 1980s, some of these countries had a relatively high share of euro-direct first filings in their EPO filings; however, by 2000, these countries have switched to using the PCT system to obtain patent protection in the EPO. Other bloc countries tend mostly to file subsequent patent applications to the EPO (whether directly or via the PCT).

Table 7.3. Filings by route: Total

Dependent variable: ln (TOTAL/Labor)			
	(1)	(2)	(3)
Constant	-0.109	-1.002***	0.017***
	(0.071)	(0.250)	(0.006)
Lag 1	0.694***	0.653***	0.469***
	(0.052)	(0.056)	(0.059)
Lag 2	0.123**	0.021	-0.075
	(0.065)	(0.069)	(0.064)
Lag 3	0.159***	0.256***	0.194***
	(0.072)	(0.049)	(0.056)
ln RD		0.073***	0.526***
		(0.020)	(0.144)
No. of Obs.	371	331	295
Adj. R-sq	0.98	0.98	
M2 p value			0.806
Method of Estimation	OLS	GLS	GMM

The equations are estimated over the period 1980–1996. OLS denotes ordinary least squares, GLS generalized least squares, and GMM generalized method of moments. Lag n refers to the dependent variable lagged n period(s), and ***, **, * denote significance levels of 1%, 5%, and 10% respectively. Standard errors are shown in parentheses. M2 p-value denotes the p-value associated with the test for 2nd order autocorrelation in the residuals. TOTAL refers to the sum of EF (Euro-Direct First Filings), ES (Euro-Direct Subsequent Filings), PF (euro-PCT-IP First Filings), and PS (euro-PCT-IP Subsequent Filings). ln RD is the natural log of gross expenditures on research and development (GERD) per worker (in real 1995 US dollars).

4.1.1 Estimation

Estimates of the forecasting equations are shown in Tables 7.3 and 7.4. In Table 7.3, the dependent variable is the natural log of total EPO filings per source country worker. In Table 7.4, the dependent variable is the natural log of EPO filings per worker by mode of filing (i.e. EF, ES, PF, and PS). Different model representations were examined (among others): AR3 (autoregressive model of order 3) and RE3 (regression model with the first three lagged values of the dependent variable and the flow of real R&D expenditures per source country worker). In other words, RE3 is AR3 augmented with R&D. Other variables were included in preliminary analyses, such as GDP per capita, but were found to be correlated with R&D and/or contributed marginally to the forecasting exercises (such as patent filing costs).

Thus the RE3 model is:

$$p_{it} = \eta_0 + \eta_1 p_{it-1} + \eta_2 p_{it-2} + \eta_3 p_{it-3} + \eta_4 r_{it} + \varepsilon_{it} \tag{4}$$

where the lowercase letter p denotes the natural log patent filings at the EPO by source country i per source country labor, and r the natural log of source country research and development expenditures (in real 1995 US dollars) per source country worker. The AR3 model is where η_4 is set to zero.

The motivation for these different models is to highlight the role of R&D in predicting patent filings. A comparison, for example, between AR3 and RE3 shows whether R&D has any predictive power over and above the autoregressive model. A large fraction of the variation in the data can be captured by autoregressive terms (i.e. by the lags of the dependent variable) without any additional variables like R&D.[5]

In Table 7.3, the models were estimated over the period 1980–1996, so that out of sample forecasts for 1997–2000 can be made. Column 1 presents the results of the AR3 model. The coefficient on the first lag is just under 0.7. The patent-elasticity of R&D is measured to be 0.073 (meaning that a 1% increase in a source country's R&D leads, on average, to a 0.073% increase in its EPO patent filings) – if the equation is estimated by generalized least squares (random effects). If the model is estimated by generalized method of moments, the measured elasticity rises to 0.526. The R&D variable is strongly statistically significant by either method of estimation. For the GLS estimation, the null hypothesis of no correlation between the individual error term and the regressors could not be rejected. For GMM, the null hypothesis of no second-order autocorrelation in the differenced residuals cannot be rejected (which would otherwise indicate that the estimates are inconsistent).

In Table 7.4, for considerations of space, the AR3 results are not shown. Just the estimates of Eq. (4) by GLS and GMM are shown for each mode of filing. As with the case for total filings, GMM measures a higher elasticity of R&D. For EF filings (i.e. euro-direct first filings), none of the lagged dependent variables are statistically significant when estimated by

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[5] The lag length was determined in preliminary examinations via quasi-likelihood ratio (QLR) tests; see Woolridge (2002), pp. 370-371.

GMM. Under GLS, all those variables are significant at or beyond conventional levels. As for ES filings (i.e. euro-direct subsequent filings), R&D is statistically significant at the 5% level under GLS but at the 10% level under GMM. As for the PF filings (i.e. euro-PCT-IP filings), R&D is statistically significant only at the 10% level under GLS but at the 1% level under GMM. Moreover, the second and third lagged dependent variables are insignificant under GMM. As for PS (i.e. euro-PCT-IP subsequent filings), R&D is measured to be important only under GMM.

Table 7.4. Filings by route: euro-direct, euro-PCT-IP, first and subsequent filings

Dependent Variable: ln (x/Labor)				
where x =	EF (1)	ES (3)	PF (5)	PS (7)
Constant	-1.142***	-0.418***	-2.191***	-0.802***
	(0.434)	(0.207)	(0.586)	(0.298)
Lag 1	0.536***	0.656***	0.548***	0.863***
	(0.056)	(0.043)	(0.058)	(0.043)
Lag 2	0.296***	0.214***	0.106*	0.038
	(0.061)	(0.051)	(0.062)	(0.049)
Lag 3	0.106**	0.108***	0.198***	0.039
	(0.056)	(0.043)	(0.053)	(0.034)
ln RD	0.071***	0.032**	0.07*	0.063
	(0.028)	(0.016)	(0.04)	(0.023)
No. of Obs.	330	460	247	353
Adj. R-sq	0.93	0.97	0.81	0.97
Method of Estimation	GLS	GLS	GLS	GLS

Dependent Variable: ln (x/Labor)				
where x =	EF (1)	ES (2)	PF (6)	PS (8)
Constant	0.019**	-0.043***	0.087***	0.044***
	(0.009)	(0.006)	(0.014)	(0.010)
Lag 1	-0.015	0.279***	0.234***	0.695***
	(0.063)	(0.046)	(0.065)	(0.052)
Lag 2	0.039	0.149***	-0.037	0.037
	(0.056)	(0.044)	(0.057)	(0.049)
Lag 3	0.044	0.229***	0.082	0.025
	(0.052)	(0.041)	(0.056)	(0.040)
ln RD	0.741***	0.268*	0.437***	0.343***
	(0.261)	(0.159)	(0.224)	(0.185)
No. of Obs.	292	413	218	308
M2 p-value	0.96	0.32	0.22	0.49
Method of Estimation	GMM	GMM	GMM	GMM

For terminology, see Table 7.3.

Thus, to sum up, the estimation results are sensitive to the method of estimation and to mode of filing. In particular, the effect of R&D (quantitatively and qualitatively) varies across different settings.

4.1.2 Forecast accuracy

Each of the forecasting equations discussed above can be compared for their ability to forecast. As each of the above equations was estimated over the period 1980–1996, the estimated – or fitted – equations can thus be used to generate out-of-sample forecasts of filings in 1997–2000. Table 7.5 reports the root mean square proportion error (RMSPE) associated with each equation's performance in predicting patent filings (whether it be total, EF, ES, PF, or PS) in year 1997, 1998, 1999, and 2000. Thus for each year, each of the models generates a forecast for each source country. By comparing these forecasts with the actual source country filings, the RMSPE computes a summary measure of the forecast errors across the source countries.

In general, it is tough to beat the AR3 model, but adding R&D does in some cases help to improve forecast accuracy (with some exceptions). For total filings, the model estimated by GLS tends to be best in the short run (1997 and 1998). AR3 has the lowest RMSPE for 1999 and GMM for 2000. The model estimated by GMM does best in the short run for predicting EF and PF. Otherwise, for euro-direct and euro-PCT-IP (first or subsequent) filings, the random effects model tends to do best for 1999 and 2000.

4.1.3 Sample forecasts

Table 7.6 provides some sample forecasts for a select sample of source countries. In this table, forecasts for total EPO filings in 1998 are used as an example. This could easily be replicated or reproduced for other years and for detailed modes of filing: EF, ES, PF, and PS.

For total filings, the AR3 and RE3 both under-predict the overall (i.e. all country) filings, but not by much. The shortfall is about 7% of the actual filings. For the US, the RE3 model's forecast is 97% of actual; for Japan, it is about 95%, and Germany 86%. For overall EF, the AR3 and RE3 models are off by about 1 800 filings (which are about a quarter of actual filings). The model estimated by GMM produces a sum forecast which is (marginally) closest to the actual. In the bigger scheme of things, the total forecasts and forecasts by source country are mildly different across the different models and methods of estimation.

Table 7.5. Summary of forecast errors: Aggregate EP filings

			Root Mean Square Proportion Error			
Model	Variable	N	1997	1998	1999	2000
AR3	Total	371	0.153	0.149	0.125	0.190
RE3	Total	331	0.139	0.145	0.126	0.189
GM3	Total	295	0.159	0.167	0.163	0.173
AR3	EF	362	0.378	0.545	0.359	0.422
RE3	EF	330	0.379	0.539	0.341	0.455
GM3	EF	292	0.276	0.405	0.474	0.517
AR3	ES	511	0.298	0.319	0.502	0.278
RE3	ES	460	0.307	0.315	0.483	0.273
GM3	ES	413	0.378	0.420	0.604	0.367
AR3	PF	249	0.473	0.424	0.418	0.759
RE3	PF	247	0.409	0.341	0.383	0.719
GM3	PF	218	0.394	0.217	0.447	1.081
AR3	PS	393	0.293	0.289	0.175	0.275
RE3	PS	353	0.245	0.242	0.170	0.225
GM3	PS	308	0.372	0.271	0.270	0.218

Notes: The forecast errors correspond to the estimated models in Tables 7.3 and 7.4 (but the AR3 results were omitted in Table 3B for space considerations). Each entry is the RMSPE (root mean square proportion error) associated with each model. AR3 autoregressive model of order 3, RE3 random effects model of R&D and three lags of the dependent variable, and GM3 model of R&D and three lags of the dependent variable estimated by GMM. N denotes the number of observations, EF euro-direct first filings, ES euro-direct subsequent filings, PF euro-PCT-IP first filings, and PS euro-PCT-IP subsequent filings. Total is the sum (=EF+ES+PF+PS).

Table 7.6. Sample forecasts of EP filings: Actual vs. predicted values for 1998

		Total Filings:		
Source Country	Actual	AR3	RE3	GM3
France	7115	6671	6653	6164
Germany	19860	17557	16971	17381
Japan	16169	15395	15479	15784
UK	5041	5449	5370	4969
USA	36860	34918	35548	35868
Other	25378	22701	22168	23086
All 53 Countries	110423	102691	102189	103251

AR3 refers to the autoregressive model of order 3, RE3 to the random effects model with 3 lags of the dependent variable, and GM3 to the model with 3 lags of the dependent variable estimated by GMM.

4.2 Case 2. Sectoral filings (joint clusters)

EP filings can be broken down by technological field. The patent applications at the EPO are put into one of fourteen technological divisions, called joint clusters (JC):

JC1	Electricity and electrical machines
JC2	Handling and processing
JC3	Industrial chemistry
JC4	Measuring and optics
JC5	Computers
JC6	Human necessities
JC7	Pure and applied organic chemistry
JC8	Audio, video and media
JC9	Civil engineering and thermodynamics
JC10	Electronics
JC11	Polymers
JC12	Biotechnology
JC13	Telecommunications
JC14	Vehicles and general technology

Fig. 7.1 shows the percentage distribution of filings by joint cluster (JCs 1–14) for 1998. Most of the EPO filings were in the field of handling and processing, followed by pure and applied organic chemistry and human necessities. Relatively small shares of filings occur in the new (emerging) fields of computers, biotechnology, and telecommunications.

Instead of analyzing the filings in each of these JC technological fields, this chapter examines functionally related groups of joint clusters. A judgment call has to be made as to which JC classes should be grouped together. It is beyond the scope of this chapter to determine the best grouping. Rather the objective is to apply forecasting methods to paneled groups of JC filings. Thus the fourteen JC fields are put into the following five technology groups (G1 to G5):

G1	Group 1	Electricals	JCs 1, 8, and 10
G2	Group 2	Chemicals	JCs 3, 7, 11, and 12
G3	Group 3	Manufacturing	JCs 2, 6, and 14
G4	Group 4	Physics	JCs 4 and 9
G5	Group 5	Computer related	JCs 5 and 13

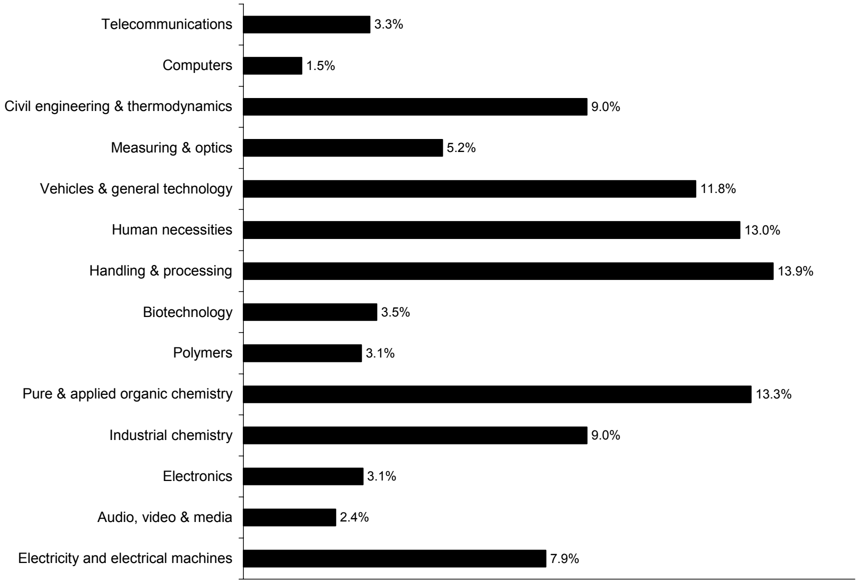

Fig. 7.1. Percentage of EP Filings by joint cluster: 1998

4.2.1 Estimation

Tables 7.7 and 7.8 show estimates of the model by technology group (where Table 7.7 presents the GLS results and Table 7.8 the GMM results). For reasons of space, only the total filings (that is, the sum of EF, ES, PF, and PS) are shown. Also the results for the AR3 model are omitted.

The models are estimated from 1980–1996, so that out-of-sample forecasts can be generated for 1997–2000. First, the GLS results suggest that, other than for Group 1 (Electricals) and Group 5 (Computer related), only the first lag of the dependent variable explains patent filings. Business enterprise R&D is a statistically significant determinant of total filings for all groups. Under GMM estimation, the measured elasticity of R&D is much higher, but nonetheless qualitatively significant at conventional levels. Moreover, under GMM estimation, typically the second and third lags of the dependent variable are statistically insignificant (except in the case of Group 2), and the coefficients of the first lag are under 0.3 indicating a low degree of persistence or momentum in filings. For Group 5 filings, however, the null of no second-order autocorrelation can be rejected, suggesting that estimates of the model are not consistent.

Table 7.7. Sectoral regressions on total filings by generalized least squares

Dependent Variable: ln (TOTAL/Labor) By Technology Group:	G1	G2	G3	G4	G5
Constant	-0.054	-0.129	-0.149	-0.441***	-0.269
	(0.235)	(0.204)	(0.145)	(0.177)	(0.387)
Lag 1	0.586***	0.670***	0.955***	0.717***	0.506***
	(0.074)	(0.073)	(0.068)	(0.073)	(0.075)
Lag 2	0.141*	0.131	-0.089	0.139*	0.283***
	(0.079)	(0.086)	(0.086)	(0.085)	(0.080)
Lag 3	0.146**	0.078	0.081	0.051	0.076
	(0.067)	(0.065)	(0.065)	(0.063)	(0.077)
Business-Enter. R&D	0.163*** (0.052)	0.135*** (0.034)	0.042** (0.020)	0.063*** (0.024)	0.160*** (0.074)
No. of Obs.	175	176	176	176	173
Adj. R-sq	0.94	0.96	0.97	0.96	0.86
Method of Estimation	GLS	GLS	GLS	GLS	GLS

Business Enter. R&D is the natural log of Business Enterprise Research and Development (BERD) expenditures per worker. For other terminology, see Table 7.3.

Table 7.8. Sectoral regressions on total filings by generalized method of moments

Dependent Variable: ln (TOTAL/Labor) By Technology Group:	G1	G2	G3	G4	G5
Constant	0.015*	0.011**	0.011	0.016***	0.067***
	(0.008)	(0.004)	(0.004)	(0.004)	(0.015)
Lag 1	0.266***	0.207***	0.283***	0.224***	0.125*
	(0.075)	(0.071)	(0.063)	(0.069)	(0.076)
Lag 2	0.044	0.136**	0.053	0.089	0.048
	(0.071)	(0.063)	(0.059)	(0.065)	(0.077)
Lag 3	0.074	0.040	-0.018	-0.072	-0.009
	(0.069)	(0.054)	(0.051)	(0.059)	(0.087)
Business-Enter. R&D	0.768*** (0.132)	0.642*** (0.072)	0.652*** (0.067)	0.627** (0.081)	0.868*** (0.205)
No. of Obs.	156	156	156	156	154
M2 p-value	0.25	0.39	0.38	0.38	0.02
Method of Estimation	GMM	GMM	GMM	GMM	GMM

For terminology, see Tables 7.3 and 7.7.

Table 7.9. Summary of forecast errors: Sectoral filings (by joint cluster)

G1 Technology Group 1 (Electricals):

Model	Variable	N	1997	1998	1999	2000
AR3	Total	177	0.205	0.155	0.111	0.248
RE3	Total	175	0.198	0.166	0.113	0.199
GM3	Total	156	0.126	0.147	0.111	0.194

G2 Technology Group 2 (Chemicals):

Model	Variable	N	1997	1998	1999	2000
AR3	Total	178	0.162	0.193	0.113	0.092
RE3	Total	176	0.154	0.183	0.107	0.093
GM3	Total	156	0.123	0.189	0.114	0.117

G3 Technology Group 3 (Manufacturing):

Model	Variable	N	1997	1998	1999	2000
AR3	Total	178	0.123	0.072	0.107	0.110
RE3	Total	176	0.118	0.073	0.095	0.096
GM3	Total	156	0.101	0.128	0.116	0.137

G4 Technology Group 4 (Physics):

Model	Variable	N	1997	1998	1999	2000
AR3	Total	178	0.155	0.129	0.116	0.135
RE3	Total	176	0.149	0.130	0.117	0.114
GM3	Total	156	0.092	0.143	0.139	0.141

G5 Technology Group 5 (Computer related):

Model	Variable	N	1997	1998	1999	2000
AR3	Total	175	0.345	0.285	0.267	0.306
RE3	Total	173	0.325	0.298	0.255	0.304
GM3	Total	154	0.224	0.271	0.186	0.221

The forecast errors correspond to the estimated models in Table 6A–B. Each sub-table here represents a different technology group. Each entry in each sub-table is the RMSPE (root mean square proportion error) associated with a model: AR3 autoregressive model of order 3 (whose estimation results are omitted in Table 7 to conserve space), RE3 random effects model of R&D and three lags of the dependent variable, and GM3 the regression model of R&D and three lags of the dependent variable estimated by GMM. N denotes the number of observations and Total the sum of all filings, aggregated across different routes (i.e. TOTAL=EF+ES+PF+PS, where EF is euro-direct first filings, ES euro-direct subsequent filings, PF euro-PCT-IP first filings, and PS euro-PCT-IP subsequent filings).

4.2.2 Forecast accuracy

Table 7.9 reports on the root mean square proportion errors associated with each of the technology group regressions discussed above. Each of the estimated models was used to make forecasts for 1997 – 2000 inclusive. Note that panels AE of Table 7.9 refer to Groups 1 to 5 respectively.

In general, the forecast performance is improved using R&D (relative to that of the AR3 model), whether the model is estimated by GMM or GLS. For predicting Group 1 filings, the model with R&D produces lower forecast errors than the AR3, although for 1999, the GLS estimations produce a slightly higher forecast error. For Group 2 filings, the model with R&D performs better than the AR3 for the very short run (1997 and 1998). For 1999 and 2000, the model estimated by GLS performs best in relative terms. For predicting Group 3 and 4 filings, the model estimated by GMM produces relatively the largest errors from 1998 on. The model estimated by GMM produces relatively smaller errors for 1997 and 2000. There is not much improvement over AR3 for 1998–1999. Finally, for predicting Group 5 filings (Computer related), the model with R&D as estimated by GMM produces relatively the lowest forecast errors. Thus forecasting can be enhanced using R&D as a predictor, but there is no definite forecasting advantage exhibited by either method of estimation.

4.2.3 Sample forecasts

Next, the forecast totals for 1998, summed across individual source countries, can be seen in Table 7.10.

For total filings, the model does quite well for technology groups 1–4. For instance, in terms of overall country filings, the predicted sum of Group 1 filings is 90% of the actual sum. The predicted cross-country sum of Group 2 filings is 94.3% of the actual sum; for Group 3 it is 95.8%, and for Group 4, it is 91.3%. But for Group 5, the predicted overall sum of filings is 74.1% of actual. Quantitatively, there are not as many filings in Group 5 as there are in each of the other groups. Perhaps a greater degree of uncertainty or unpredictability is a characteristic of innovation in computers and telecommunications such that actual patenting activity deviates substantially from what trends in R&D and past patenting behavior would suggest.

Table 7.10. Sample filing forecasts by technology groups: Actual vs. predicted Values for 1998

Technology Group	Actual	RE3 Model	GM3 Model
G1	19388	17479	18093
G2	31860	30269	29344
G3	28366	27084	25724
G4	13890	12302	12207
G5	10795	8001	8836

The model estimated by GMM produces a predicted sum of filings (aggregated across source countries) that is somewhat closer to the actual filings for Groups 1, 3, and 5.

4.3 Case 3. Patent family filings

In this section, attention is shifted from patent applications to patent families. International patent applications and other documents relating to the same invention would comprise a patent family. The patent family data are indexed by the priority number of the first filing, with information on subsequent filings for that invention in four blocs (EPC contracting states including the EPO, US, Japan, and Other countries). The database can be filtered to select different types of patent families (e.g. trilateral patent families, which are families that involve patent filing activity in each of the trilateral blocs: US, Japan, and EPC).

Patent family data thus depend on the appearance of patent publications that can index a patent family (link subsequent filings and priority filings). There is a timeliness problem due to this dependence on patent publication lags. Consequently, there may be some under-reporting of subsequent filing activities connected with an earlier priority forming filing. This particularly affects the more recent years, such as 1999 and on. The timeliness problem particularly affected data for the US where, until 2000, patents were published only upon grant. Thus the figures for the US could only be updated after several years of delay.

Table 7.11 provides a breakdown of international patent families that are based on priorities filed in 1999. The format follows that of the Statistical Annex of the Trilateral Statistical Report 2004 edition (EPO, JPO, USPTO 2005.) The 1999 figures are provisional, so that there will be an underestimation of patent family formation for this particular year. In this table, the subsequent filing destinations are available only by blocs (EPC, US, Japan, and Other). The first column provides the quantity of first filings associated with the priority country and the remaining columns show different types of subsequent filings as a percentage of first filings. Note that these percentages (in each row) need not sum to 100% since the various bloc combinations shown are not mutually exclusive.

Table 7.11. Patent families derived from first filings in 1999, by country of origin

Priority Year 1999		Families with activity outside the Bloc of Origin (% Priority filings claimed in Country of Origin From):						
Country Bloc	First Filings	All Other Blocs	Other Trilateral Blocs	EPC	Japan	USA	Other Countries	Trilateral Patent Families
EPC	130999	34.1%	17.1%	-	8.3%	12.3%	24.4%	3.9%
Japan	356397	12.7%	11.6%	8.3%	-	7.1%	5.1%	3.8%
US	153350	41.6%	30.1%	28.7%	9.2%	-	32.2%	7.8%
Other	157888	6.2%	6.2%	3.5%	2.1%	2.5%	5.1%	0.5%

Source: European Patent Office, PRI database.

In 1999 (as in all other years), Japan leads with the most first filings (in excess of 350 000), the vast majority of which are domestic filings. The very large number of such filings has been attributed to the practice in Japan of filing domestic patent applications with single claims. The US has the second most priority filings, with a total of 153 350, which is slightly more than the Other Country Bloc. The EPC as a whole has 130 999 first filings, almost half of which come from Germany. The next most productive country for first filings within the EPC is the UK, followed by France. About 12 000 euro-direct first filings at the EPO took place in 1999, which are just under 10% of all first filings within the EPC bloc. Among the Other Country Bloc, most first filings occur in China, followed by Korea, Russia, and Australia.

More than 40% of US first filings formed patent families with at least one other bloc (EPC, Japan, or Other), 30.1% formed patent families with at least one other trilateral bloc (Japan, EPC, or both), 32.2% formed patent families with at least a non-trilateral country or bloc, 28.7% formed patent families with at least the EPC, 9.2% with at least Japan, and just under 8% formed a trilateral patent family. For Japan, the percentages of patent family formation are generally smaller due to the large number of its first filings (i.e. in the denominator). For the EPC as a whole, the rates of patent family formation are generally between those of the US and Japan. Switzerland leads with the highest rate of trilateral patent family formation, followed by France, then Germany. The medium to lower income EPC states, such as Greece, Ireland, Monaco, Portugal, and Spain produce a negligible number of trilateral patent families. Among the Other Bloc countries, the largest number of trilateral patent family counts comes from Korea, and very small or zero trilateral patent families come from Brazil, Bulgaria, China, Hungary, Mexico, Philippines, Poland, Romania, and Russia[6]. The EPC obtains relatively most secondary filings from Korea, Australia, Canada, New Zealand, Norway, South Africa, and Israel. Again, it should be remembered that the observations for year 1999 should be treated as provisional until further subsequent filing data are obtained.

4.3.1 Estimation

Patent family formation rates are now the dependent variables of interest. The focus is on the numbers of families with activity in the EPO, other countries, other trilateral blocs, or trilateral patent families.

In the case of patent family formation, lagged priority filings are used as a regressor (which will replace the second and third lags of the dependent variable, since lagged priority filings capture past patenting and innovative activity). Conceptually, the priority filings reflect the overall level of new inventions that are patented in a particular period; the subsequent filings measure the transfer of those patentable inventions abroad. Thus priority filings are a measure of inventiveness, subject to the qualification that not all inventions are patented or are patentable, while subsequent filings are a measure of international technology diffusion. Here, first filings refer to priority filings of the source country, where source country refers to the country of origin of the first filings (from which priority claims are made by all other patents) and not necessarily to the country of residence of the patent owner or inventor.

R&D is modeled as a determinant of subsequent filings. That is, R&D affects the innovative potential of a source country and the propensity to make subsequent filings. One reason that research and development can stimulate the transfer of technologies abroad is that the R&D expenditures may reflect the investment effort level (and possibly thereby the quality level) of a source nation’s patentable inventions. Thus, the greater a source country’s resources devoted to R&D per worker, the greater the number of innovations that might be worthy of patenting subsequently in other markets. Support for this view comes from previous studies on patent valuation. This research indicates that worthy patents can be “screened” by observing which ones are renewed frequently over time or which ones are used to apply for patents in more destinations (markets), and thereby form

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[6] Note that for the Other Bloc, the second and third columns in Table 7.11 coincide as a result of the fact that where a patent family is formed with at least one other bloc, that bloc is one of the trilateral blocs.

larger families.[7] Thus, on theoretical grounds, R&D could stimulate both first and subsequent filings. The greater the R&D content, for example, in a nations' supply of patentable inventions, the greater the proportion of priority filings that will be likely used as a basis for subsequent filings in other markets.

In what follows, models of subsequent filing behaviour are estimated for the sample years 1981–1994, corresponding to the priority filing years 1980–1993. The estimated models are then used to generate out-of-sample forecasts for families containing subsequent filings in 1995–2000. We then compare these forecasts with actual data. It will be seen that the models generally over predict for 1999 and 2000, which is consistent with the fact that there is a timeliness problem in reporting families incorporating subsequent filing activity for these years. It is for this reason that the out-of-sample forecast interval was expanded and in-sample estimation period decreased.

Table 7.12. Patent family regressions: Families with activity in the EPO and trilateral patent families

Dependent Variable: ln (Patent families involving x / Labor)				
where x =	EPO (1)	EPO (2)	Trilateral (3)	Trilateral (4)
Constant	-2.705***	0.039***	-3.238***	0.025***
	((0.427)	(0.007)	(0.520)	(0.007)
Lag 1	0.829***	0.348***	0.828***	0.224***
	(0.021)	(0.055)	(0.026)	(0.056)
ln FF	0.062***	0.154**	0.037*	0.241***
	(0.021)	(0.065)	(0.023)	(0.063)
ln RD	0.250***	0.083	0.279***	0.574***
	(0.036)	(0.132)	(0.043)	(0.167)
No. of Obs.	469	425	429	384
Adj. R-sq	0.97		0.97	
M2 p-value		0.03		0.03
Method of Estimation	GLS	GMM	GLS	GMM

FF refers to priority forming first filings. For other terminology, see Table 7.3.

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[7] For studies that infer patent value from patent renewal behaviour, see Pakes (1986), Schankerman and Pakes (1986), and Lanjouw et al. (1998). For studies that infer patent value from patent family size, see Harhoff et. al. (2003), Lanjouw and Schankerman (1999), and Putnam (1996). Harhoff et. al. (2003), p. 1343, for example, argue that "patents representing large international patent families are especially valuable."

The estimation results are in Table 7.12. For each type of dependent variable, GLS and GMM estimates are provided. The first two columns focus on counts of families with activity at the EPO and the last two columns on trilateral patent families. For each type of dependent variable, an AR3 model was estimated, though the results are not shown. Thus, in effect the comparison is between the forecast ability of an AR3 versus that of a model with a lagged dependent variable, lagged priority filings, and R&D. Note that first filings are lagged one period because, in accordance with the Paris Convention as discussed in Sect. 1, applicants have up to one year to file subsequent patent applications and to refer to the priority date associated with the first filing.

Random effects estimation indicates that a 1% increase in priority filings leads to a 0.062% growth in families with activity at the EPO, whereas a 1% increase in R&D stimulates a 0.25% increase in those filings. For trilateral patent families, a qualitatively similar pattern is exhibited. The previous period's patenting activity or intensity influences a current period's activity. R&D also has a statistically significant influence on the technology transfer rates. However, lagged priority filings weakly determine the number of trilateral patent families. This finding implies that the mere size or stock of patentable inventions (as measured by the flow of priority filings) does not influence international technology diffusion (holding other factors constant). It is, in other words, not necessarily the case that the more inventions there are the more international patent family formation. Some countries have a relatively large number of priority filings, yet have a comparatively smaller propensity to patent abroad (e.g. Japan), while others have a relatively small number of priority filings, yet have a comparatively high propensity to patent internationally (such as Canada). This result might suggest that patentees make separate decisions concerning their priority filings and subsequent filings.

GMM estimates paint a somewhat different picture. The coefficients of lagged first filings are statistically significant at conventional levels. The measured elasticity of R&D is generally higher, but R&D is found to be statistically insignificant in explaining families with activity at the EPO. However, the presence of second-order autocorrelation suggests that the estimates are not consistent.

4.3.2 Forecast accuracy

Table 7.13 shows the root mean square proportion errors (RMSPE) associated with each patent family model estimated thus far. Since the estimated equations in Table 7.12 were estimated up to year 1994, the actual (realized) values of the independent variables for 1995–2000 are used to make predictions of the dependent variable.

The forecast performance between AR3 and RE1 (i.e. model estimated via random effects) is fairly similar for families with activity at the EPO. The AR3 performs relatively better for the earlier years (1995–1997) but the momentum captured in the AR3 does not extend well into a longer time horizon. For the number of trilateral patent families, the AR3 performs generally better than the RE1 model (which incorporates lagged priority filings and R&D per worker). However, the RE1 model generally performs better than the simple AR1 model. Nonetheless the differences in forecast errors between AR3 and RE1 are of small magnitude. Note the relatively large forecast errors for predicting trilateral patent family filings for 1999 and 2000. This reflects the timeliness problem of obtaining actual or realized trilateral patent family data for those years.

For predicting families with activity at the EPO, the model estimated by GMM produces larger forecast errors. (Recall that in this case, R&D does not have explanatory power, but that the estimates are not consistent.) Likewise, for predicting trilateral patent families, GMM produces larger forecast errors (except for 1997) and gives estimates that are not consistent (see Table 7.13). Thus, in general, AR3 and random effects estimation perform better on the RMSPE criterion.

Table 7.13. Summary of forecast errors: Patent family regressions

			Root Mean Square Proportion Error		
Model	Variable	N	1995	1998	2000
AR3	EPO	405	0.319	0.257	1.330
RE1	EPO	469	0.420	0.250	1.312
GM1	EPO	425	0.731	0.278	1.392
AR3	Trilateral	366	0.414	0.812	0.850
RE1	Trilateral	429	0.530	0.859	0.854
GM1	Trilateral	384	1.104	0.988	1.924

4.3.3 Sample forecasts

Table 7.14 provides some sample forecasts by source country for 1998. For predicting the number of patent families with activity at the EPO, the RE1 model does generally better overall. The predictions are quite close for US, Japan, and Germany. The RE1 predicts a total, country-wide, forecast of 102 150 families with subsequent EPO filings. This is just 158 filings shy of the actual (or an error rate of just 0.154%).

Table 7.14. Sample patent family forecasts: Actual vs. predicted values for 1998

	(A) Families with activity at the EPO:			
Source Country:	Actual	AR3	RE1	GM1
France	6087	5983	5809	6241
Germany	20088	18558	17314	20463
Japan	21000	20428	23258	21367
UK	6151	5748	5106	6252
USA	35627	32785	37152	33768
Other	13355	13336	13511	13727
All 53 Countries	102308	96838	102150	101818
	(B) Trilateral Patent Families:			
Source Country:	Actual	AR3	RE1	GM1
France	1537	5983	5809	6241
Germany	5267	18558	17314	20463
Japan	17119	20428	23258	21367
UK	1549	5748	5106	6252
USA	24058	32785	37152	33768
Other	3338	13336	13511	13727
All 53 Countries	102308	96838	102150	101818

(A) represents families with activity at the EPO by the source country, (B) represents trilateral patent families by the source country. AR3 are forecasts from an autoregressive model of order 3, RE1 are forecasts from a random effects model of R&D and a lagged dependent variable, and GM1 are forecasts from a model of R&D and a lagged dependent variable estimated by GMM.

For predicting the formation of trilateral patent families, all the models over-predict. While the total, country-wide, forecasts of trilateral patent families are relatively not as good, the forecasts for individual countries vary in accuracy. For example, for US, the RE1 model produces good forecasts. But generally, the model over-predicts these kinds of filings for most countries. The errors appear to be systematic and suggest that forecasts of 1998 may also suffer from the timeliness problem. Clearly, the model has fit well historically over the truncated sample period (up to 1994), yet the RMSPE for 1998 exceeds 0.8 (suggesting that the predictions are 80% greater than, or almost double, the actual). This means either that the model has omitted important variables with predictive content, or that there is a severe lag in the reporting of actual trilateral patent families. It would be useful to re-do the forecasts at a later point in time in order to determine the more likely source of the forecast errors.

The model estimated by GMM (i.e. GM1) also provides a total forecast of families with activity at the EPO that is quite close to the actual, but GM1 overpredicts trilateral patent families. However, country by country, the pattern of forecasts appears to be qualitatively similar, independently of the way the model is estimated. Although more testing is desired, obtaining good (practical) forecasts may not be too sensitive to the underlying method of estimation.

5 Conclusions

Patenting activity is intense within the EPO. The US, Japan, and the EPC contracting states together account for the bulk of world patenting activities. This is in large part due to their relatively high incomes (which provides for larger markets), their greater productivity (which makes their inventors more prolific producers of knowledge capital), their greater R&D and science and engineering resources, and their stronger intellectual property systems. But the increased patenting in the EPO is also attributable to the institutional system itself. With the benefits of single filing and centralized procedures, the economic cost of patenting in EPO member countries has been reduced. Moreover, membership in the EPO has particularly helped the smaller member economies to obtain increased technology inflows. This is largely due to the low marginal cost of designating additional EPO states (beyond the top three to five states).

By 1999, nearly all the EPO states have been designated in EPO patent applications. Despite reducing fees and improving procedures for filing patents, the EPO receives very few patents from developing countries or emerging markets. This is due in good measure to factors internal to those nations (their policies and environment). However, to the extent that they depend on access to foreign markets in Europe, US, and Japan for their development, their lack of involvement in international patenting activities becomes an important issue.

The main highlights of the empirical investigation are as follows:

- R&D better explains total filings rather than the different modes of filing (EF, ES, PF, and PS). It does not explain well why agents choose to file at the EPO first or subsequently or why they would (or would not) opt to seek protection in the EPO via the PCT system.
- Models with lags of the dependent variable (usually the first three lags) plus R&D produce quite good forecasts. Typically 90% or more of the actual filings is predicted. Note though that these forecasts are generated using actual R&D values realized during the forecasting period. In practice, for predicting filings beyond the sample period (e.g. 2005 and beyond), forecasts of R&D (as well as models of R&D behavior) need to be developed.
- Generally, predictions of euro-direct (or euro-PCT-IP) subsequent filings are better (in the sense of lower RMSPE) than predictions of euro-direct (or euro-PCT-IP) first filings.
- Forecasts by technology (joint cluster) groups were also quite close to actual, except for Group 5 (computers and telecommunications). As with forecasting aggregate filings (across technological fields), the models forecast better for total filings rather than filings by different modes. Also, at the sectoral level, subsequent filings are easier to predict than first filings.
- For predicting counts of patent families, R&D is useful for predicting families with activity at the EPO and trilateral patent families.
- Lagged priority filings were also useful at predicting numbers of families with activity at the EPO but weakly useful at predicting trilateral patent families. This is because, across countries, there is not a tight connection between domestic filings and international filings (since some countries have large domestic filings and relatively less international, and vice versa). Of course, the transfer rate (i.e. ratio of subsequent filings to first filings) may be stable over time for each country, but across countries there does not seem to be a monotonic relationship between the transfer rate and level or size of first filings.
- Due to the timeliness problem, forecasts of patent families were less accurate for 1999 and 2000 (and even for 1998 in the case of trilateral patent families). For periods where the timeliness problem is not a problem, the forecasts are generally quite good (i.e. close to 99% of actual).

In conclusion, there are several possible extensions to this study. Firstly, more research is needed to better understand and explain patent granting behavior. This requires more detailed knowledge about the patenting authorities – their objectives and constraints. The existing literature has predominantly focused on the behavior of patent applicants. Secondly, it would be of interest to explore the feedback effects, if any, from the EPO system to R&D activities in various source countries. Inventors or firms should perceive the EPO region to represent a large (or larger) market. This surely should have impacted on their incentives to do R&D (including inventors in developing countries). The larger market should justify a larger investment in innovation or greater risk-taking. Thirdly, it would also be useful to derive destination variables for the EPO. Thus far the models of patenting behavior in this study have only incorporated source country characteristics. The chapter discussed the challenges posed in constructing destination variables. Nonetheless, in future work, destination variables should be explicitly modeled.

Finally, the panel data framework above imposes the same coefficients (on say R&D) for all source countries. It would be useful in the future to model source country heterogeneity (in, for example, their patenting responses to R&D). Panel data are useful where the time-series dimension is not especially large (e.g. 1980–2000 for the full sample or 1980–1996 for the forecasting sample) so that cross-sectional observations add more variability. It would be valuable, though, to capture differences in "slopes" by source country.

Annex: Technical notes

The following are brief sketches on the methods of estimation used in this chapter. Interested readers are referred to Baltagi (2001) for more details. The statistical software package, STATA, provides routines to conduct these estimation methods on panel data[8]; for example, the commands xtregre performs generalized least squares (random effects) and xtabond performs generalized method of moments for models with lagged dependent variables. STATA also provides a number of post-estimation commands, such as predict, to generate out-of-sample forecasts.

- Generalized Least Squares (GLS)

Suppose $P_{it} = \beta_0 + \beta_2 x_{it} + \upsilon_i + \mu_{it}$, where P denotes the log of patent filings per worker and x an exogenous regressor (such as the log of research and development per worker). Under GLS, the individual effect ν_i is assumed to be random, and the variables are transformed. For example,

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[8] See http://www.stata.org.

$$P_{it}' = P_{it} - \theta_i \overline{P}_i$$

$$x_{it}' = x_{it} - \theta_i \overline{x}_i$$

where

$$\overline{P}_i = \sum P_{it}/T_i,\ \overline{x}_i = \sum x_{it}/T_i,\ \text{and}\ \theta_i = 1 - \sqrt{\frac{\mathrm{var}\,(\hat{\mu}_{it})}{T_i\ \mathrm{var}\,(\hat{v}_i) + \mathrm{var}\,(\hat{\mu}_{it})}}$$

such that a least squares regression is run on the transformed variables. For consistent estimates, the random effects specification requires no correlation between x_{it} and ν_i.

- Generalized Method of Moments (GMM)

With a lagged dependent variable, the model becomes:

$$P_{it} = \beta_0 + \beta_1 P_{it-1} + \beta_2 x_{it} + \upsilon_i + \mu_{it}$$

Correlation exists between ν_i and one of the explanatory variables (namely the lagged dependent variable), since the above equation holds in the previous period and the individual effect is time-invariant (thus P_{it-1} is a function of υ_i). GLS would be biased. The traditional way to solve this problem is to first difference and eliminate the individual effect and use lagged differences and lagged levels of variables as instruments. The Arellano and Bond (1991) method allows for the exploitation of more sample information; for example, the orthogonality conditions between the disturbances and the lagged values. For example, if the moment conditions are:

$$E[(Z^T(P - x\beta)] = 0$$

where Z is the matrix of instruments and ^{T} indicates transposition, GMM involves choosing the value of the parameters β to minimize the following loss function:

$$L = (P - x\beta)^T Z \hat{W} Z^T(P - x\beta)$$

where $\hat{W}$ is a symmetric, positive semi-definite (estimated) weighting matrix.